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Research Article

Knowledge Worker Roles and Actions—Results of Two Empirical Studies

Wolfgang Reinhardt[1]*, Benedikt Schmidt[2], Peter Sloep[3] and Hendrik Drachsler[3]

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[1] *University of Paderborn, Department of Computer Science, Computer Science Education Group, Fürstenallee 11, 33102 Paderborn, Germany*
[2] *SAP Research and University of Darmstadt, Department of Computer Science, Telecooperation Group, Bleichstraße 8, 64283 Darmstadt, Germany*
[3] *Open University of the Netherlands, Centre for Learning Sciences and Technologies, 6401 DL Heerlen, the Netherlands*

This paper proposes a typology of knowledge workers and their respective knowledge actions. The extant literature on the definition of knowledge work actions is examined and evaluated. The existing classifications of roles of knowledge workers are evaluated and extended with additional literature and empirical findings on the definition of a typology of knowledge worker roles. The empirical data in this paper comes from two studies. In the Task Execution Study 20, a knowledge worker had to carry out a selection of prepared tasks. The computer system that the participants were using was equipped with sensors, so that the execution steps of the tasks could be traced and analyzed. The data from the second study comes from a questionnaire survey of knowledge workers, which yielded 43 responses. The paper shows that the sampled users take on all identified knowledge worker roles, and that the knowledge work actions can be recognized in the sensor data from the first study. This paper contributes to the literature by proposing a new way of classifying the roles of knowledge workers and the knowledge actions they perform during their daily work. Furthermore, the paper provides a preliminary understanding of the relation between knowledge-intense work tasks, the roles they are executed in, and the tools that are used to accomplish the respective tasks.

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INTRODUCTION

Knowledge work has become the major driver for the present research and development efforts. As early as 1959, Drucker identified the transformation of the society into a post-industrial state, where the main shift was from manual towards non-manual work (Drucker, 1959). The main feature differentiating knowledge work from other conventional work is that the basic task of knowledge work is thinking. Although all types of jobs entail a mix of physical, social, and mental work, it is the perennial processing of non-routine problems that require non-linear and creative thinking that characterizes knowledge work. Organizational knowledge management (KM) positions knowledge as an organizational resource and emphasizes the importance of knowledge work and knowledge worker productivity to achieve competitive advantages. Research in the field of KM has focused on four scopes: (1) the nature of knowledge and how it differs from data and information; (2) the organizational aspects of its implementation; (3) the creation and utilization of knowledge management systems (KMS); and (4) motivational aspects of knowledge sharing within the organization.

(1) The first scope of knowledge management has received notable attention with the approaches to differentiate between implicit and explicit knowledge (Polanyi, 1967; Nonaka and Takeushi, 1995; Alavi and Leidner, 2001; Day, 2005; Walsham, 2005), along with research towards the organizational extraction and usage of implicit knowledge. Although knowledge has always been a determinant of personal and organizational success, its relation to the

*Correspondence to: Wolfgang Reinhardt, University of Paderborn, Department of Computer Science, Computer Science Education Group, Fürstenallee 11, 33102 Paderborn, Germany. E-mail: wolle@upb.de

concepts of data and information, together with distinctive features, are constantly discussed in the philosophical and technical domains.Although data is commonly defined as raw symbols or numbers that are recorded through measurement processes (Ackhoff, 1989), a definition of information needs to be developed, which includes at least a contextual and a technical point of view. Erren (2010) incorporated both a human and a technical dimension in his definition of information when he stated that “Information is that part of perception or measuring that gets noticed making a cognitive or technical difference by standing out.” The precise definition of knowledge, however, is something that researchers tried to come up with during the last two millenniums. For this article, and following (Spender, 1996), we will consider knowledge as “a process or a competent goal-oriented activity rather than as an observable and transferable resource” that allows the derivation of new understanding in non-routine problems (Billet, 1998).

(2) The organizational aspects and derivation of models for organizational knowledge flow have also received attention from researchers. Several models have proposed to map the personal and organizational flow of information and knowledge in various settings and with differing focal points. Holsapple and Jones (2004, 2005) have developed an advanced knowledge flow model, which portrays and discusses activities in knowledge work. Furthermore, Walsham (2005) introduced a model for the transfer of knowledge in organizations that was extended by Riss *et al*. (2007). The model’s distinguishing feature is the representation of connections between the different knowledge types in the transfer process. The knowledge maturing process introduced by Maier and Schmidt (2007), identifies phases of inter-individual knowledge exchange and the analysis of disruptions in the exchange. The model distinguishes between diverging phases in the development of knowledge and associated information artifacts of different maturing levels with those phases. Barth (2004) and Nissen (2005), on the other hand, focussed on models that depict the influence of tools and different forms of knowledge on the knowledge flow.

(3) The third stream focuses on the creation, implementation, and practical utilization of knowledge management systems. Whereas from a practitioners’ perspective, the stream was dealing mainly with the adoption and adaption of existing software solutions and the development of methodologies for knowledge management implementation (Quaddus and Xu, 2005; Stieger and Aleksy, 2009), this scope of research also includes the critical analysis of the value that arises from the utilization of KM systems (Kautz and Mahnke, 2003).

(4) In recent years, the motivation of employees has also been widely studied. Researchers as well as practitioners recognize motivation to be a major factor for the acceptance and usage of knowledge management systems. Kunzmann *et al*.(2009) discussed the relevance of integrating both intrinsic and extrinsic motivation of knowledge workers into the design of learning support strategies in organizations. Knowledge workers’ motivation to use KM systems is, hence, depending on three dimensions: the individual, the inter-personal, and the work context dimension. Andriessen (2006) pointed out that individual knowledge sharing behavior depends on multiple factors and processes including the individual intention and capacity to share as well as the perceived barriers for sharing and characteristics of the organization. Considering knowledge workers as investors of knowledge and energy in an organization (Stewart, 1998; Davenport, 1999; Efimova, 2004), knowledge workers are to engage in knowledge sharing activities if they have the right motivation to do so. Following the task of knowledge management should then be to establish work conditions that stimulate and activate employees to participate in active knowledge sharing (Kelloway and Barling, 2000).

Extensive research in the four domains notwithstanding, most of the relevant literature considers the organizational members who are entangled in knowledge as fixtures of the organization’s processes (Geisler, 2007). Thus, knowledge workers are often perceived as human objects whose cognitive dimension is targeted with knowledge management systems. The different roles knowledge workers possess, the activities and actions they are embedded in, and the potential role conflicts that emerge during work execution are only touched upon. A detailed typology of knowledge worker roles is thus needed to support such research.

Three basic questions guide our research presented in this paper. First, are there distinguishable roles that knowledge workers take on during their daily work? Second, what general knowledge actions are the knowledge workers performing on their job? And third, what tools are knowledge workers using in specific tasks, and how do they relate to the identified knowledge actions and knowledge worker roles?

This paper proposes a typology of knowledge worker roles and a classification of knowledge actions that link the generation and application of organizational knowledge to its users. The typology identifies 10 roles in the processing of knowledge. The final section of the paper discusses the

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implications for further research on the topic and the practical implications towards personal knowledge management (PKM) and organizational knowledge management (OKM) systems.

METHODOLOGY

As researchers of the physical and digital workplace, we investigated the roles and actions in organizational knowledge work by using integrated, qualitative, and quantitative research methods. Research focused on well and ill-structured knowledge-intense workplaces at all levels of the organization, including senior managers, first-level and second-level supervisors, technical engineers, junior and senior researchers; it covers several companies and research institutes in Europe. Participation was voluntary, and responses were kept completely confidential.

Research design

Research included various methods, from techniques that incorporated none to little interaction between researcher and respondent (i.e., observation of task execution or questionnaire), to those that involved greater levels of researcher–respondent interaction. The used approaches reflect our understanding that knowledge work and workplace learning occur in a continuum between the implicit and explicit. Understanding knowledge work demands a better understanding of "what people are doing" and the practices involved (Schultze, 2000a, 2000b). Practices unfold solution strategies of knowledge workers in repeated and rehearsed actions. A central element of solution strategies is the application of tools. The tool, forming the center-of-gravity of most practices in knowledge work ,is the personal computer with its various stand-alone and web-based applications (Pyöriä, 2005). Therefore, we consider understanding the practice of task execution with a personal computer as an important element of understanding the present knowledge work.

In the following, we describe our research methods and the total number of participants assessed for both studies.

Qualitative research methods

Qualitative research aims at gathering data and in-depth understanding of human behavior and the reasons that govern such behavior. One method to collect qualitative data by observation is shadowing. Shadowing refers to the observation of an individual or group, where the researcher does not disturb the participants except to ask brief questions for clarification. Shadowing allows researchers to see how task execution and learning takes place in its natural setting.

To gain insight into the practices of task execution with a personal computer, we have conducted an explorative task execution study (TES), which observed the knowledge worker when interacting with a computer system.

Task execution study

Our explorative study had the following setup. Twenty participants (16 men, 4 women; among them: six Post-docs, two Researchers, eight PhD students, and five Master students) working for an international software company in research had to execute a selection of tasks, using the standard computer environment provided by the company. The computer environment includes operating system, office suite and web browser. It represents a standard toolset used in many companies.

Each user executed six tasks, randomly selected from a repository of nine tasks. The users were familiar with the tasks, as they normally occur during their daily business (e.g., review applications for a job, create presentation based on different user input). The tasks were knowledge-intensive in the sense that they required individual planning of the execution steps, including the selection of involved information sources and tools in the given environment. To track the task execution process, we equipped the computer system with sensors, which generated 26 different event types, triggered by interactions with the system (128,507 events). Each event contained detailed information about the user interaction and the visual content presented to the user in the context of the interaction. After each task execution, the participants had to fill out a short survey sheet. The sheet asked for the main elements of the task execution process, the user's intention, and the awareness of decisions that were considered.

Only little research is conducted in the domain of execution of knowledge-intensive tasks. Several studies exist about algorithmic performance and features for task identification based on user-system interaction data in the domain of machine learning, for example, (Lokaiczyk *et al.*, 2010); (Rath, 2010); and (Brdiczka, 2009). The process of task execution is not in the focus of these studies. We generate interaction data, such as in the given examples, but focus on explorative data analysis to find manifestations of individual solution strategies of knowledge workers within the interaction data.

The data analysis revealed various aspects that required further investigation. Thus, a second study synthesizing those aspects was conducted and described in the following section.

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Quantitative research methods

Although qualitative research provides an in-depth understanding of the execution of tasks, quantitative research, in the form of surveys, gathers data on the diverse opinions and views on knowledge work. It is a useful complement to the qualitative data. In the knowledge worker roles questionnaire (KWRQ), we prepared an online questionnaire using the free software LimeSurvey (Schmitz, 2010), as it was the most suitable approach for the quantitative part of this research. The KWRQ consisted of 46 questions in four groups and was targeted at European knowledge workers in both well-structured and ill-structured working environments. The link to the questionnaire was sent to two European research projects and personal contacts at 10 small and medium enterprises for distribution among the employees. Moreover, we shared the link in Twitter and two professional networking sites in dedicated groups for knowledge Q4 management. Out of 149 participants who started the answering of the questionnaire, only 43 participants completely finished the questionnaire. On average, it took the participants 39 minutes to fill in the questionnaire.

