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Abstract

Virtual teams are increasingly common in research as in corporate reality. While collaborative work in enterprises has received considerable attention, detailed understanding of collaborative work in virtual research teams is missing. To close this gap, we develop a model of the collaborative research process from idea generation to communication. We illustrate that the research phases require different support functions on the individual as well as on the team level. We explain that software tools, in particular social software, can provide support for collaborative work in virtual research teams.

1. Introduction

With the first collaborative scientific paper published in the year 1665, collaboration in research can nowadays be regarded as standard procedure [1]. While previous literature on research collaboration defines *generic collaboration* as "a mutually beneficial relationship entered into by two or more parties to achieve common goals" [16] and Schrage [21] specified it to be a "process of shared creation", *collaboration in research* has some specific additional characteristics. Scientific research is a dynamic process, dealing with typically complex problems. Collaborators are by nature highly specialized in their field and act in a very dynamic context [9]. The strong increase of paper publication illustrates that fact: in the period of 1981 to 1994, the global output of scientific papers went up by 3.7 per cent each year, which signifies a doubling of the global scientific output every nineteen years [17] – already at *that* time! Parallel to this development, the amount of publications by multiple authors has increased, not least influenced by "publish or perish" mentality. In some disciplines, an amount and speed of publication is required which can nearly exclusively be attained by a combination of forces – intellectually as well as financially [14]. This combination often takes place in collaborative research projects between a number of institutions, diverse departments and on different academic levels. The collaborating members of a research project can hence be regarded as a *virtual team*. Their interaction is supported by information and communication technology (ICT) and various software applications, as the characteristic of local disparity renders face-to-face interaction rare.

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Whereas the details of computer supported collaborative work (CSCW) in a corporate context have been widely researched, there is very little literature on *research collaboration* and supportive applications. If research collaboration has been examined at all, focus has been nearly exclusively on natural science [4, 11]. However, social sciences like economics, less characterized by the need for expensive equipment, have not yet been addressed in detail. Accordingly, a deep understanding of the potential to support virtual research teams of all fields by the use of software applications is still lacking. To close this gap, we aim at gaining a clearer understanding of how collaborative research projects work, comparing the status quo with the requirements of the researchers. Our research consequently explores the overall research questions: "Which are the necessary support functions to virtual teams doing collaborative research? Which kind of software provides these support functions?"

We address our research questions by a qualitative approach in the German research landscape. This setting is particularly suitable to gain first insights as German state agencies like the German Federal Ministry of Education and Research (BMBF) require their sponsored member organizations (e.g. Fraunhofer) to build research collaborations with other institutions and cooperate with the industry [2]. Also by their funding policy, the BMBF as well as the German Research Foundation (DFG) strongly encourage collaborative and interdisciplinary research programs [6]. In the German research landscape, so-called collaborative research centers (SFB) play an important role. As denotes their name, these collaborative research projects promote collaborative interdisciplinary research; they usually consist of different departments from up to three universities. Collaborators on different academic levels are jointly working towards a common goal (typically defined by a project definition) and share knowledge as well as resources to reach this goal [9]. In these projects, research collaboration is flanked by administrative tasks, e.g. documentation of results for dissemination, coordination of meetings, and networking with representatives of the funding institution. These elements of communication, coordination and cooperation are classified to be weaker occurrences [5] as well as prerequisites for successful collaboration [19]. Communication comprises the exchange of information while coordination regulates task assignment and further elements to reach efficient organization. Finally, cooperation means "playing in the same game with others according to a set of behavior rules" [5] and thus sets the framework for interaction.

The paper proceeds as follows: the next section provides the theoretical background on the research process as well as on virtual teams. It shows first findings on potential support functions on both the individual and team level of collaborative research. We then describe the methods we used in the data collection and analysis phase, and subsequently present our findings and a model derived from theory and empirical findings.

2. Research Process & Virtual Teams – Foundations

To develop the knowledge necessary to better understand the (IT supported) interaction of *virtual teams* in collaborative research, we started from existing knowledge on virtual teams, research collaboration, and the young strand of research on so-called web 2.0 applications.

Literature characterizes virtual teams by a dispersion of the team members across geographical, temporal, and organizational boundaries, with members often coming from different backgrounds of expertise and sharing interdependent goals [10, 15, 24]. Communication between team members is usually mediated by technology that pertains to the area of computer-supported collaborative work, or more recently, social software. Research partners consequently form a virtual team if they work together with partners in other institutions and locations, striving to reach a common goal, e.g. a publication.

