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Teppo Räisänen

ALL FOR ONE, ONE FOR ALL

ORGANIZATIONAL KNOWLEDGE CREATION AND UTILIZATION USING A NEW GENERATION OF IT TOOLS

*FACULTY OF SCIENCE,
DEPARTMENT OF INFORMATION PROCESSING SCIENCE,
UNIVERSITY OF OULU*

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Organizational knowledge creation and utilization using a new generation of IT tools

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Abstract

Over the past half a decade, new forms of knowledge sharing, collaboration and online participation have emerged. As a result, a new generation of IT tools are being used for the creation and exchange knowledge. This dissertation uses a knowledge management framework known as the 7C model and applies a multi-method approach to deepen the understanding on how new knowledge emerges with these tools. As the benefits of knowledge are realized when it is applied, this dissertation places special emphasis also on the usability of the knowledge.

The results indicate that the knowledge creation sub-processes of comprehension and conceptualization need more scientific attention. In addition, the results suggest that comprehension can be supported by helping users to reflect and by utilizing guideline information. Supporting deeper interaction and improved linking with the existing content, allowing users to stay in a state of flow, and using decision aids can help in comprehension. Conceptualization can be supported through knowledge rationale, metaphors and analogues, decision aids, and by helping users to reach common ground and shared understanding.

In order for the knowledge to be really usable, the knowledge creation should aim at producing knowledge in explicit and actionable form. Producing knowledge in the form of guidelines was found to be beneficial for the utilization of knowledge. Guidelines support learning-by-doing and reflection-in-action, which are crucial for the emergence of new tacit knowledge. Evidence-based information and decision aid tools can help in choosing the knowledge that is to be applied. Finally, the results suggest that in the era of Web 2.0, many low-cost experiences inducing constant exposure to knowledge might work better than a few high-cost experiences requiring very deep thinking. The reason for this is that contemporary users seem to be so accustomed to the ease-of-use of Web services that they simply will not use more useful but less usable solutions.

Keywords: communities of practice, knowledge, knowledge creation, knowledge utilization, Web 2.0, 7C model

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List of Original Papers

I Räisänen T & Oinas-Kukkonen H (2007) A System Architechture for the 7C Knowledge Environment. In: Jaakkola H, Kiyoki Y & Tokuda T (eds) Information Modelling and Knowledge Bases XIX, IOS Press: 217–236.

II Oinas-Kukkonen H, Räisänen T & Hummastenniemi N (2008) Patient Relationship Management: An Overview and Study of a Follow-up System. Journal of Healthcare Information Management 22(3): 24–29.

III Oinas-Kukkonen H, Räisänen T, Leiviskä K, Seppänen M & Kallio M (2009) Physicians' User Experiences of Mobile Pharmacopoeias and Evidence-Based Medical Guidelines. International Journal of Healthcare Information Systems and Informatics 4(2): 57–68.

IV Räisänen T, Oinas-Kukkonen H, Leiviskä K, Seppänen M & Kallio M (2009) Managing Mobile Healthcare Knowledge: Physicians' Perceptions on Knowledge Creation and Reuse. In: Tan J & Olla P (eds) Mobile Health Solutions for Biomedical Applications: 111–127.

V Räisänen T (2009) Supporting the Sense-Making Processes of Web Users by Using a Proxy Server. Proc 42nd Annual Hawaii International Conference on Systems Sciences, Waikoloa, Hawaii, IEEE Computer Society Press.

VI Räisänen T & Oinas-Kukkonen H (2010) Making Sense of Argumentation-based Knowledge: The Lost on the Moon Experiment. Proc IADIS International Conference on Information Systems 2010 (IADIS-IS 2010), Porto, Portugal.

Contents

1 Introduction

Over the past half a decade we have seen the rise of the second generation of Web-based services, such as social networking sites, wikis, communication tools, and tagging. What is common in these applications is that they emphasize online collaboration and the sharing of information and knowledge between users (*e.g.* Hoegg *et al.* 2007). At the same time, the improved capabilities of mobile devices have allowed mobile users to participate in these services as well. As organizations utilize these services for knowledge management our understanding of the status of information, knowledge, and the role of the user in information applications is changing (Tredinnick 2006).