Survey respondents' demographics

The following demographics illustrate the range and diversity of the questionnaire's respondents:

- 60% are male, 40% are female
- 58% work in educational or research organizations, 40% work in corporate organizations, 2% work in open-source software-development projects
- 47% are between the ages of 25–30 years, 14% are between the ages of 31–35 years, 12% are between the ages of 36–40 years, and 28% are 41 years and older with a maximum age of 60 years
- 56% work in Germany, 9% in the Netherlands, 7% in Switzerland, 7% in the UK, and 5% in Estonia. Other respondents work in Austria, Belgium, Finland, and Sweden.
- 21% work in the educational sector, 16% in the research sector, 12% in the computer software sector, 9% in e-learning, and 9% in information technology. Other respondents work in the marketing and advertising sectors.

Survey respondents' work experience

Again, the following data about the respondents' work experience illustrate the range and diversity of survey responses.

- On average, the respondents have 9 years of overall work experience, ranging from 1 to 38 years in the extremes. Thirty per cent have an overall work experience of up to 5 years, another 30% have between 6–10 years of overall work experience. Twenty-three per cent of the respondents have between 10–20 years of work experience, and 16% have more than 21 years of work experience.
- The respondents have worked in their current positions for 3 years averagely; 56% have worked in their current position up to 3 years, 28% between 4 to 10 years, and 16% for 11 years or more.

KNOWLEDGE WORK AND KNOWLEDGE AS RATIONAL CAPACITY

The notion of knowledge work coined by Drucker (1959) and Bell (1974) has proven useful to capture a class of work of vital importance for modern economies: work with an increasing integration of information creation and consumption into daily work processes. Brinkley *et al*. described the knowledge economy as, "the story of how new general purpose technologies have combined with intellectual and knowledge assets—the intangibles' of research, design, development, creativity, education, science, brand equity, and human capital—to transform our economy" (Brinkley, 2008). This knowledge economy is based on workers who engage in knowledge-intensive tasks in their daily work. Knowledge-intensive tasks resist standardization because of their contingent nature. But the fact of the matter is that, a standardized classification of knowledge work is difficult. Pyöriä (2005) studied knowledge-work definitions focusing on the nature of work as non-routine task, the education of knowledge workers, or the use of technologies such as IT. Pyöriä showed that none of the existing definitions of knowledge work captured all types of knowledge work, described in the literature. Therefore, Pyöriä is in favor of project-specific knowledge work definitions as an adequate way to cope with the diversity of existing definitions.

Following this idea, we want to give a specification of the knowledge work type, which is subject of this study. In this paper, we concentrate on knowledge work as the execution of knowledge-intensive tasks (e.g., decision-making, knowledge-production scenarios, and monitoring organizational performance), with IT support. In this domain, knowledge work essentially consists of the organization of information artifacts, their creation, consideration, and transformation. The work process is dominated by communication, data production, and consumption actions: sending and processing e-mails, web browsing, working on documents, or doing calculations.

The major characteristic of knowledge-intensive tasks executed using a computer is the weak structure of work execution processes (Byström and Hansen, 2005). The work process is the result of the individual application of knowledge to solve problems. This execution-centric perspective on

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knowledge favors the definition of knowledge as rational capacity: a potential, which only becomes manifest in action (Kern, 2007).

Utilizing knowledge as rational capacity in the work process shall be investigated further by an examination of rational human–world interaction. To specify this, we use an extension of the k-system model by Stachowiak (1976). Figure 1 depicts the individual context of a knowledge worker and his relation to the environment. The individual and world are connected by two modes of interaction: action and perception. Perception is a selective process, as it includes the identification of those elements of the environment, which are related to an individual intention (intrinsic context factors), and those elements that are not related to an intention (extrinsic context factors). Action connects the individual to the environment in the sense of an active transformation of the environment. Perception and action are guided by plans, which are generated based on individual intentions. The generation of plans towards a given intention, an objective with the resulting actions, perception of the environment, and continuous adaptation of plans, is the process of knowledge activation.

We give an example of a knowledge-intensive task and its execution. An individual is asked to create a presentation on the research topic “Augmented Reality” for a later presentation to other colleagues. The individual accepts a new intention, explicitly the creation of the presentation. The individual generates a plan guided by personal experience and consequently also guided by a possible lack of experience on certain aspects of the task (e.g., selection of PowerPoint as application, identifying the demand to search for details on Google, or ask colleague). The plan closely follows the perception (Where is the button to start PowerPoint?, Is a colleague online in the instant messaging tool?, etc.), and guides the action of the individual (open PowerPoint by moving mouse and clicking on it, open web browser by using a shortcut). As a result, only those elements of the world are considered relevant, which are aligned with the intention (e.g., an e-mail might arrive but is not processed further after identifying the sender as not related to the current task and not considered important enough to switch tasks). The results of the actions are permanently perceived and interpreted with respect to the plan (the colleague is not online, thus find another source of the required information or other ways to communicate with the colleague). Once the presentation is finalized, the individual reviews it again to assure the appropriate finalization of the task.

Most aspects of the given model exist only implicitly in the user. Apart from the produced artifacts, the action is the only observable fact that externalizes knowledge work. We assume that tracking of actions and reasoning about underlying motivations allow us to get a better idea of knowledge work as rational capacity, and as such, as actual work execution. Thereby, we focus, in this paper, on task execution on the computer desktop. Based on tracked user data, we assume that patterns of actions and internalized solution procedures of knowledge workers emerge.

ACTIVITIES, KNOWLEDGE ACTIONS, AND OPERATIONS

We explored the relevance of knowledge work for organizational progress and advance in research in the previous section. Moreover, we distinguished knowledge work from other types of work. As knowledge work does not simply mean the application of existing knowledge and its exploitation in a new setting, concepts applied in traditional process or workflow management seem to be inappropriate for their application. Thus, it is necessary to develop alternative concepts that are useful to describe the creative, unstructured, spontaneous, and improvement-oriented learning process that distinguishes knowledge work from other forms of work. The focus on work practices to study knowledge work is a common procedure and recommended by Blackler (1993), for example.

Activity theory (AT) has often been proposed as theoretical framework for the exploration of knowledge work practices. Following our distinction between data, information, and knowledge, the latter should be understood as something that is constantly subject to change within personal learning expressed in individual work practices. We will briefly introduce the basic assumptions of AT and their implications on the existence of what we call knowledge actions.

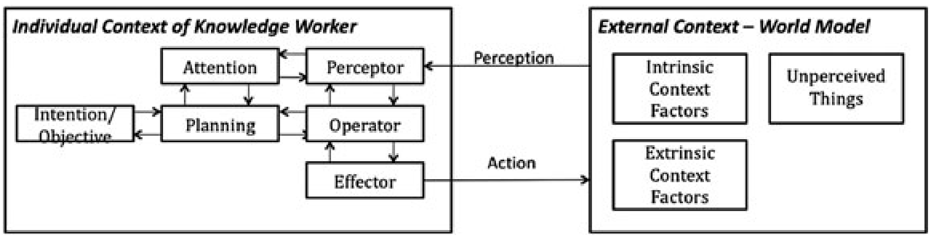

Figure 1 Human-world interaction model

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Activity theory finds its roots in the works of the Russian psychologist Vygotsky and was further developed by Leont'ev and Rubinstein. Vygotsky is the founder of cultural-historic psychology and was aware of important concepts that the Western social science only began to become aware of, about 40 years later, at the end of the 1970s. Vygotsky was synthesizing Karl Marx's conception of human nature as not to be fixed, but rather continuously shaped by productive activity (Hädrich, 2008). Marx's conception was mainly related to the production of material goods, but can also be referred to mental ideas (Blackler, 1993; Tolman, 2001). In his work, Vygotsky pointed out that higher mental models have their origin in social processes (also see (Tönnies, 1988) elaborations on community and society for that discussion). The smallest possible unit that Vygotsky suggested for the analysis of social processes is the so-called activity. According to Leont'ev (1977), activities should be seen as those processes "that realize a person's actual life in the objective world by which he is surrounded". Activities related between individual motives, expected outcomes, and the tools used within the actions of the process. Engeström (1987) updated Vygotsky's activity theory model to a more contemporary version including aspects of division of labor, the role of a community in the social process, as well as the existence of implicit and explicit rules. Engeström's version of activity theory then received substantive attention in the fields of human–computer interaction (HCI), computer supported cooperative work (CSCW) (Kuutti, 1991; Nardi, 1997; Nardi and Engeström, 1999; Mwanza, 2001; Collins *et al*., 2002; Nardi *et al*., 2002), and knowledge management (Boer *et al*., 2002; Clases and Wehner, 2002; Hasan, 2002).

In Engeström's activity system, activities have a hierarchical structure that is depicted in Figure 2 (Kuutti, 1997; Hasan and Gould, 2003). Each activity is driven by a common motive and accomplished by a set of actions, whereas each single action can be part of multiple activities. Several alternative actions and combinations of actions can achieve the objective of each activity. Research shows that actions consist of at least two phases: orientation phase and execution phase (Kuutti, 1997; Byström and Hansen, 2005), and that each action is directed towards goals. The first phase is typically described as the supporting phase, in which planning for action and reflection of planned operations takes place. The second phase is the actual execution of the action by a chain of operations that are executed under certain conditions. At the moment, operations are the smallest piece of knowledge work that can be traced with information technology. The three levels of activities share a vital relationship as concepts on higher levels may collapse into concepts on lower levels whenever learning or habitualization (also routinization) (Kuutti, 1997; Hasan and Gould, 2003) takes place. They unfold to higher levels, if changes occur, and learning is necessary.

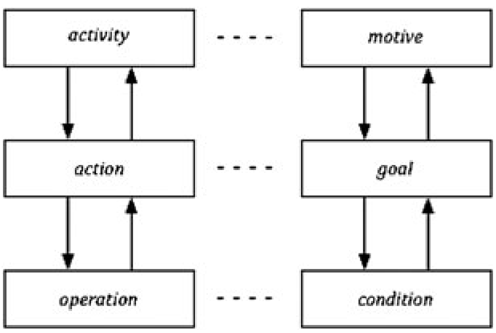

Figure 2 Hierarchical structure of activity, action, and operation (based on Kuutti, 1997)

A number of researchers and knowledge management practitioners have written about objective work occurrences in knowledge work. In the following, we classify the described work occurrences by activities, actions, and operations. The following classification is not all-inclusive and may be different for a specialized domain of work, but presents a basic understanding of the terms.

