Collaboration and the Knowledge Economy: Issues, Applications, Case Studies
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Collaborative Working Issues and Challenges in Knowledge Work Environment: Insights from Two Cases

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Abstract: Effective and efficient collaborative working in project teams becomes more and more important. Still, adoption of this work style remains limited. This paper identifies the theoretical issues in understanding and modelling collaborative work routines and respective coordination related challenges, which are derived from the engineering and research specific cases. Considerable differences are identified in ways of how actors communicate and coordinate their work, which leads varying degrees of quality in knowledge intensive work. Evidences from the cases show that high complexities, unforeseeable uncertainties associated with innovation and user involvement and high number of interdependencies, are major drivers towards intensive collaboration. The analysis of the cases also shows that there is currently little support by collaboration tools in all patterns and each pattern is better or less suited to the different types of collaborative work. The results can be used to achieve a smoother collaborative working phase through innovative technical developments.

Keywords: Collaborative working, knowledge work, coordination

1. Introduction

The term “knowledge work” has been used for decades to describe a new type of work whose value stem from the productive use of knowledge [1]. Such knowledge work involves the exchange of information, complex problem solving, making of judgements, and output creation [2]. Unlike manual or physical work, knowledge work is unique and difficult to standardise; knowledge workers are autonomous and almost impossible to control [3]. A major difference between knowledge work and manual work is that knowledge work is information-based, whereas manual work is materials-based.

Knowledge work's primary product is knowledge, which is circulated across and through organizations. Knowledge work tends to be organized in distributed, heterogeneous networks rather than in functional hierarchies and encourages connections across trades, disciplines and fields. These connections lead to more flexibility and collaboration within networked organizations [4; 5].

The construction industry is an industry that has frequently been invoked as operating in the mode of knowledge work. Construction is a complex activity, carried out by many parties collaborating for the successful completion of a project creating value for all involved. The projects are knowledge-intensive requiring extensive collaboration and communication between parties involved including all designers, constructors, suppliers, and client [6; 7]. Thus, the construction projects can be considered as interesting cases, which address the concept of collaboration and lateral communication across different disciplines. On the other hand, research & innovation is another domain which includes

knowledge intensive work processes to achieve a specific goal, such as setting up a new project, creating a specific project output (e.g. prototype, deliverable), or monitoring and steering the project. To cope with the complexities of such work processes, professionals from different organisations collaborate to gain access to complementary skills and resources [8]. Therefore, set up and operation of research & innovation projects within professional communities are highly relevant cases to present the different aspects of collaborative working within and across organisations.

The objective of this paper is; therefore, to better understand the collaborative working issues and challenges within construction and research & innovation domains.

Based on the case study analysis, three major theoretical implications are emerged: First, in the face of collaborative projects, considerable differences are identified in ways of how actors communicate and coordinate their work which leads varying degrees of quality in knowledge intensive work. Second, evidences from the cases also show that there is currently little support by collaboration tools in all patterns and each pattern is better or less suited to the different types of collaborative work. Third, high complexities (large number of participants and interactions), unforeseeable uncertainties that are associated with user involvement (the inability to recognize the relevant influence variables and their functional relationships) and high number of interdependencies (task inter-relations) are major drivers towards intensive collaboration within the collaboration projects.

The remainder of the paper is structured as follows: The next section provides a short review of related research streams on the emerging networks of knowledge workers and the concept of routines. Section 3 introduces the research methodology and presents the data collection method with a short description of the cases. Section 4 addresses the overview description of the respective processes with a brief presentation of the specific issues and challenges identified in different stages of the cases. Section 5 presents different coordination approaches within the context of knowledge work processes, information systems used and derives a list of requirements as a basis for technical developments with a set of collaboration applications. The paper concludes with a brief discussion of the results and recommendations for future research.

2. Research Theory

2.1 Emerging Networks of Knowledge Workers

Whereas there are many projects researching the concepts, principles, methods and technologies of collaborative working, an analysis of literature and available cases reveals that there are only a few case studies of existing collaboration networks available.

Knowledge worker networks are especially relevant to the phenomenon of collaborative innovation. Emphasis of open innovation literature [11] is strongly on the importance of business models to govern sustainable business collaboration. As a wider form of open innovation within a network, linking business models to collaborative working, the model of creative communities or “creation nets” has been proposed [12]. Such creation nets include tens to thousands of participants from diverse institutional settings collaborating to create new knowledge, to learn from another, and to appropriate and build on one another’s work. Collaborative networks thus embody collaboration between companies based on a business model as well as personal collaboration within and between specialist teams or networks of professionals across the companies. An interesting example explored in ECOLEAD, 6th framework project, is the attempt to establish a virtual network of engineers in the Apulia region of Italy. This network is supported by a web collaboration infrastructure and offers a professional virtual community base services. An example in the car manufacturing industry of how in response to an emergency, ad-hoc networks may

emerge and function is the Toyota community [13], demonstrating informal ways of self-organisation without contracts, where experts and companies stepped in where possible.