Virtual teams have been widely researched in different contexts. Martins et al. [15] have adapted the inputs-processes-outcomes (I-P-O) model [8] popular in team research, to match the specific

characteristics of virtual teams. In this model, input factors like team size or technology influence the team processes (e.g. communication processes and interpersonal processes like trust). These, in turn, have an impact on team outcomes (affective outcomes like satisfaction of the team members as well as performance outcomes like the time required to fulfill the task). Hence, an optimization of team outcomes in virtual research teams is likely to be dependent on inputs and internal processes which form the behavior of the team members. Despite this broad and deep knowledge base on virtual teams, there is still the necessity to better understand both the individual research process as well as the team activities in order to identify support functions for virtual research teams.
The *research process* of an individual researcher is conceptualized by Graziano and Raulin [7] as divided into different, mutually interdependent phases. They have proposed a comprehensive and generic model of this process (see figure 1). Due to its generic character, this model with its seven phases is supposed to be applicable for research projects of all domains.

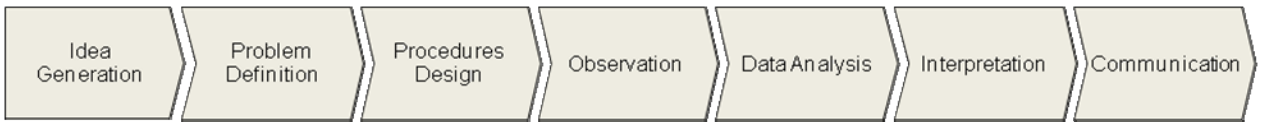

Figure 1: Research Process [7]

The first phase, *idea generation*, deals with the identification of topics of interest; hence creativity, literature review and communication with peers are important drivers [7]. The following *problem definition* phase focuses these rather broad and fuzzy ideas into precise research questions [7, 28]. *Procedures design* encompasses all activities concerning the preparation of data collection, i.e. definition of research design and methodology. The following phase is called *observation*. By this rather specific denotation, the authors summarize different methods of data collection. Quantitative or qualitative analysis of collected data is the major task of the subsequent *data analysis* phase. During the *interpretation* phase, the results are related to the research question and contribution to the targeted knowledge bases is identified. In the *communication* phase, research results are distributed to share and transfer knowledge; communication is typically done by publications and conference attendance.
Building on the model of research phases, adapted from Graziano and Raulin, Yao and Tang [23, 28] identified five support functions that can facilitate the research process, i.e. exploring support, retrieval support, reading support, analyzing support, and writing support. These support functions can be provided by software tools. While *exploring support* helps to identify relevant work of fellow researchers, the task of *retrieval support* is to find necessary literature to the topic [23]. *Reading support* can take place in the form of support for linking information fragments and making notes [23]. Besides the analyzing tools themselves, providing suggestions on methods and how they should be used, is one of the tasks of *analyzing support*. *Writing support* extends from automatic correction to suggestions for possible references, as well as systems that support citation.
Collaborative research projects encompass parts or the entirety of the individual research process from idea generation to communication of results; in addition, activities related to the (virtual) research team are necessary, e.g. coordination of meetings and efficient as well as effective communication. Also, these team support functions can be improved by appropriate software tools, e.g. weblogs and wikis [20]. Weblogs and wikis belong to the group of webbased software applications which are denoted as *social software*. This term became popular with the advent of web 2.0 and is nowadays used for a multitude of applications that allow direct or indirect interaction between users and also enable representation and support of users' relationships on the web [12]. Besides the already mentioned weblogs and wikis, social software tools include social networking services, collaborative filtering, social bookmarking, and a broad range of further tools [3]. Social software has recently received attention from the community of information systems researchers,

not least because social software relates to the original idea of the World Wide Web, i.e. to enable discussions within scientific communities and sharing of ideas [3].
Hence, first ideas on the potential of social software tools to support one or several phases of the research process can be found in literature. Yao [26] suggests the use of weblogs as a research diary that allows for a documentation of the research process. The commenting function of a weblog can help at the same time to further explore and develop ideas by the integration of colleagues or other experts in the individual research process [20, 26]. Beyond this use of weblogs as *exploring support*, they can also provide *retrieval support*. For example, by hyperlinks in the related posts that directly point to related websites, a network of indirectly related knowledge sources can be easily maintained and tapped [26]. Social bookmarking not only provides *retrieval support*, but also *reading support* since it establishes logical connections of different articles [26, 27]. Social software applications like Many Eyes[2] are useful tools for *analyzing support* as they help interpret statistical data. Eventually, *writing support* could take place by the use of wikis that allow for collaborative editing of documents and at the same time could serve as an additional communication channel [25].
As has been shown, there are considerations in research on the necessity to particularly support virtual teams. In this context, social software has come into focus of attention. Due to its main advantages, ease of use [12] and often low cost (stemming from its open source nature), social software is suitable to realize the support functions. However, there is still need for an analysis that shows which support functions are required most in virtual research teams. We consequently aim to gain a better understanding of the characteristics of the research process in virtual research teams. Thus, we identify areas where social software can potentially provide support to the individual researcher as well as to the virtual research team.