An activity stands for an individual commitment towards a motive. To realize the activity, different actions are required. A relevant part of knowledge work involves the application of recurring working techniques, which demand the creative and thoughtful adaptation to new situations. In the following, we use the term knowledge actions, following Hädrich (2008) to describe fundamental building blocks of knowledge work, providing work execution patterns. Frequent use improves the application of knowledge actions, but the automation to a subconsciously executed operation is not possible. Actions such as planning, checking, and so on that are carried out in personal and organizational knowledge work.

Knowledge actions, in general, have their foundation in the perspective of practices of knowledge work as described for example in Blackler *et al*. (1993). As Wenger (1998) pointed out, practice is the source of coherence of a community because of mutual engagement, joint enterprise, and shared repertoire. Kasching *et al*. (2010) linked to the work of Daskalaki and Blair (2002), when they argued that "practices formed by individuals that are part of semi-permanent work groups are examples of how knowledge work can be framed as a social process". Following the works of Schultze (2000a, 2000b; Hädrich 2008; and Kasching *et al*. 2010), we believe that knowledge work is characterized by certain knowledge actions and different roles that knowledge workers take on (Nonaka and Takeushi, 1995; Davenport and Prusak, 1998). In the following, we review literature towards the definition of knowledge actions that influenced the typology of knowledge actions presented here.[1] A number of researchers and knowledge management practitioners have written about KM practices and listed actions that are carried out in personal and organizational knowledge work. Davenport (1998) discussed the need to explore individual work actions to focus on knowledge worker productivity and to better understand knowledge work processes. Markus (2001) described a series of necessary actions for re-using knowledge in an organization with reference to Davenport (1999), such as documenting knowledge, packaging knowledge for re-use, and disseminating knowledge. Skyrme (1999) identified a set of knowledge networking actions, such as self-awareness, communication, and developing networks. Barth (2004) defined a PKM process model that is centered on knowledge actions and also mentioned tools that can be used. The actions are: accessing information and ideas (desktop search), evaluating information and ideas (collaborative filtering), organizing information and ideas (diaries, portals), analyzing information and ideas (spreadsheets, visualizations), conveying information and ideas (presentations, web sites), collaboration around information and ideas (messaging, meeting), and securing information and ideas (virus scanner). Davis (2003) discussed the effects of ubiquitous computing on the productivity in knowledge work and identified affordances that provide support for the knowledge actions: authoring, review, planning, collaboration, and communication. Efimova (2004) examined knowledge sharing and network development practices of knowledge workers involved in weblog actions. She suggested personal knowledge actions that incorporated awareness, establishing and maintaining networks, and organizing ideas. Holsapple and Jones (2004, 2005) developed an advanced knowledge flow model that reflects knowledge work actions, such as knowledge acquisition, coordination, and measurement of knowledge work. According to North (2007), planning, analyzing (including searching, structuring, and reflecting), synthesizing (including combination, reconfiguration, designing), communication and documentation, and learning are core value creation components in knowledge work. Hädrich (2008) identified a set of eight reoccurring knowledge work actions as particles of knowledge work. Each action is an abstraction from the actual task execution process and described as: authoring, co-authoring, training, acquisition, update, feedback, expert search, and invitation. Völkel (2010) empirically found use-cases in personal knowledge work such as learning, idea management, document creation, argumentation, and personal social network management. In T1 Table 1, we list a selection of relevant existing taxonomies for knowledge actions that influenced our synoptic knowledge work action list.

Not only did researchers investigate the nature of existing knowledge work actions but also different attempts to identify more granular knowledge actions exist. Operations are homogeneous work occurrences, that is, recurrent work occurrences are completely similar and do not require adaptation. As an effect, operations can be internalized and executed without much effort. All interactions with tools are operations, for example, using a pen, typing with a keyboard, or coordination with the mouse. Even complex work occurrences can become operations, as long as they are similar, which is the case for workflows (e.g., working on a form-based workflow might become an operation although the workflow itself solves a complex problem). Hädrich (2008) decomposed knowledge actions into different steps based on interviews. The model of Geisler (2007) was based on interviews with managers, who were actively engaged in knowledge management in their organizations. He worked out four stages of what he calls "knowledge processing", namely generation, transfer, implementation, and absorption that are then further described using concrete knowledge actions. Völkel (2010), on the other hand, investigated knowledge cues and processes in personal knowledge management. His knowledge model comes with seven main knowledge processes that are extended by four additional processes in collaborative knowledge work. The knowledge processes of the Völkel model are then further investigated and split in finer-grained process steps.

These approaches differ with respect to the granularity of descriptions and distinction of activities, actions, and operations. Where Hädrich's decomposition describes routinized aspects of knowledge-actions, Völkel (2010) and Geisler (2007) rather described explicit operations. Further research on the relation between activities, on the one hand, and operations, on the other hand, is much needed. Here, we focus on the level of knowledge actions.

A typology of knowledge actions

Based on the knowledge actions identified in the existing literature, in the following section, this article presents a coherent typology of knowledge actions. Each knowledge activity is characterized, and its related concepts from the literature are presented as well as typical actions for each activity.

Acquisition means the gathering of information with the conscious goal of either developing personal skills or a project. Acquisition also relates to the goal of obtaining a physical or digital asset in the context of one's work process. This action can be found in the sets of relevant knowledge actions

[1]Despite intensive literature study, we are aware that we might not have considered all existing classification schemes for knowledge work activities and actions that are out there.

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Table 1 Existing taxonomies for knowledge actions

(Davenport, 1999)	(Davis, 2003)	(Sellen and Harper, 2003)	(Efimova, 2004)	(Holsapple and Jones, 2004, 2005)	(Hädrich, 2008)	(Bernstein, 2010)
acquisition	authoring	acquiring	awareness	acquisition	acquisition	analyzing
application	review	annotating	collaboration	assimilation	authoring	applying
creation	planning	composing	conversations	control	co-authoring	evaluating
dissemination	collaboration	organizing	creativity	coordination	expert search	organizing
documentation	communication	processing	establishing and maintaining relations	emission	feedback	presenting
packaging			exposure	generation	invitation	retrieving
			lurking	leadership	training	securing
			making sense of information	measurement	update	sharing
			organizing ideas	selection		storing

of Davenport (1999), Markus (2001), Sellen and Harper (2003), Barth (2004), Holsapple and Jones (2004), and Hädrich (2008).

Analyze means to examine something carefully, and to completely understand it. This knowledge action can be found in the works of Barth (2004), North (2007), and Bernstein (2010).

The knowledge action *authoring* relates to the creation of textual or other media content with the help of technology. Authoring is embodied in the existing sets of knowledge actions, but it is partially paraphrased with other terms. For example Davenport (1999) mentioned the documentation of knowledge for its later reuse, which is clearly related to the externalization of one's knowledge in exchangeable artifacts. Sellen and Harper (2003) on the other hand, called an important action "composing", and Völkel (2010) called it "document creation". Hädrich (2008) explicitly mentioned the actions "authoring" and "co-authoring", where the latter could also be interpreted as "document creation" in Völkel's wording.

Co-authoring is the extension of authoring by a collaborative aspect and thus all "documentation" actions (North, 2007; Davenport, 1999) can also be subsumed to the collaborative creation of assets.

Dissemination means spreading information or information objects and often has the connotation of the propagation of one's own work results over various communication channels. Such an action can be found in most of the literature examined although, also here, the authors use various terms for describing the action. Davenport (1999) is the only author that used the term dissemination, whereas others use communication (Davis, 2003; Skyrme, 1999), exposure (Efimova, 2004), conveying information (Barth, 2004), emission (Holsapple and Jones, 2004) or sharing and presenting (Bernstein, 2010) for the same action.

The knowledge action *expert search* means the retrieval of an expert in a certain topic or domain to discuss an issue or solve a problem collaboratively. The only exact occurrence of this phrasing is in Hädrich (2008), but Efimova (2004) described the process as establishing relations to other knowledgeable researchers.

Giving *feedback* on something means to assess an idea or asset according to individual or community rules. This knowledge action is often described as evaluating some idea or asset or reviewing it (Davis, 2003), (Barth, 2004), (Bernstein, 2010), or it is directly named feedback as in (Hädrich, 2008).

Also, the knowledge action of *information organization* looms in the existing knowledge work literature. For example, Sellen and Harper (2003) and Bernstein (2010) explicitly named organizing knowledge a relevant action. Efimova's (2004) view on knowledge work is shaped by the usage of weblogs as tools, but she nevertheless mentions the organization of ideas as relevant and weblog-supported knowledge action.

Information search is a knowledge action, different than acquisition as the consciousness of the exact goal may be missing, or the precise asset to look for is unclear. Information search thus means looking up information on a specific topic or problem in a specific form. Often, knowledge workers use personal and organizational file storages during the action, or they avail themselves of information retrieval services, such as search engines. This knowledge action can be directly found in the works of Barth (2004), North (2007), and Bernstein (2010) and is also discussed in a broader meaning in (Davenport, 1999), (Skyrme, 1999), and (Sellen and Harper, 2003).

The *learning* action refers to the informal learning processes during the execution of work and in the exchange with others, as well as to formalized

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training courses. Besides thinking out of the box, lifelong learning is one of the key requirements on knowledge workers and the modern society (Delors, 1996). The ongoing concern with the latest research results, best practices, and newest technologies is important for a knowledge worker's productivity and effectiveness. Therefore, learning is part of the here-presented typology of knowledge actions. The action can also be found in the works of North (2007) and Hädrich (2008).

Monitoring is a knowledge action that refers to staying up-to-date about a selected topic or domain. Monitoring is a basic action, for example, analyze or feedback, and includes the self-directed updating about relevant topics after a period of having been absent from work. Monitoring is sometimes paraphrased as updating (Hädrich, 2008) or controlling (Holsapple and Jones, 2004, 2005). Skyrme (1999) and Efimova (2004) used the broader term awareness as relevant knowledge action, which comprises the active monitoring of a topic or community as well.

Networking means the physical or technology-mediated interaction with other people or organizations, with the goal to exchange information and to develop contacts or networks of experts. Thus, it comprises existing actions such as collaboration (Davis, 2003), (Efimova, 2004), (Barth, 2004), and communication (Skyrme, 1999), (Davis, 2003), (Holsapple and Jones, 2004, 2005). Moreover, networking needs to be a coordinated process (Holsapple and Jones, 2004, 2005) of conversations (Efimova, 2004) that is closely related to the knowledge action of expert search. Furthermore, there are explicit mentions of developing professional networks in (Skyrme, 1999), (Efimova, 2004) and (Bernstein, 2010).

The knowledge action *service search* refers to the retrieval of specialized services for a given problem. In (Davis, 2003), the topic of ubiquitous computing is introduced and related to the creation of text-based artifacts. Another example is the retrieval of a translation or booking service. This search action differs from the two other search actions presented not only because of the different object to be retrieved but also in terms of technology used and existing goals and motivation. In the broadest sense, the action of securing information or knowledge (Barth, 2004), (Bernstein, 2010) can be taken into account in this action as a knowledge worker may need to explore the existing service propositions within or outside the organization for securing their work.