2.2 The Concept of Work Routines

In little more than twenty years, the notion of routines has become a central construct in economics as well as subsequently in various fields in business administration, mainly organization theory and strategic management. The most commonly referred to discussion of routines by [9], defines a routine as a "repetitive pattern of activity in an entire organisation". Routines - interchangeably with the terms work practice or process - include all activities, rules, strategies, and cultural attitudes that are employed by organisational members to achieve a specific goal [10]. As such, one can understand that the capabilities of an organisation are largely captured in its routines.

In this paper, we mainly focus our interest on collaborative routines that they require which have not yet received the attention they deserve. Collaborative work routines can be defined as recursive and collective processes of working together toward common objectives. In order to capture the emerging realities around collaboration, it is essential to look at the nature of routines, how they shape and are shaped by organizational structures.

Collaboration becomes a routine if actors in an organisation use very similar approaches and activities for similar needs, even if they occur in different situations. For example, actors in an organisation might have the same project definition approach (planning and assigning tasks) regardless of the type or size of project, or they use the same strategies of e.g. calling a meeting to solve a problem, regardless of the situation the problem occurs in. Deliberately looking into routines of actors in actual work contexts can offer rich and conceptualized pictures of what today's workers do, how they collaborate in their everyday work activities, how they interact with other people, which collaboration/communication tools they use in distributed collaborative working environments.

3. Case Study

3.1 Research Methodology

Case studies are used for many purposes, e.g. to provide a description, to generate a theory or to extend a theory. Case studies can be exploratory, descriptive, explanatory or confirmatory, they can consist of one (single case study) or several cases (multiple-case study) and they can be based on qualitative or quantitative data collection. Usually, they combine several data collection methods. Actually, a major strength of the case study method is the opportunity to use many sources of evidence (data triangulation), and many data collection methods (methodological triangulation). Multiple sources of evidence and multiple methods provide a better validity for the findings [14; 15].

The main purpose of this study is to describe theoretical issues and actual challenges in the collaborative working environment. The case study method offers a possibility to gain a deeper understanding of current practices and problems regarding collaboration, especially in construction and research & innovation domains. In this study we have ongoing deep insight in all steps of the process and therefore could apply both methodological triangulation by combining several data collection methods, and triangulation of the data sources by comparing the perspectives of people from different points of view.

3.2 Data Collection

This research can be characterized as explorative and aims to understand in-depth the collaboration issues within the context of collaborative work environment. Rich data and good data analysis are two necessities for case study's success. As case study preparation,

an analysis framework and potentially relevant constructs were developed. The main data was collected through interviews and informal participant observation through the course of the projects. Moreover, many artefacts (documents, drawings, and pictures) were collected related with the cases and used as background information and for cross-checking. Field notes and written material such as memos, emails and meeting minutes were further used for data analysis.

3.3 Case Description

The case study-based, practitioner-led inquiry presented in this paper attempted to describe main collaborative working issues and challenges within different project settings – a building reconstruction project and a scientific research project. The potential of such an inquiry was explored to broaden the understanding of collaborative projects as complex social arrangements and the quality and level of collaboration as well as the different coordination approaches. The case projects are active, real projects, but their names and the names of the actors participating in the cases have been changed to ensure anonymity.

First case study, Alpha, refers to the house-office building re-construction project. The project work was organized in three phases where; phase 1 of the project was dedicated to constructive building of foundations, walls and roof, phase 2 then was focused on technical installation such as heating system and the electricity grid, and phase 3 was reserved for the finishing work of plaster, painting, floor decoration and such.

Second case study has been conducted in Beta which is formally an independent, non-profit research institute focusing on technology and innovation management. The institute is organised as an extremely networked platform of knowledge workers from across the world that collaborate among them and with partners from industry, public organisations and academia. The case refers to the collaborative authoring of a scientific research project proposal in Beta.

4. Case Results

In this section, overview descriptions of different work routines encountered in different stages of projects are introduced. When looking at the respective knowledge intensive work routines, some important issues and challenges have been observed related with coordination, inter-dependence, complexity, and user involvement.

4.1 Collaborative Engineering in Alpha

This case mainly puts its focus on collaborative engineering issues in a house-office building re-construction project which highly includes the aspects of knowledge work such as the combination and alignment of different people's contributions to an innovative result.