Many of the applications and services that are successful seem to share certain principal features. For example, most of them are delivered as services so that they can be utilized through any client with a suitable Web browser. In addition, they rely heavily on user participation. YouTube is an example of such a service, by which users can store videos and share them with their friends. Typically, these kinds of services get better the more users they can appeal to (O'Reilly 2005). The reason why users are important is because they create value for the service (Fogg & Eckles 2007). Content production is probably the most common form of how Web users contribute value to the service. The content can be, *e.g.* text (like in Wikipedia), video (YouTube), pictures (Flickr), or any other format.

The amount and quality of the content matter. For example, a video streaming service with 10 videos is not very appealing to users. But a service that has tens of thousands of videos is much more valuable, as the more content there is, the more likely it is that users with varying interests find what they are looking for. While a service with little content may be very valuable to a distinct group of users (*e.g.* videos about dogs for dog enthusiasts), the target group will be much smaller than it would be if there was more content to choose from. This limits the attractiveness of such services among the masses.

As it is the users who produce most of this content for the services (*e.g.* videos on YouTube), the more users a service has, the more content gets produced. The participation and content production requires time and effort from the users. First, the content has to be prepared, and then it needs to be published using the service. The users usually benefit from this by initiating a discussion and getting others to participate or by gaining a reputation (Hoegg *et al.* 2006).

Thus, by creating value and producing content the users play a key role in the success of the companies. When a company launches a service, it does not have many users and the amount of content is typically small. By using technologies and functionalities like profiles, data importing and exporting, sharing, editing and inviting, to name a few, users gradually start to create the content and user base for the service in question. One key factor in all this is the perceived ease-of-use (Davis 1989) of the service.

One reason for the pronounced importance of ease-of-use stems from the state of the electronic business. The competition among Web applications is tough because development costs have gone down, thanks to open source software and scalable Web hosting services. This lowers the market entry barriers, which means that usually when there is a successful Web application there will soon be many competitors (Räisänen *et al.* 2008). As most of the applications are free (Hoegg *et al.* 2006), the users can decide which applications they want to use. Ease-of-use is one major aspect that can help in making this decision.

Another reason – perhaps an even more important one – relates to the way people adopt technology into use. According to the Technology Acceptance Model (TAM, *e.g.* see Davis 1989), IT adoption is influenced by perceived usefulness and perceived ease-of-use. While perceived usefulness relates to the user's assessment of IT's extrinsic outcomes, such as how IT helps users in the task at hand, perceived ease-of-use relates to the intrinsic characteristics of IT, *e.g.* ease of learning, flexibility and the user interface (Gefen & Straub 2000). On the Web, it is the intrinsic characteristics that seem to receive special emphasis. For example, if a user wants to use a video streaming service, the perceived usefulness of the available solutions is quite similar (*e.g.* they allow videos to be stored, shared, played and commented on), and therefore the decision has to be based on other factors. In such situations, the perceived ease-of-use is one major factor. Other factors might include, for example, costs and visual appearance. Another example of the importance of ease-of-use could be the success of touch-screen controlled mobile devices - such as the iPhone - over traditional keypad controlled devices.

In spite of the relative importance of ease-of-use, it is not a virtue by itself (Oinas-Kukkonen *et al.* 2009). Without meaningful content, ease-of-use is wasted. Luckily, ease-of-use helps in content production, too. For instance, the easier it is to upload a video to a streaming service, the more likely it is that users will do so. If for some reason the uploading process of a particular system is not easy enough, users can probably find streaming services for a similar purpose that are easier to use.

In fact, the ease-of-use paradigm seems to go deeper than just the user interface; it seems to be at least partially rooted in the whole Web 2.0 user experience. For example, Braun, Schmidt and Walter (2007) state that part of the success of Web 2.0 applications is their compelling simplicity. This can also be seen, for instance, in Web-based argumentation tools and their usage – or lack thereof. Examples of argumentation tools are gIbis (Conklin & Begeman 1989) and Compendium (Buckingham Shum *et al.*, 2006). Just because an argumentation service is easy to use does not mean there will be a lot of communication going on within the service. As soon as the users realize that argumentation requires them to do a lot of cognitive work, they may stop using the service. Another example is the relative success of folksonomies over taxonomies. Folksonomy is a method of classification where users themselves can decide the classification. So while folksonomy and taxonomy both require users to come up with specific words that classify the content (*e.g.* a photo or a video), users prefer folksonomy (Ebner *et al.* 2007). Users are more willing to classify the content as they see fit (folksonomy) than to think about where in a predefined hierarchy the content fits (taxonomy).