T2 Table 2 provides an overview of the typology of knowledge actions, their description, and a selection of typical knowledge actions as part of the action.

In the following section, we explore the existing body of knowledge regarding the existence of differentiable roles of knowledge workers and present our typology of knowledge workers.

Table 2 A typology of knowledge actions

Knowledge action	Description
Acquisition	Means gathering of information with the goal of developing skills or project or obtaining an asset.
Analyze	Means examining or thinking about something carefully, in order to understand it.
Authoring	Means the creation of textual and medial content using software system, for example, word processing systems/ presentation software
Co-authoring	Means the collaborative creation of textual and medial content using software applications, for example, word processing systems/ presentation software.
Dissemination	Means spreading information or information objects, often work results.
Expert Search	Means the retrieval of an expert to discuss and solve a specific problem.
Feedback	Refers to the assessment of a proposition or an information object.
Information organization	Is the personal or organizational management of information collection.
Information search	Means looking up information on a specific topic and in a specific form. Often we search using the folder structure of a file system or we search using an information retrieval service.
Learning	Means acquiring new knowledge, skills or understanding during the execution of work or based on formalized learning material.
Monitoring	Means keeping oneself or the organization up-to date about selected topics, for example, based on different electronic information resources.
Networking	Refers to interacting with other people and organizations to exchange information and develop contacts.
Service search	Refers to the retrieval of specialized web services that offer specific functions, for example, a translation service.

TYPOLOGY OF KNOWLEDGE WORKER ROLES

Whereas in classic manual work, physical materials are transformed into tangible products, the transformation in knowledge work is a cognitive one. As described earlier, knowledge work requires prior individual and communal knowledge and the ability to apply knowledge in action and generate new potential knowledge. Drucker coined the term of the knowledge worker in (Drucker, 1969), where he describes him or her as "...the man or woman who applies productive work ideas, concepts and information rather than manual skill or brawn". It is difficult to develop a clear understanding of what exactly distinguishes a knowledge worker from a manual worker from this short description. Despres

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and Hiltrop (1995) offered more insight with their definition of knowledge work as being the "systematic activity that traffics data, manipulates information and develops knowledge. The work may be theoretical and directed at no immediate practical purpose, or pragmatic and aimed at devising new applications, devices, products or processes". Kelley (1990) pointed out that knowledge workers are "hired for their problem solving abilities, creativity, talent and intelligence" and Erren (2010) added that they "constantly [need to] familiarize themselves with new (scientific) findings in their respective fields of work in order to stay up-to-date on possible problems and innovative ways of solving them (including instruments and tools)".

Although the existing literature deals extensively with the nature of knowledge work and the distinction between knowledge and manual workers, only little research is carried out on the breakdown of different knowledge worker roles.

Merriam Webster describes roles as "expected behavior patterns"; roles structure and organize work. Within processes, roles are used to describe expected behavior of individuals within given processes. For organizations, roles have a broader scope and are accumulations of expected behavior, comprising a huge set of tasks. Using roles to organize tasks of knowledge workers highlights the different facets of knowledge work and supports the identification of different types of knowledge workers. An existing breakdown of knowledge work into roles has been carried out by Snyder-Halpern *et al*. (2001) who described the roles of data gatherer, information user, knowledge user, and knowledge builder in the domain of nursing. The four roles demand definitions for data, information, and knowledge and are very generic. Beckstead and Vinodrai (2003) proposed a knowledge-worker classification, which is based on the Canadian Standard Occupation Classification. They identified 40 occupational knowledge-based categories and categorize them in three classes of workers: professional workers, management workers, and technical workers; they all have at least a post-secondary education.

Brown *et al*. (2002) investigated the need for a person whose main task would be to integrate dispersed knowledge within an organization. They identified a knowledge integrator node that refers to people who consciously integrate knowledge gained during the communication with peers and then disseminate that knowledge across organizational boundaries. The authors are not concerned with general knowledge workers in companies, but specifically with those people involved in the creation of new knowledge ("knowledge creation crew" as Nonaka and Takeushi (1995) called them). Even if the early knowledge management literature suggested that knowledge was an asset that could be simply externalized, circulated amongst knowledge workers and internalized by them (Nonaka and Takeushi, 1995), we now know that knowledge cannot be stored in a knowledge management system: it being conceived of as rational capacity held by humans prevents that (Nonaka *et al*., 2001). Without dispute, artifacts can serve as "external memory" (Keil-Slawik, 1990), and knowledge workers externalize their individual knowledge in multimedia assets that are shared within a community or organization. The main reason why many authors regarded knowledge as exchangeable asset seems to be based on exactly this necessity of external artifacts for acquiring, storing, and sharing knowledge (Erren, 2010), (Alavi and Leidner, 2001), (Carlsson *et al*., 1996) (McQueen, 1998) (Zack, 1998). The roles identified in (Nonaka and Takeushi, 1995), namely knowledge practitioners, knowledge engineers, and knowledge officers are thus not directly relevant for the typology of knowledge workers presented here.

Davenport and Prusak (1998) on the other hand, pointed out that those knowledge practitioners, who have a wide variety of experience and are able to communicate with both colleagues and customers, may act as boundary spanners. They also may act as people who are searching for ways to solve complex issues and understand problems of fellow workers. Moreover, Davenport and Prusak (1998) described that skilled knowledge engineers can become sharers of knowledge and insight thus relating existing organizational knowledge to new visions. Fellow workers trust in the skills and knowledge of these engineers, who are well connected in the company's network. They further elaborate that knowledge officers can take on the role of a knowledge broker (gatekeeper or boundary spanner) and are connected to people outside the company who are looking for certain type of knowledge. Knowledge officers are hence often engaged in business-to-business networks.

A Forrester study from 2005 investigated the knowledge worker workplace and spotted lack of tool support for three types of knowledge workers (Moore and Rugullies, 2005): (1) Dreamers, people who develop new marketing ideas or strategize a company's future direction, lack tools for brainstorming, strategic planning, and business status visualization, (2) Problem-solvers, who are engaged with implementing the ideas and strategies developed by dreamers lack tools for decision-support and sharing best practices, (3) Doers ("people at the frontline") lack tools of monitoring the companies' performance "and streamlining exceptions like non-availability of resources or people" (Moore and Rugullies, 2005). In an empirical study, Geisler (2007) investigated factors that motivate knowledge workers working with organizational knowledge and identified three types of knowledge actors: generators, transformers, and users. Geisler (2007) pointed out that organizational members "play the

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roles intermittently," and that role switches may lead to role ambiguities and role conflicts.

Existing literature reveals a scattered view on the roles of knowledge workers. Based on the works reviewed, this paper presents a typology of knowledge workers roles that is more selective. Table 3 presents the nine knowledge worker roles that we identified, gives a short description of the individual roles, and names typical knowledge actions that we expected to be associated with the roles. The roles are that of controller, helper, learner, linker, networker, organizer, retriever, sharer, solver, and tracker. The role of a learner cannot be identified in the existing literature, but it is beyond question that all authors consider continuous learning and updating with the latest research findings, technology, methods, and materials as a core competence and requirement of a knowledge worker. Thus, we added this role to the typology to verify its existence and the corresponding knowledge actions in the KWRQ.

FINDINGS

In the following, we discuss the task execution study and the KWRQ. The studies conducted give evidence for the knowledge work roles and knowledge actions described in the previous section.

Task execution study

The participants of the task execution study executed a selection of tasks (see Table 4 for the given tasks). The tasks are knowledge intensive and were created with a focus on different aspects of similarity and variance. The freedom of the user during task execution varied. Some tasks explicitly propose different resources to be used and thus implicitly define a topic of the task (e.g., task 3 explicitly hints to application resources), whereas other tasks leave it to the participants as to which topic they worked on (e.g., task 1).

Table 3 Typology of knowledge worker roles

Role	Description	Typical knowledge actions (expected)	Existence of the role in literature
Controller	People who monitor the organizational performance based on raw information.	Analyze, dissemination, information organization, monitoring	(Moore and Rugullies, 2005) (Geisler, 2007)
Helper	People who transfers information to teach others, once they passed a problem.	Authoring, analyze, dissemination, feedback, information search, learning, networking	(Davenport and Prusak, 1998)
Learner	People who use information and practices to improve personal skills and competence.	Acquisition, analyze, expert search, information search, learning, service search	
Linker	People who associate and mash up information from different sources to generate new information.	Analyze, dissemination, information search, information organization, networking	(Davenport and Prusak, 1998) (Nonaka and Takeushi, 1995) (Geisler, 2007)
Networker	People who create personal or project related connections with people involved in the same kind of work, to share information and support each other.	Analyze, dissemination, expert search, monitoring, networking, service search	(Davenport and Prusak, 1998) (Nonaka and Takeushi, 1995) (Geisler, 2007)
Organizer	People who are involved in personal or organizational planning of activities, e.g. to-do lists and scheduling.	Analyze, information organization, monitoring, networking	(Moore and Rugullies, 2005)
Retriever	People who search and collect information on a given topic.	Acquisition, analyze, expert search, information search, information organization, monitoring	(Snyder-Halpern *et al.*, 2001)
Sharer	People who disseminate information in a community.	Authoring, co-authoring, dissemination, networking	(Davenport and Prusak, 1998) (Brown *et al.*, 2002) (Geisler, 2007)
Solver	People who find or provide a way to deal with a problem.	Acquisition, analyze, dissemination, information search, learning, service search	(Davenport and Prusak, 1998) (Nonaka and Takeushi, 1995) (Moore and Rugullies, 2005)
Tracker	People who monitor and react on personal and organizational actions that may become problems.	Analyze, information search, monitoring, networking	(Moore and Rugullies, 2005)

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Table 4 Taks with different configurations

Task	Description	Topic
Task 1	Provide information on related work on individual topic	User defined
Task 2	Set up meeting to discuss conference paper review	Conference details
Task 3	Decide on applicant invitation and communicate your decision	Applications and job offers
Task 4a	Plan a trip and inform your colleague with all involved information	ECAI 2010 conference
Task 4b	Plan a trip and inform your colleague with all involved information	ECEL 2010 conference
Task 5 extended	Present a paper from a foreign language to your colleagues	Complex event processing
Task 6a	Find application partners and experts for research project	Complex event processing
Task 6b	Find application partners and experts for research project	Augmented reality
Task 7	Search for Information on software functionality and save for later use	Microsoft visual studio

ECAI=European Conference on Artificial Intelligence; ECEL=European Conferences on e-Learning.

The task execution study generated videos, protocols, screen recordings, system events, and survey sheets filled out after task execution. A review of the data showed that the data could be analyzed following a division of the task execution process into three steps: task planning, task execution, and task completion. This is similar to a generic task execution process described in (Byström and Hansen, 2005) (Figure 3).