Within the context of reconstruction process, some interesting practices were identified which address key aspects towards collaborative engineering. One interesting case in this context was the collaborative effort of the electrical engineer. Because of the relevance of the field bus system, which in fact becomes the electrical nervous system of the house linking all other subsystems, he was not subcontracted to the prime contractor but engaged in a collaborative team setting with expected self-coordination. This collaboration worked well with most of the other engineering services, but not with the ventilation and heating engineers, who persistently insisted on hierarchical coordination.

The issue of architectural innovation or changing boundaries was obviously observed in phase two where user involvement and innovation was increased and project organization was changed towards a collaborative project team. All parties cooperated for the first time in this project and were invited because of their special competencies.

The issue of interdependency was seen as a major driver towards good collaboration in the project. As observed in the course of the project, interconnected systems are normally avoided as much as possible in construction, for example by giving enough space that water, gas, electricity and other pipes do not interfere. In construction projects, space constraints create such interdependencies when as in this case; the space for technical pipes in an old monumental house is much smaller than in comparable industrial buildings.

During the construction phase, unexpected changes evolved first from the unexpected inconsistency of the basement, which required re-planning, and secondly from the "user" involvement requesting innovation in sustainability and work place design for big impact on the execution of the task, not only on the big lines of the project, but in many details.

4.2 Collaborative Proposal Writing in Beta

This case is focused on the development of a project proposal which also shows the key aspects of the knowledge work such as substantial collaboration across boundaries towards output creation.

The routine starts with planning the proposal. This includes gathering as much information as possible from the funding bodies about the call for proposals, related guidelines and requirements, and deadlines. Also a collaboration platform was established and potential partners were identified.

During the concept development, partners have been developed increasingly a common understanding of the objectives, approach and potential contributions. Based on extensive, usually virtual discussions, the final partner consortium was emerged, as well as a short concept document listing the key points and the sections of the proposal.

During the next phase, different partners take in turn responsibility for further developing the proposal sections towards increasing maturity and quality. After a partner has worked on a section, another partner reviews and improves it. Any problem was discussed between all affected partners, known by their role and competence within the proposal.

A facilitator constantly has managed the versions of the document and a central maturity display, by which everybody has an overview of the current status and work that needs to be done. The final product was then reviewed in total and any issues were solved. In the closure stage, the facilitator has submitted the proposal both via post or tendering workspace.

5. Cross Case Analysis

5.1 Coordination approaches

In the early stages of the Alpha, a traditional and hierarchical coordination approach was used to manage and coordinate the project activities which resulted in a significant centralization of management authority and control which in turns potentially jeopardized the project completion. On a high level, work was coordinated by formal mechanisms and assignments. Work was clearly divided according to disciplines and phases in the project and assigned through the project plan assuming little ongoing collaboration between individuals. Coordination was generally quite effective since the building space was less complex, requiring fewer interactions between the disciplines. Every actor has a specific work to do such as design, detailed engineering or installation within a clearly defined specialization scope. A large portion of the planning and coordination on the project was occurred primarily in the engineers' heads and was not supported explicitly in a collaborative way.

In parallel, with increasing intensity towards the second stage of the project, a second coordination approach was observed to which we refer as coordination through heedful

interrelating, in form of self- coordination of different crafts for interconnected reconstruction activities [16]. In mid of second stage, it has been decided to achieve the coordination mainly through managing the maturity levels of different tasks and sub-tasks. Therefore, almost all parties formulated their expectations and predictions regarding the demands of the tasks and the actions and needs of others towards re-developing the joint vision of the project. Especially the foreman collected the feedback and contributions from others and immediately incorporated them into new planning versions whilst at the same time updating the status overview and issue list for the whole task. Rather than as a central coordinator involved in problem solving activities in a formal way, foreman acted as a facilitator who is partially involved in communication and coordination activities.

The coordination in Beta is fundamentally different than the first phase of Alpha, but similar to the second phase. It starts with not having a powerful project manager, but a facilitator who ensures communication, while the responsibility was shared between partners. Through an extensive preparation and goal seeking process, all participants developed a joint vision and understanding of the future project. They have positioned themselves in the proposal, as well as understood other partners' roles. A second part of the preparation process was to agree on a common working approach through having some intensive discussions within an instantly or previously organized Skype sessions and establish related practices and tools. During the operative phase, coordination was achieved through managing the maturity levels of different parts of the tasks. Participants directly see where maturity was not yet sufficient and focus their activities on these, reporting to the central person only that they were currently working on this part.