3. Data Collection & Analysis

To gain a deeper understanding about the characteristics of the research process in virtual teams and their requirements of support, we chose an explorative research approach. As empirical field, we examined seven German institution-spanning collaborative research projects. These research projects were publicly funded with project duration of three years each. Collectively, they represent a total budget of about ten million Euros, with partner institutions covering Southern, Middle and Eastern Germany. Taking into account the amount of competence and budget associated with these projects, a closer look at their inner workings and in particular their required support functions promises to provide interesting insights.

We proceeded by interviewing researchers in collaborative projects who were at PhD level (ten interviewees) and postdoctoral level (four interviewees). The interview candidates were chosen due to their membership in collaborative, private public partnership research projects focusing on applied research. They hold jobs as university-employed researchers in the area of economics, business information systems and computer science. All interviewees had two to four years of experience as researchers in their field. We conducted half of the semi-structured interviews face-to-face, the others via telephone. The interviews were all recorded and transcribed. The transcripts provided the basis for our in-depth analysis. Following the content analysis procedures to code data [18], we structured our data according to the seven phases of the research process as proposed by Graziano & Raulin [7] as well as according to the five support functions identified by Yao and Tang [23, 30]. All data were coded independently by three parties and then compared, using a process of analyst triangulation [29].

[2] Further information available online at http://services.alphaworks.ibm.com/manyeyes/home (2008/11/11).

A cross-examination of both data sets led to a gap analysis and identification of additional areas of support. In this interpretative approach to data analysis, we used Atlas.ti, a computer assisted qualitative data analysis software package [13].

4. Findings

Our data show that during their research process, virtual research teams need support on two levels. We found evidence for the five functions of research support as identified by Yao [28] in the research process of *individual* researchers. In addition, we identified a crucial need for support concerning the collaborating research *team* – e.g. support for communication or coordination. The subsequent figure shows our *framework of research support functions*, combining different support functions on both individual and team level. While we separate support for the individual and team level, there are also interdependencies between these levels. For example, social bookmarking services (e.g. del.icio.us[3]), provide both, support for the individual researcher (collection support) as well as support for the entire team (awareness support). These interdependecies were not regarded in detail in this study. The framework of research support functions is presented below.

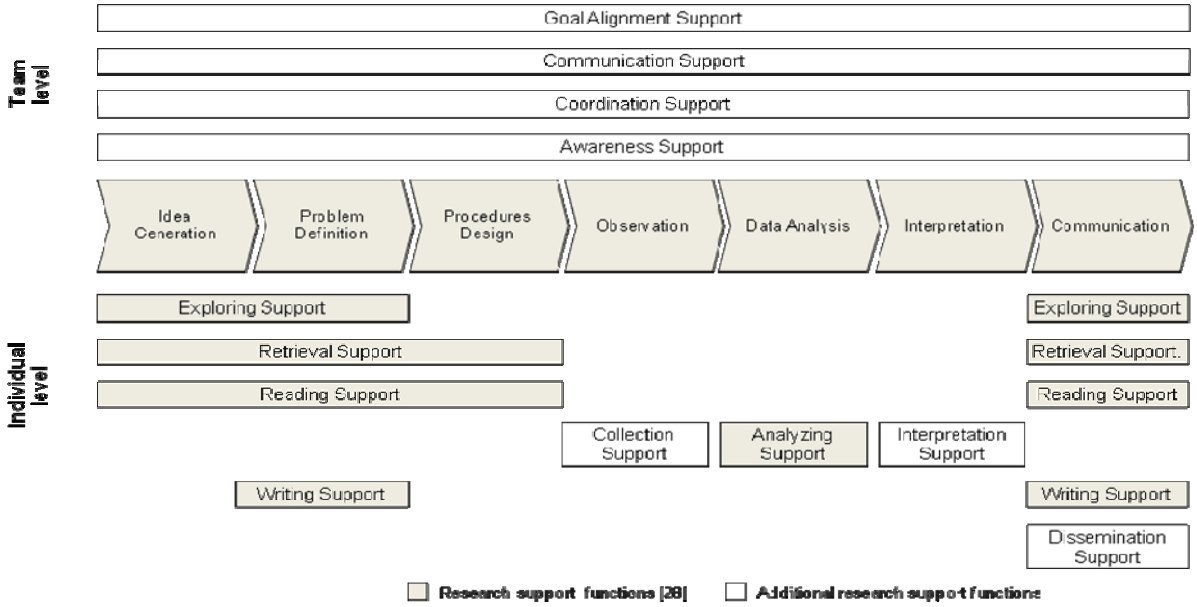

Figure 2: Framework of Research Support Functions

From several interview statements, we conclude that support for *goal alignment* throughout the entire research process is crucial. Contrary to expectations at the official start of the research projects, perceptions of collaborating researchers regarding the research problem heavily differ.