For the construction phase, we use protocols, direct observation, and sheets filled out after task completion. The construction phase can be described as hierarchical task decomposition: the task performer interprets the information given about the task and deduces goal, context, and execution actions and operations. In some cases, task performers asked for details, if they could not identify goal, context, or related subtasks with associated actions. Our survey showed that in 76 tasks out of 115 tasks, the participants considered alternative task execution processes. The participants started executing the task once they had identified the first action they could execute with the system. The initial plan generally was not complete, as it was adapted and changed during execution (Speech acts such as "… and now?" or "I thought it was here…"). Generally, the planning relied on answers to the questions "How-do-I-do?" and "How-can-I-know?" "How-do-I-do?" stands for speech acts related to the identification of a process (e.g., deciding on applications and application functionalities). "How-can-I-know?" stands for speech acts related to required information, which is represented as information resources or knowledge of the user. The participants had huge difficulties with task execution, whenever no answer to these questions could be given.

Reviewing the task execution times showed that the execution times for some tasks vary to a high degree among users (task 3, user 1: 1849 seconds, user 3: 389 seconds). A Shapiro–Wilk test shows that for all, but two tasks (task 2 and task 6), a normal distribution of execution times can be assumed (see Table 5). One aspect is a different working habit, as some users are slower and are working more solid. Still, such individual aspects do not explain the different execution times, as these users are not slower for all tasks (see Figure 4). A lack of "How-do-I-do?" and "How-can-I-know?" knowledge could be the main reason for the varying durations.

Figure 3 Task execution process (Byström and Hansen, 2005)

Those tasks, which required frequent searches and aggregations of information and decision-making, required most time of all users. These are especially the decision for applicant invitation (task 3), planning of a conference travel (task 4), translation of a document (task 5), and a decision on application partners for a research project (task 6) (see Figure 4).

Re-occurring actions and relations to applications

We have segmented the user actions in situations. A situation is specified as the time when a user is working with one application. Each change of the foreground application creates a new situation. We have only taken those situations into account that lasted longer than 3 seconds. A review of the situations that were shorter than 3 seconds showed that they did not include valuable process information. The biggest amount of situation switches was in

Table 5 Shapiro–Wilk test results

Task	W	P
Task1	0.92	0.097
Task2	0.86	0.008
Task3	0.94	0.235
Task4	0.95	0.354
Task5	0.92	0.091
Task6	0.88	0.015
Task7	0.96	0.654

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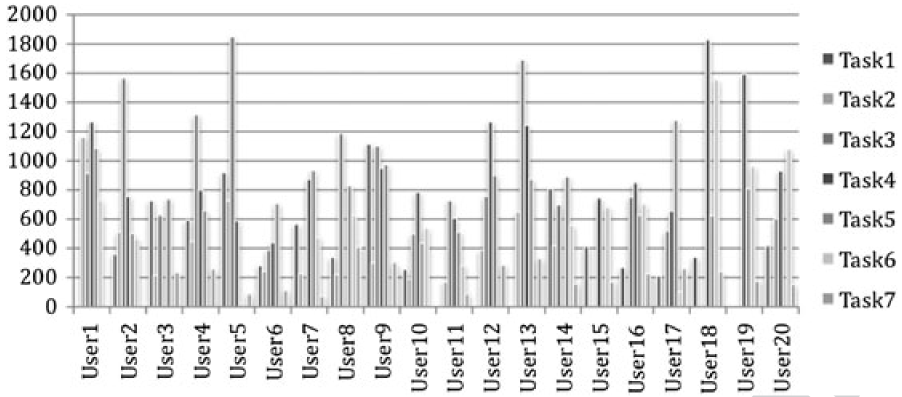

Figure 4 Distribution of execution times on tasks per user

task 3 by users 13 and 15 who had 71 and 75 situations, respectively (also see Table 7).

The switches generally occurred between the applications Internet Explorer, Excel, PowerPoint, Adobe Reader and Outlook. With 269 switches, the application most frequently switched to was Windows Explorer (involving the Windows Desktop, Program Manager, etc.), which includes all types of file operations, such as opening, searching or T6 moving of files (see Table 6). This shows the relevance of file operations for all types of tasks. The web browser additionally shows high relevance and was mainly used for information searches. Information search occurred during all tasks but did not focus on the "How-do-I-do?" The searches focused on content required to work on within the T7 task, using a process already known. (Table 7).

The sequence of situation represents the execution process. In the following, we review the execution process in three steps: (1) we analyze the user descriptions of the execution sequences, (2) we analyze the sensor events as the actual execution process, and (3) we compare the user description of the actions and the actions actually monitored.

Analyzing task execution descriptions given by users

After the completion of each task, the users filled out a survey sheet, to describe the task execution process with their own words. Users have an individual vocabulary to describe their desktop operations. As the users' vocabulary was not conterminous, we mapped the descriptions of the users to a newly created vocabulary. After the mapping, a similar core process was revealed in the users' descriptions. For example, the task "Decide on applicant invitation and communicate your decision" involves reading of the different included documents (also referred to as "look through," "browse and read"), decide (also referred to as "choose," "analyze and decide") and communication of the decision (also referred to as "send," "inform," "forward") for all study participants. Some participants included additional subtasks and decomposed some tasks to a finer granularity, describing operations (e.g., "open file"). To sum up, all participants show strong awareness of a similar core process, although different vocabularies are used to describe it. Difference exists on the granularity of perceived actions and the awareness of information requirements. This underlines the problem of distinguishing operations and actions: there are no strict borders between operations and actions, and individual perception differs.

Analyzing task execution as situations by sensors

The monitored actions are of very low granularity. For further analysis, we clustered the activity using the vocabulary, which emerged in the user analysis, and similar vocabulary used in the literature (cf., section Activities, knowledge actions and operations). For each element in the vocabulary, rules were created using the Drools framework.[2] The final vocabulary comprises five knowledge actions (e.g., authoring, communicating, browsing, organizing, executing) for complex activity sequences and 25 desktop actions (e.g., open application, create resource, . . .) Applied to our situations, we generated useful overviews of task execution processes.

We highlight the following findings from comparing execution processes as sequences of knowledge actions and desktop actions: 1) one can identify a similar core process. Still, the sequences in which the core processes are manifest, highly differ, and 2) the resources used were different. Users used different information providers in the Internet and opened different desktop objects to execute the given tasks.

Comparing task execution descriptions by users with situations by sensors

The resulting sequences of subtasks involved many actions and operations, which were not visible in

[2]See http://jboss.org/drools for more information.

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Table 6 Selection of most frequent transitions between applications (Read from row application switched to column application)

	Windows Search	iexplore	EXCEL	Powerpoint	AcroRd32	Communicator	Calc	Notepad	Windows Pic and Fax Viewer	Winword	Outlook	Explorer
Wind. Search												2
Iexplore			24		2						36	92
Excel		22									4	32
PowerPNT		4										2
AcroRd32								2		12	6	20
Communicator	2										2	16
Calc		4	8									4
Notepad					2					4		4
Windows Pic and Fax Viewer										2		14
Winword					12			2			14	18
Outlook	4	42	2		6	2				10		44
Explorer	4	90	32		18	6		8		20	46	

the description, given by the users in the survey. This refers especially to the creation of information objects, and data transfer between different applications. Cross-application actions are "glued together" by actions and operations users do not consider to be important to mention because they are deeply habituated. Such operations are, for example, Copy–Paste of information, creation of draft data objects (e.g., notepad is used to collect information later pasted in an e-mail), and information searches, which do not take much time. Additionally, the uses of software functionalities to realize the described actions (all execution steps included in rules) are not considered relevant for the transfer of task knowledge. Reoccurring operations are habitualized practices, which are activated in specific situations (Kuutti, 1997; Schultze, 2000a, 2000b). Individuals tend to omit those ingrained practices, when they talk about the task execution process (e.g., participants of the study omitted searching for a free conference room when describing the task in the survey sheet, although they performed that search). This is a potential danger with respect to knowledge transfer scenarios.

The linear sequence of the descriptions, provided by the users, did not occur in the actual execution. The actions are mixed. For example, a user initially reads documents, and then begins authoring, goes back to reading, etc.

To conclude:

1. All performers show a strong awareness of a similar core process, although different vocabularies are used to describe it.
2. Even if elements of processes are similar, they can be performed by different operations, for example, opening of a file is achieved by clicking "open" in a context menu, hitting Enter or a double click.
3. The resulting sequences of subtasks involved many actions, which were not visible in the user given description. This especially means the creation of information objects, data transfers between different applications. Cross-application actions and operations get "glued together" by actions users do not consider to be important to mention. For example, the copy–paste of pieces of information, switching between different applications, information searches, which do not take much time and activation of software functionalities that is known-by-heart. Thus, there exist "automated practices" not reflected by the user, and thus left out when describing a task. This is a potential danger with respect to knowledge transfer scenarios.
4. The linear sequence of the user given descriptions did not occur in the actual execution. The actions are mixed. For example, a performer reads initially documents, and then begins authoring, goes back to reading, etc.

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Table 7 Switch time for tasks

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7
Mean number of switches	12.85	6.50	33.05	22.70	30.80	10.35	7.50
Mean time between switches	25.32	46.72	16.94	21.51	11.44	42.57	15.47

The task execution study explored task execution on the user desktop. It hints towards two major characteristics of task execution: (1) the actual use of knowledge actions by individuals to structure work execution, and (2) the relation of individual work roles to such knowledge actions (Figure 5). F5

Knowledge worker roles questionnaire

The aim of the KWRQ was to find out which of the roles we identified earlier are taken on by knowledge workers in rather structured, as well as unstructured working environments. The questionnaire was split into four question groups: the first group of questions investigated which knowledge worker roles the participants take on, and how they characterize the respective roles. In the second group, we were asking questions regarding the relevance of presented knowledge work actions for the different roles of knowledge workers. The last questions group looked at demographic data of the participants.

Knowledge worker roles

The questionnaire shows that all participants (N=43) take on all described roles at least once a month. Of the participants, 70% take on the role of a learner, 65%, the role of a linker or solver, and 61% of the participants take on the role of a sharer. Of the participants, 58% see themselves in the roles of a retriever or organizer, 56% act as networker, and 54% as helper. Only 37% take on the role of a tracker or controller (23%).