5.2 Tool Support Comparison

In Alpha, there was not a real tool support for storage and transfer of files between the different disciplines. Additionally, different actors have developed individual support tools, e.g. to keep track of tasks and status, but there was a lack of suitable mechanisms to share them. On a day-to-day working level, communication practices ranged from face-to-face discussions e.g. at the site, informing others by e-mail, phone. Because the technological infrastructure for communication and status tracking was not well established and organized in the project team, a lot of informal and time consuming collaboration, revision and improvised status tracking were needed to coordinate the work. In fact, in the later stages of the project, work was considerably diverted from the technical drawings until finally photos were made to document the building work. Information systems, such as the CAD system and project plans were aligned to this organizational setting and mainly support technical function such as technical design, making the drawings, calculating durations or cost, and so forth.

The building shared understanding and driving maturity coordination approach of Beta is finally hardly possible in a virtual setting without considerable tool support. Especially virtual presence and easy synchronous communication and collaboration provided by Skype and e-Pop conferencing system enabled the frequent interactions and joint problem solving necessary. The VE-Forum shared workspace was used for document storage and exchange, but also for displaying the latest maturity status, while the inbuilt version management and merging functionality of Word was used for integration. However, there was little dedicated support for the coordination practices which rely on the skills of the facilitator.

5.3 Collaborative Work Requirements

Based on the issues and challenges identified within two cases, a list of requirements is derived to aid on developing innovative concepts and technical solutions within the context

of collaborative working as shown in Table 1. Then, a short list of web collaboration applications are recommended for online collaboration and virtual teams.

Table 1: List of Collaborative Work Requirements

Case	Requirements	Applications
Alpha	• Mobile devices to access data on travel or mobile and to exchange CAD drawings between design teams and site offices • Devices which shall allow multiple images to be superimposed on each other • User interfaces that are adapted to collaborative engineering practices • Shared workspaces which shall allow the exchange of documents from any device. • Management dashboards to better understand who is doing what and to keep the track of progress.	• Ajaxworkspace (hosted suite of collaboration applications) • BSCW (collaboration platform for document sharing, work coordination, version management, online communication) • Buzzsaw (online workspace oriented toward engineering firms & construction) • Central Desktop (easy-to-use group workspace with features discussion forums, file libraries, calendars, task tracking, wikis, live conferencing) • Google Apps (Free service offering web-based creation and editing of word documents, spreadsheets, and web pages) • IBN-CS (Powerful, secure collaboration, communication and tracking solutions for any size organization) • Sharepoint (facilitates collaboration, provide content management features, implement business processes, and supply access to information • Vista Suite (collaborative 3D viusalization environment for engineering and construction)
Beta	• Use/integrate different file management systems (shared drives, workspace, PDM) • Effective version management with change history, merge versions, branching • Tagging, other mechanisms beyond folder structure • Linking mechanisms of files into work context • Easier offline usage (e.g. through offline context) • Dashboard on the right level of overview • Integration of project support tools (calendar, time sheet, planning) • Making activities visible for participants • Share information and collaborate on documents	

6. Conclusion

The paper sheds some light on the nature of collaborative working in the construction and research domain with special focus on the concept of work routines/practices. Furthermore, the paper illuminates emerging requirements which might help to provide a good basis for information system development. Based on the analysis of the coordination approaches used in the case projects, different coordination strategies seem to cause considerable productivity differences within the context of collaborative work.

For management, this implies that there are very different coordination approaches possible for the same work and that these matter considerably. Coordination is key part of the tacit interactions [17] that drive performance variance in knowledge intensive work processes. Current project management practices work well for coordinating one part of collaborative tasks, namely those that are loosely interdependent in the sense that they need only be coordinated as a sequence over time. In situation where modularity can not be achieved in advance, or is lost through not anticipated events in the course of the project, traditional project management contributes little to predict the outcome of projects. This research needs to set out with identifying coordination mechanisms, for example heedful interrelating, that are not incorporated in mainstream project management literature and find ways to link and accommodate them. We conclude that tool support matters for collaborative working, however only if it is well aligned with the specific requirements.

Future research is concerned to establish and model the causal relationship between the factors and the effectiveness of coordination approaches on overall team and project productivity.

The practical contribution of the paper to all practitioners is a hypothesis of why collaborative projects are as difficult as they are. To professionals, we contribute the insight that there is a point where they should distrust their project management instruments and rather rely on the not so "common sense" of good facilitator. For research and theory, the paper calls for some review and extension of the routine concept, catering more specifically for the management and coordination level of activities, as well as patterns that are very flexible in their application to different situations, but at the same time very consistent. Such routines can in our eyes be expected to lead to different specifications for collaborative engineering information systems. We feel that this proposition can easily be verified, if it eventually leads to adoption of information systems.

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