> The project was defined - which does not mean that each member knew what he had to do.[4] [Interviewee D; TL1][5]
>
> Every project partner had a different conceptualization of what was to be done. [Interviewee A; TL1]
>
> What you want to do does not entirely fit with what the project partners would like to have done. [Interviewee B, TL1]

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3 Further information available online at http://delicious.com (2008/11/11).

4 All interviews were conducted in German language. Interviewees' statements have been translated into English. For reasons of privacy, we have used an alphabetical coding scheme to identify interviewees.

5 Team level has been abbreviated to TL, individual level to IL. The issue domain numbers (e.g., TL1) identify both the level and the issue to which a quote refers. The issue numbers for team level are 1, goal alignment; 2, communication; 3, coordination; 4, awareness. The issue numbers for individual level are 1, exploring; 2, retrieval; 3, reading; 4, collection; 5, analyzing; 6, interpretation; 7, writing; 8, dissemination.

From our data we conclude that continuous and iterative goal alignment is an important antecedent of successful collaborative projects. We hence introduce a team-level support function *goal alignment support*.
Social software can provide goal alignment support by a platform that enables convergence of opinions by unhindered information flow. Technical solutions can be helpful in this context, especially wiki systems as a central information base:

> Our goal alignment could have been improved by using a wiki, if the partners had documented what they were thinking so that a convergence would have been possible. [Interviewee A; TL1]
> We see our wiki as a central repository for any information in the project. [Interviewee E; TL2]

The individual research process starts with *idea generation* and *problem definition*, when individual researchers have a strong need for *exploration, retrieval, and reading support*. This support is necessary to facilitate gaining ideas and directions for new research based on previous research, which implies a lot of browsing, finding and reading sources. Access to relevant information is a central requirement that researchers have:

> Not always all necessary information had been readily available, so there were a lot of requests by phone and a loss of time. A central collaboration platform would have been very helpful. [Interviewee L; IL2]

In addition, we found that social software tools can provide support, either by provisioning a repository or by communication tools that are easy to use:

> We set up a wiki to collect information in one place. [Interviewee E; IL2]
> We also worked a lot on a peer-to-peer basis, mostly using instant messaging. [Interviewee G; TL2]
> We have been using del.icio.us as a social bookmarking solution - we set up a joint account for the team and tagged any Internet sources that seemed relevant to provide them to the team. [Interviewee I; IL2]

For the phases of *procedures design* and *observation* in which the researcher has to select specific procedures he wants to apply, as well as conducting the actual observations, Yao does not mention a dedicated support function [28]. *Procedures design* is of major importance to every collaborative research project. As one researcher put it:

> The survey design was harmonized in workshops, [for this task] it is necessary to sit next to each other [Interviewee C; TL2]

Having completed the procedures design phase, the individual researchers in the team turn to *observation*, i.e. data collection, an activity often dependent on the industry partners' willingness to cooperate.

> Motivation was blemished because of one industry partner who did not deliver data / results. [Interviewee D; IL4]
> Our partner from the industry also had a high interest in the empirical results; therefore they were willing to provide us with the data. [Interviewee C; IL4]

Support for observation is not explicitly mentioned among the five support functions identified by Yao [28]. We found that problems between partners arise very often if partners from industry do not deliver the needed empirical data. We therefore add *collection support* to the individual support functions. Transforming data collection in a peer-based approach, e.g. by collectively writing case studies, supports the individual researcher. Approaches to collective data collection in the natural

sciences have been quite successful: "Swivel"[6] for example allows exploring data and statistics of other peers.
The above mentioned collaboration in procedures design and observation highlights two further decisive team activities, *coordination* and *communication*. Mostly, meeting coordination was handled by communication via email and telephone, with some projects utilizing specialized software like "doodle"[7]. Feedback on these approaches to coordination underlines the need for coordination and communication support, for which web 2.0 tools appear suitable:

> Coordination was primarily performed by email, but had a lot of problems, since a lot of team members did not respond at all, so we had to call by phone in addition to that. [Interviewee G; TL3]
> We liked doodle for appointment coordination. It is easy and fast. [Interviewee D; TL3]

The subsequent phases of *data analysis* can be directly linked to *analyzing support*. In this phase, results from the previous phases are processed using qualitative or quantitative methods. There are specialized tools that facilitate utilization these methods which usually require specific knowledge to make full use of them. Interviewees stress the proposition by Yao [28] to provide information on which tools and methods to use best as well as an explanation feature that helps in their utilization:

> It is a major problem to find the method you use best. I felt like guessing. [Interviewee C; IL5]

A general collaboration area or a knowledge base, like a wiki, might be helpful for collaborating researchers to exchange information and question regarding usage of the tools.
The subsequent phase of *interpretation* needs additional, dedicated support, i.e. *interpretation support*. In this phase, it is helpful to use technical means promoting discussions between researchers. A central storage of potential interpretations in a wiki system, for example, makes them available within the team and allows for discussion.

> Collaboration functioned especially well when there was a lot of interactivity between members. [Interviewee C; TL2]
> There was a lack of trust and awareness of what the others were doing in and with the project [Interviewee A; TL4]

Occurring problems could be discussed not only with research partners within the collaborative project, but also with other experts of the domain. In chemistry, this already takes place in "usefulchem"[8], an open source science project to discuss specific problems that need solutions.

The final phase of *communication* is concerned with dissemination of the results and lends itself naturally to *writing support*. This comprises firstly writing and secondly the publication and dissemination. In terms of collaborative writing, use of traditional communication media leads to dissatisfaction, while the use of shared documents applications, e.g. "zoho"[9] seems to be promising:

> Sending documents with comments by email is far from ideal – version management is hard. [Interviewee E; IL7]
> We used google docs - a far better experience than sending documents with changes. Also, motivation seemed to be higher – simultaneous work on a document conveys team feeling. [Interviewee M; IL7]

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6 Further information available online at http://www.swivel.com (2008/11/11).
7 Further information available online at http://www.doodle.ch (2008/11/11)
8 Further information available online at http://usefulchem.wikispaces.com/ (2008/11/11).
9 Further information available online at http://www.zoho.com (2008/11/11)

Beyond its usefulness to support communication, collaborative writing enhances transparency and thus awareness about the activities and state of project partners' work. Our data shows the importance of awareness throughout the entire project:

> We set up a homepage to generate a form of awareness of what the others are doing. [Interviewee A; TL4]
> It would have eased work if progress of team members could have been made publicly visible. [Interviewee B; TL4]
> Awareness was seriously disturbed in our project – the fact that there was a (potentially helpful) wiki system was announced two days previous to our final meeting. [Interviewee B; TL4]

We consequently introduce *awareness support* as an additional team-level support function. This support function has been shown to be provided for by web 2.0 tools. For example, "OpenWetWare"[10] is an effort to promote sharing of information, know-how, and wisdom among researchers and groups who are working collaboratively in the field of biology.
Our empirical results have revealed the need for support functions, both at the team level as well as on the level of individual support. We have shown that social software can provide these support functions by its capabilities to facilitate direct and indirect interaction between researchers as well as representation and support of their relationships [12].
We condense our insights to the proposition of a name for virtual research teams collaborating with support of social software: *Open Research*. We define Open Research as collaborative research by actors that are distributed among different institutions, locations and hierarchical levels. The research work is supported by tools that support information distribution, communication, coordination and collaboration across different time horizons. A central characteristic of Open Research is the opening of research work to existing and potential partners in and outside the own project, and the integration of a number of continuously developed (social software) tools to support the research. We propose a need to further study this phenomenon in detail.

5. Discussion

In order to support virtual research teams in their process of Open Research we learned that a systematic approach to the collaboration process is needed. Our data suggest a bisected process with an individual and a team level (each characterized by particular characteristics) for which we have proposed an enhanced framework combining previous work and our findings. The interdependencies between the individual and the team level need a closer look in future research. We have highlighted the different support functions which are necessary to virtual research collaboration as well as indicated the potential of social software tools to facilitate these support functions. Results of our research have to be tempered with its limitations. In order to gain a first insight, we examined a limited array of projects. Further research on Open Research might focus on projects with different funding structures, including more academic levels (PhD candidates, postdoctoral researchers, and full professors), and additional types of collaborators, e.g. industry partners. We estimate that different contexts of Open Research will lead to different requirements for support functions, both on the individual and team level.

[10] Further information available online at http://openwetware.org/wiki/Main_Page (2008/11/11).

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