In this section, the responses of the KWRQ are described and interesting facets of the roles are highlighted. This information is then further investigated in the two upcoming sections that deal with the detailed investigation of knowledge work actions and the software used to accomplish them. For each knowledge action, we asked the participants whether they think the action is used within the respective roles (5-step Likert scale from fully disagree (1) to fully agree (5), and the possibility to rate the action not applicable). We then calculated the means for all answers to make them comparable.[3]

The work of *controllers* is the most pre-structured (mean, 4.4) from all roles investigated: controllers tend to work on their own (mean, 3.7). Moreover, controllers use few dedicated applications to execute their work (mean, 3.4) and interact with predictable information sources (mean, 3.4). The effort for collecting and combining information needed in the role of a controller is balanced (mean, 2.7). Of the participants, 70% take on the role a few times a week. Regarding the germane knowledge actions of controllers, the questionnaire reveals that they are actively engaged in analyzing information or the facts of a business case (mean, 4.3). Moreover, they disseminate information in their personal and organizational network and give feedback on organizational propositions or information objects. Controllers are less involved in the authoring and co-authoring of new information objects, and the least engaged in formal and informal learning, networking with others, and the retrieval of specialized web services (Figure 6). F6

The role of a *helper* is taken on at least once a week by 78% of the participants; 48% of the participants take on the role even several times per week. Helpers tend to act rather proactive (mean, 2.65), and have to expend low effort for collecting and combining information needed in their role (mean, 3.0). The work as helper is hardly pre-structured and takes place in the interaction with others (mean, 2.52). Based on those results, knowledge actions associated with the role are consistent: helpers most prominently analyze the problem (mean 4.04) on which they are consulted. They search for additional information on the problem, consult internally and externally available sources, provide feedback on the original question or problem and disseminate their findings within a larger community (colleagues, team or organization). Even if helpers often interact with other people, it seems as if they do not co-author information objects very frequently (mean, 3.38). Also, the search for useful services is not carried out recurrently (mean, 3.35) (Figure 7). F7

Learners are mostly working alone (mean, 3.7) and have to deal with unpredictable information sources in many diverse applications. Learning takes place in hardly pre-structured work processes in a rather pro-active way. The role of a learner is taken on daily by 63% of the participants and several times a week by 87% of the participants. Nevertheless, the efforts for collecting and combining the

[3] According to Lord and Novick (1968, p. 21), the calculation of means for ordinal measurements is practicable as long as the results can be meaningful for the evaluation.

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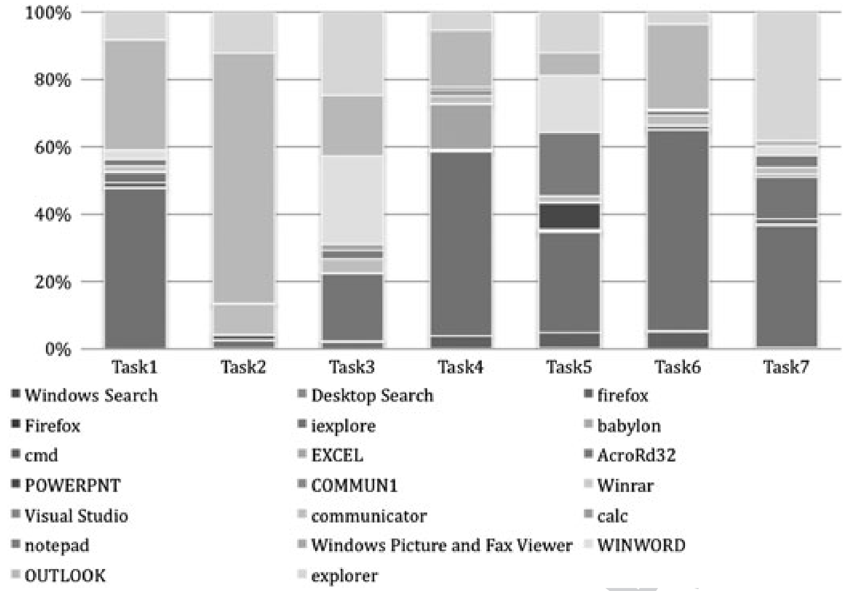

Figure 5 Application relevance per task

information needed are rather high (mean, 2.57). Regarding the knowledge actions that learners carry out during their work, it becomes obvious that learning happens during all kinds of work processes. The participants agreed that learning happens in nearly all knowledge actions and underline the fact that learners engage in information search (mean, 4.6) and analyzing of information objects and business cases (mean, 4.53) at an above-average rate. Also the knowledge actions formal and informal learning (mean, 4.34), acquisition (mean, 4.53) and information organization (mean, 4.38) were strongly related to the role of a learner. The collaborative creation of new information objects as well as the dissemination of work results seems to
F8 be less important in the role of a learner (Figure 8).

Of the participants, 79% take on the role of a *linker* at least several times each week and work as well on their own as with other colleagues (mean, 3.07). The work of linkers takes place in hardly pre-structured environments using a manageable set of applications. In the role of a linker, knowledge workers have to deal both with known and unknown information resources that are collected and combined with rather high efforts. As linkers associate and mash up information from various sources, their most prominent knowledge actions are information search (mean, 4.22), analyzing of information objects (mean, 4.19), and the acquisition of relevant information with the goal of developing a project (mean, 4.0). According to the participants of the questionnaire, linkers' daily activities are not dealing with the search for specialized services (mean, 3.04) (Figure 9). F9

Networkers use a balanced amount of different applications for their work. From all existing roles, networkers have the least pre-structured work (mean, 2.46) and are those with the highest interactions with other people (mean, 2.25). They act rather proactive and have a balanced effort for collecting and combing information sources from rather predictable sources. Fifty-four per cent take on the role

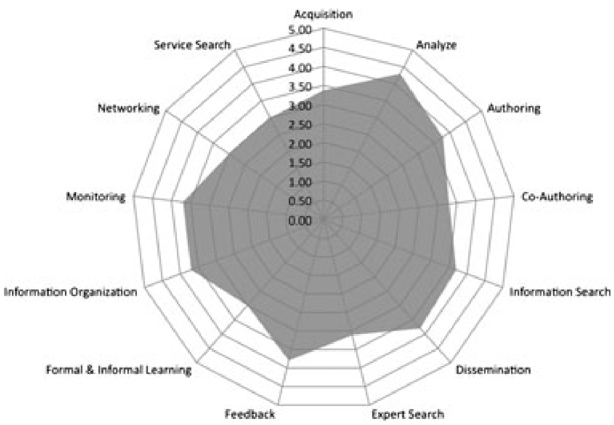

Figure 6 Knowledge actions for the role controller

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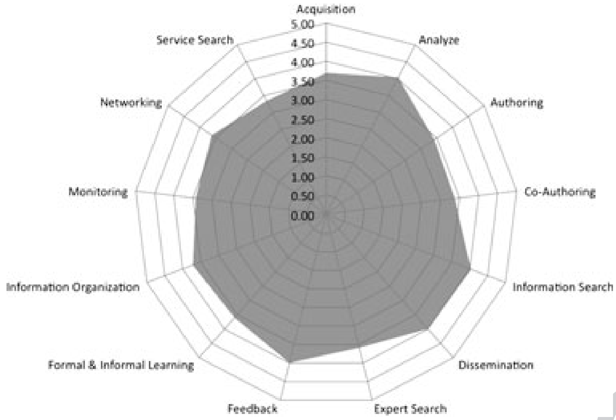

Figure 7 Knowledge actions for the role helper

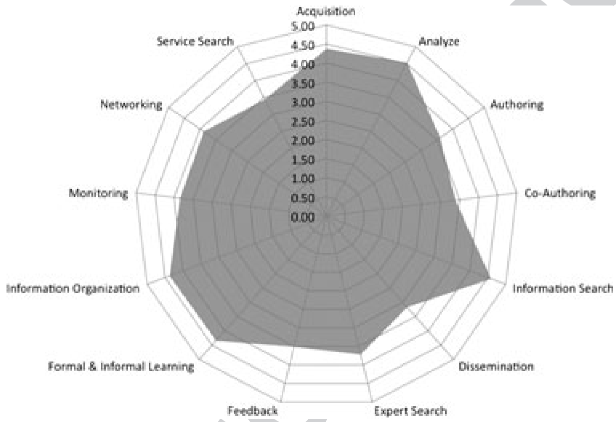

Figure 8 Knowledge actions for the role learner

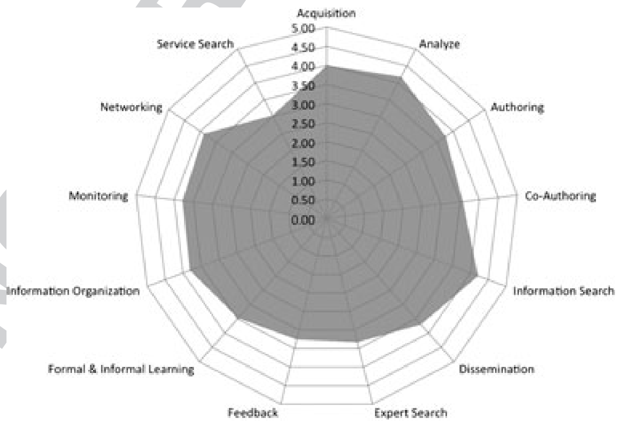

Figure 9 Knowledge actions for the role linker

of a networker at least several times a week, and 75% at least once a week. The main activity of networkers is to interact with other people to exchange information and experience or develop contacts (mean, 4.58). The search and retrieval of experts in specific domains (mean, 4.36) and the dissemination of work results and information object within the professional network (mean, 4.13), as well as the monitoring of important topics (mean, 3.90) are other important knowledge actions of networkers. The authoring of new information objects and the search for specialized services were not rated that important for the knowledge worker role (Figure 10). F10

Ninety-six per cent of the participants take on the role of an *organizer* several times a month. Organizers use the smallest number of different applications and access the most predictable information sources. On the other hand, their effort for collecting and combining information is the second highest of

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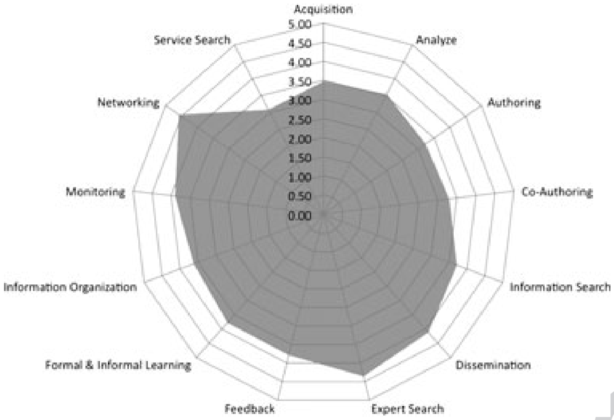

Figure 10 Knowledge actions for the role networker

all knowledge worker roles tested. The rather pre-structured work of organizers is carried out on their own. Organizers are involved in the personal and organizational planning of tasks, and thus deal with the analysis of business cases (mean, 4.21) and the organization of associated information objects (mean, 4.12). Organizers will also need to keep themselves up-to-date about selected topics in their area of responsibility (monitoring, mean 4.0). Learning and co-authoring are knowledge actions that are least often stated to be important for the
F11 role of an organizer (Figure 11).

Retrievers have the highest rate of working alone and expend the second most time for collecting and combining information. The role of a retriever is taken on at least once a week by 76% of the participants. They have to deal with hardly pre-structured working environments and are using both a balanced set of applications and information sources to accomplish their tasks. The role of a retriever deals with the acquisition, search, storage, and organization of information on a given topic. Thus, the participants stated that the knowledge actions acquisition (mean, 4.72) and information search (mean, 4.56) are most important in the role of a retriever. From the answers, it also becomes obvious that the participants regard several other actions such as monitoring (mean, 4.08), analyzing information objects (mean, 4.33), and information organization (4.04) to be important in that role. The individual (2.86) and collaborative authoring (mean, 2.73) of new information objects, on the other hand, only receives modest compliance from the participants (Figure 12). F12

Sharers have to expend the lowest effort for collecting and combining information from rather predictable sources. They use a manageable amount of applications during their work that 96% of the participants carry out at least a few times each month. Sharers are both working alone and with others in hardly pre-structured working processes. Sharers make use of their personal and professional network to disseminate information (mean 4.6). The development of such contacts and the upkeeping of one's network rank second in the list of important knowledge actions (mean, 4.2). The creation of textual and medial content to share with others takes place on their own (authoring, mean 4.0) as well as in the interaction with colleagues (co-authoring, mean 3.88). Because sharers know relevant information sources for their work, staying up-to-date seems to be a relatively 'cheap' action. The least relevant knowledge actions, within the role of a sharer are the search for services (mean, 3.28) and domain experts (mean, 3.2) (Figure 13). F13

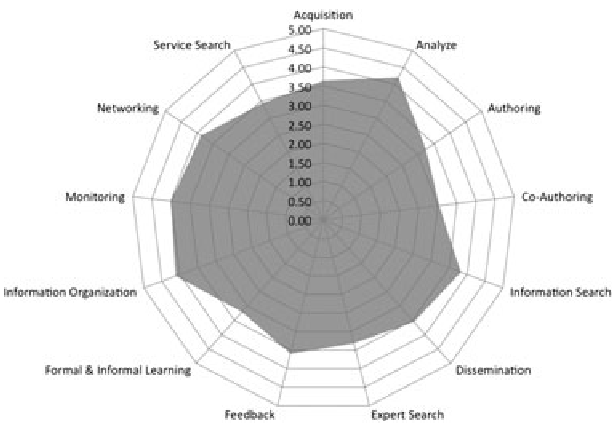

Figure 11 Knowledge actions for the role organizer

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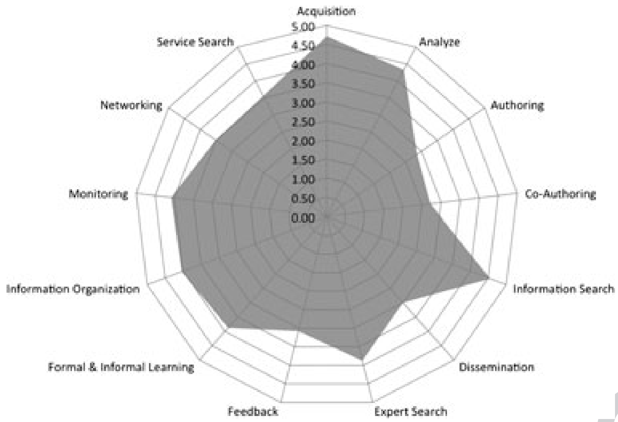

Figure 12 Knowledge actions for the role retriever

At least once a week, 75% of the participants take on their role as *solver*. Solvers have to expend the highest effort for collecting and combining information (mean, 2.25) and have to deal with unpredictable sources of information (mean, 2.89). On the other hand, solvers only use a balanced amount of different applications for their hardly pre-structured work, which they carry out for the most part on their own. Solvers are finding and providing a way to deal with a given problem. The most prominent knowledge actions in this knowledge worker role are to analyze the present case at the necessary depth and to search for additional information that could help with a solution for the problem. On the other hand, the participants do not emphasize the importance of the actions service search and co-
F14 authoring for the role of a solver (Figure 14).

The work of *trackers* is hardly pre-structured; they carry out their work in the interaction with others as well as on their own. Trackers use rather predictable sources of information with the help of a manageable amount of applications. Of the participants, 73% take on the role of a tracker at least once a week. Trackers spend a rather high effort on collecting and combining information that they use in their daily work. Trackers observe personal and organizational actions that may become problems and eventually prepare countermeasures. Thus, the monitoring of own and others' actions (mean, 4.53) and the analysis of these actions (mean, 4.33) are the most prominent knowledge actions for the role of a tracker. The search for relevant information (mean, 4.13) and the organization of those information objects are furthermore relevant for filling out the role. In contrast, the creation and co-creation (mean, 2.86 and 2.79, respectively) of new information artifacts are not key actions of trackers
(Figure 15). F15

A noticeable outcome of the questionnaire is the fact that all answers cover values between 2.3 and 2.92 between rather proactive and balanced, if asked for the activeness of the role (proactive or reactive). There are no correlations between the activeness of a role and its knowledge actions, the interaction with colleagues, and the degree to which the participants' work is pre-structured. Moreover, the most recognizable differences between the roles we identified can be seen in the structuredness of the work. Whereas the work of controllers is clearly pre-structured by organizational workflows and demands, networkers carry out their actions in a rather unstructured way. Networkers are heavily interacting with other people who influence work tasks, information resources, used tools, and

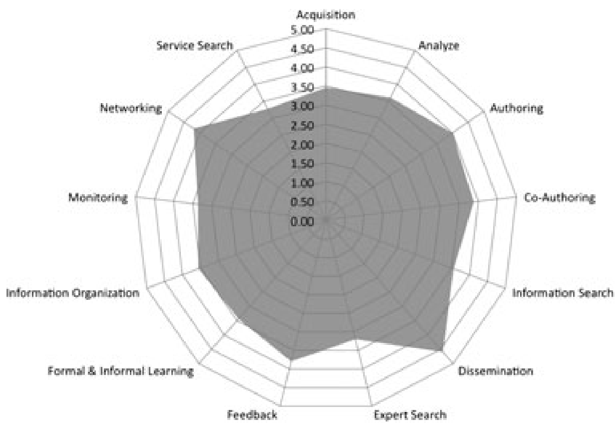

Figure 13 Knowledge actions for the role sharer

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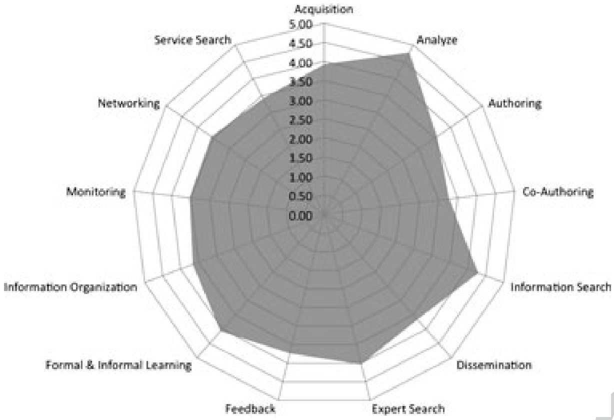

Figure 14 Knowledge actions for the role solver

personal goals, where controllers however are using a clearly defined toolset and have to stick to organizational goals.

Considering the social interactions with colleagues, customers, and external experts, it becomes clear that the work in roles that are more analytical in their nature (e.g., controllers, retrievers, learners) tend to be carried out single-handedly; whereas work in more transactional roles (e.g., networker, helper, tracker) is realized together with others.

Knowledge actions

In the KWRQ, we asked the participants to rate to which extent the presented knowledge actions are relevant for the roles they take on. Generally, all 13 knowledge actions we identified, were said to be of relatively high importance in the corresponding knowledge worker roles, resulting in high mean values of agreement (on a 5-step Likert scale with F16 1=fully disagree, 5=fully agree). Figure 16 shows the aggregated means over all knowledge worker roles and the corresponding quartiles. All knowledge actions' means rank between 3.3 and 4.25 and have low standard deviations between 0.19 and 0.43. The knowledge actions authoring, co-authoring, and service search received the least compliance from the participants, whereas analyze, and information search received the highest level of agreement throughout all knowledge worker roles (see also Figures 17(a) and 17(b)). F17

In Figure 17, we depict the characteristics of the single knowledge actions for the identified knowledge worker roles: the larger the filled area, the higher the coverage of this specific knowledge action in all knowledge worker roles. The knowledge actions analyze (a) and information search (b) received the highest level of agreement from the participants across all knowledge worker roles with slight peaks in the roles solver, retriever, and learner. Those roles are expected to collect and deal with large amounts of data to solve problems, help people find suitable information objects, and improve their own capabilities from the interaction with data. We expected to find a strong representation of the knowledge actions dissemination in all knowledge worker roles except with learners, organizers, retrievers, and trackers. Although Figure 17 (c) shows strong peaks in the roles sharer, networker, and helper, the mean in the role of an organizer is higher than expected. Figures 17(d) and 17(e) validate the expected high relevance of the

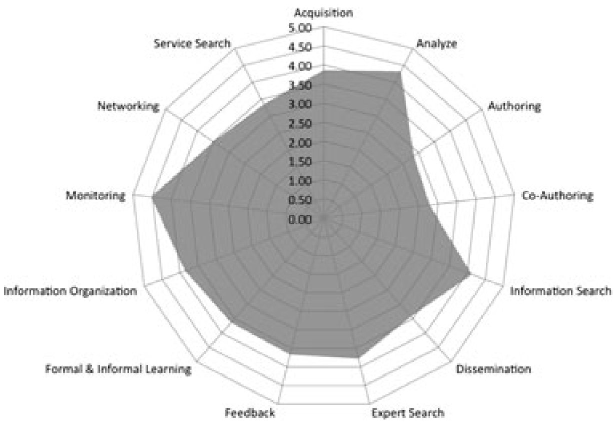

Figure 15 Knowledge actions for the role tracker

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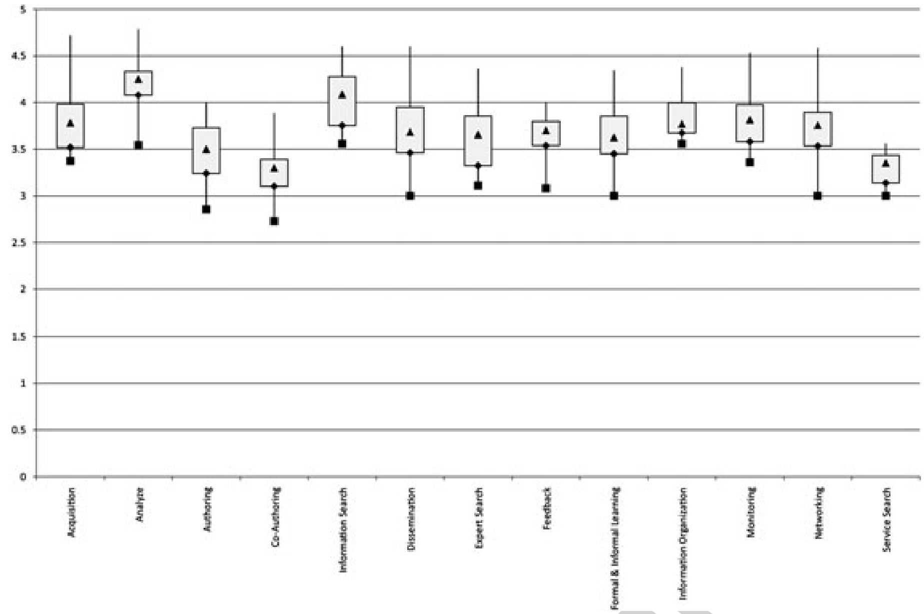

Figure 16 Box plots, means and quartiles for knowledge actions

knowledge actions networking and monitoring for the roles that are conceptual close (networker, tracker). On the other hand, they also show that other roles, such as sharer and learner need to be well-connected within the organization and to outside experts to be productive. We expected to see high agreement for the knowledge actions service search in the roles learner, networker, and solver. Interestingly, this knowledge action received the second lowest agreement of all knowledge actions (mean 3.35, only co-authoring received less agreement with a mean of 3.3), and the only slight deflection can be seen in the role of a retriever. It is also noticeable that the knowledge actions authoring and co-authoring, meaning the knowledge actions that are directly related to the externalization of individual knowledge (Nonaka and Takeushi, 1995) receive only little compliance across all knowledge worker roles.

IMPLICATIONS FOR RESEARCH AND THE APPLICATION OF KNOWLEDGE MANAGEMENT SYSTEMS

The identification of knowledge work roles and knowledge actions enables systematic research in the domain of knowledge work execution and workplace learning. This improves the understanding of knowledge work and supports the utilization of knowledge work research in business applications.

Implications for research

Knowledge work roles and knowledge actions stand for a behavior-oriented perspective on knowledge work execution. Behavior is set in a context of individual intentions and situational requirements: the execution process becomes a product of knowledge work that is worth further investigation. Ethnographic studies are required to assess the proposed knowledge work roles and knowledge work actions for different domains.

We recognize the need for larger studies with an international perspective that also considers a wide variety of knowledge work domains. Moreover, we see a pressing demand for further investigation of the relation between activities, knowledge actions, and knowledge operations (Kuutti, 1997). There is a need for investigating which operations are selected for which knowledge action in which situation or context. For this, qualitative interviews and fine-grained task execution studies are necessary. Furthermore, research should investigate what software architectures that identify switches in the knowledge worker roles based on the operations a user performs must look like. From our point of view, researchers should focus on embedding an additional layer in operating systems that provides aggregated information on a user's context via a reusable interface that can be used by application developers.

Implications for applications

Considering knowledge work as taking on roles, which guide the selection of knowledge actions, has practical implications for personal and organizational knowledge management.

Application development focusing on roles and actions structures application functionalities based on intuitive structures of work execution. Additionally, a knowledge worker role perspective should be considered in application and information integration scenarios. For example, applications could reflect different knowledge

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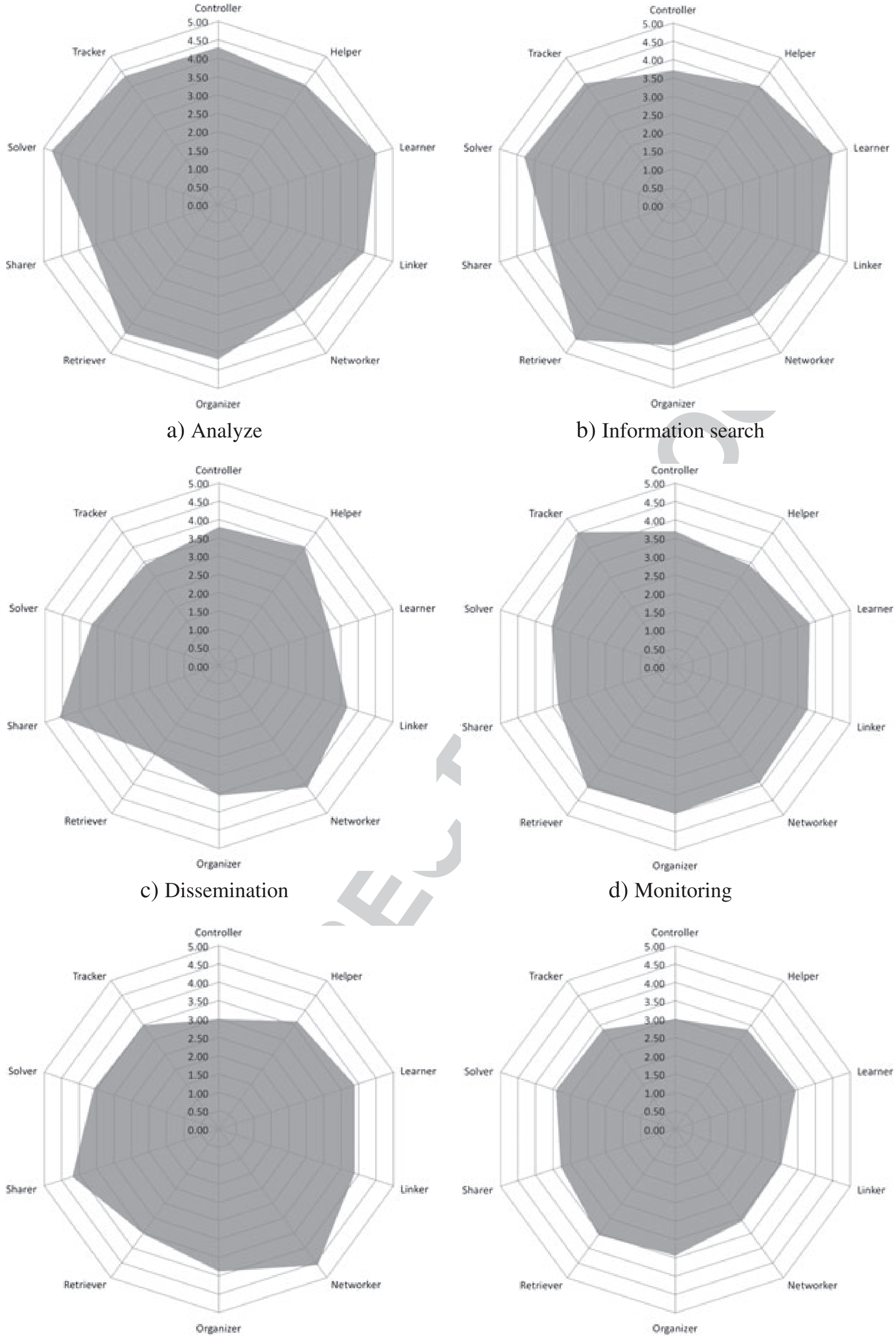

a) Analyze b) Information search c) Dissemination d) Monitoring e)Networking f) Service search

Figure 17 Characteristics of knowledge worker roles in the single knowledge actions

worker roles in diverse screen designs and menu layouts and offering customizable interfaces that come with role-optimized preselected layouts. Application designers have to consider the multimodality of their users and support switches between different roles with adaptive software systems.

Knowledge work roles and actions guide application design. The link between roles and actions directly references functionalities, which need to be provided. We have identified actions which occur frequently (even in differing types), such as information search, analysis of topics and problems, networking, support for dissemination work and monitoring of a topic / group of people. On the other hand, actions such as co-authoring of texts and service search are required only for few scenarios.

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LIMITATIONS

From the available data, we cannot explain some conspicuous anomalies, such as the lack of agreement on the importance of the knowledge actions authoring and co-authoring. Literature shows that the externalization of individual knowledge with the goal of informing others and spreading news within a community plays an important part in the knowledge society. The inexplicability could partly reside in the relatively small sample of 43 people who took part in the KWRQ. Also, the applied research methodology in the KWRQ is likely to be partly responsible, as ethnographically informed research might be a more appropriate methodology for exploring knowledge work practices. Moreover, as we pointed out in the beginning of the article, knowledge work cannot be generalized to fit all types of work and domains. The participants of both the task execution study and the KWRQ mainly had a research background, and thus the results of the studies presented are probably not simply transferable to other knowledge work domains. In sequencing studies, we will need to select knowledge worker from a larger population that is more diverse in its fields of work. Alternatively, we will run subsequent studies in the narrow field of researchers, to make more detailed claims about the work in this realm. From a methodological point of view, we see the limitations of the applied methods and will focus on ethnographically informed studies and interviews in our future work.

CONCLUSIONS

In this article, we presented a literature-informed typology of roles and actions that knowledge workers perform during their daily work. The knowledge worker roles typology contains the roles of controller, helper, learner, linker, networker, organizer, retriever, sharer, solver, and tracker; they can be found in all organizations engaging in knowledge work. Moreover, we presented a typology of 13 knowledge work actions related to the roles of knowledge workers. In two empirical studies, we showed that both the knowledge work actions and the knowledge worker roles are carried out / taken on by the knowledge workers in our sample.

Both typologies contribute to the understanding and analysis of knowledge management in the following ways. First, the typology of knowledge work actions provides a vocabulary to describe knowledge work execution, using the computer desktop. As elementary building blocks of desktop-oriented knowledge work a shared understanding of knowledge work, execution processes can be generated. Knowledge actions enable further investigation into knowledge work practices to identify domain specific extensions of the vocabulary.

Second, the knowledge worker roles typology helps to distinguish between the different roles that people play in creating, sharing, and managing knowledge in and between organizations. Furthermore, it shows the complexity of knowledge work practice and may help in developing IT systems that address this complexity and help knowledge worker in the multi-modality of their actions. The presented typologies and results of the two empirical studies may help understanding the behavioral manifestations of different knowledge worker roles and the corresponding actions.

Future research would need to explore the trinity of activity, action, and operations at a more detailed level and strive to develop a proper distinction between the theoretical concepts. Another research topic would be conducting an extended version of the present studies in a larger, international setting. Such research should also study regional differences in the characteristics and commonness of the knowledge worker roles. Moreover, research should rivet on varieties in the knowledge work actions in different industries, on gender-specific differences and role conflicts that knowledge workers with many functions may have. Another interesting research question is the relation between job descriptions, the individually perceived knowledge work roles, and the actually carried out operations and knowledge actions.

Moreover, we observe that knowledge workers get more and more connected to each other by means of social networks. Knowledge workers progressively produce artifacts as externalization of their individual knowledge. Those artifacts are then the scaffolding that some researchers call objectcentered sociality (Knorr Cetina, 1997). To capture the whole knowledge work interplay, we would need to analyze the relations between artifacts as externalization of individual knowledge, the interactions of knowledge workers with those objects and the social structures that emerge on top of this sociality. Our research on the model of Artifact-Actor-Networks (Reinhardt *et al*., 2009) seems promising in unveiling interaction and usage structures that have been hidden so far. Finally, all future research has to factor in the ever increasing mobility of the society in general and knowledge workers in particular. Technology-enhanced knowledge work systems must therefore incorporate mobile devices and context information such as location to best support future knowledge workers.

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