For the purposes of this dissertation, content is seen as explicit knowledge and this dissertation uses a knowledge management framework developed in our research group known as the 7C model (Oinas-Kukkonen 2004) to understand the various knowledge creation processes and how they can be supported in Web and mobile environments. In short, the research question tackled here is:

How can organizational knowledge creation and utilization be supported using Web 2.0 and mobile tools?

While Web 2.0 and mobile are distinguished in this dissertation they do also overlap. Many Web 2.0 tools are also utilized through mobile devices. For example mobile use of tools like Twitter and Facebook has been constantly increasing. Thus, this dissertation considers mobile technologies for knowledge creation both as an extension to Web 2.0 and as a separate technology.

In order to understand knowledge creation and utilization, the next chapter provides a review on the topic. The main focus is on the 7C model of knowledge creation. And to understand the specific requirements of Web and mobile environments, chapter 3 will focus on content creation in these settings. These two chapters provide the foundations that the rest of the research builds on.

Chapter 4 presents related research to bring together and highlight the opportunities of knowledge management and the new technologies (namely, Web 2.0 and mobile). Healthcare information systems are used as an example of the problem domain. Chapter 5 explains the research methods utilized in the research. The overall research method comprises of both an observational phase and a constructive phase.

Chapter 6 presents the contributions of the published papers. The first paper focuses on the various technologies and how they offer support for knowledge creation. A framework to support knowledge creation is presented. The next three papers examine the 7C model and how information systems (both Web-based and mobile) can support its sub-processes in organizational settings. Based on these studies, the last two papers use a constructive approach to study various tools designed to support both knowledge creation and utilization.

Chapter 7 discusses the findings of the research. A special emphasis is the usability of the generated knowledge. In addition, Web 2.0 and mobile technologies, as well as the theoretical and managerial contributions of the research, are discussed. Finally, chapter 8 concludes the dissertation by highlighting the important take-aways and implications of the research and by pointing out directions for future research.

2 Knowledge and knowledge management

In the IT literature, knowledge is usually defined by distinguishing between knowledge, information and data. Data is seen as raw numbers and facts, information as processed data and knowledge as personalized information. What is important in this classification is the distinction between knowledge and information. Knowledge should be something more than information – otherwise there is nothing new or interesting in knowledge management (Fahey & Prusak 1996). Yet, often the knowledge management that academics and business people talk about just means information management (Nonaka *et al.* 2000).

Tuomi (1999) argues that the traditional hierarchy of data-information-knowledge is actually reversed: data emerge only after we have information and that information emerges only after we already have knowledge. We must have knowledge about how to measure temperatures before we can build a thermometer to get actual temperature data.

Following Tuomi's (1999) view, Alavi and Leidner (2001: 109) state that "information is converted to knowledge once it is processed in the mind of individuals". In this view, knowledge is information plus something more. This "something more" is the associations, memories, past experiences – previous knowledge that the individual possesses – that are related to the information. Knowledge is therefore "information possessed in the mind of individuals: it is personalized information" (Alavi & Leidner 2001: 109). An interesting part of this definition is that "knowledge becomes information once it is articulated and presented in the form of text, graphics, words, or other symbolic forms" (Alavi & Leidner 2001: 109). So knowledge doesn't exist without individuals. When somebody articulates a part of his knowledge in written form, it becomes information until somebody reads it: the reader gives (his or her own) meaning to this information and it becomes knowledge again. It should be noted that the knowledge in the mind of the reader is different (it is his personalized information) than the one in the mind of the writer.

Besides the traditional data-information-knowledge view, there are many other perspectives from which knowledge can be viewed. Some of these are presented in table 1.

Table 1. Different perspectives on knowledge.

Perspective	Example
Knowledge as an object	Zack 1999
Knowledge as access to information	McQueen 1998
Knowledge as capability	Carlsson *et al.* 1996
Knowledge is knowing/understanding	McQueen 1998
Knowledge as a process	Zack 1999, Schultze 1998
Knowledge as relationship	Kakihara & Sörensen 2002
Knowledge as interpretation	Kakihara & Sörensen 2002

Knowledge as an object sees knowledge as a "thing" that can be stored and manipulated as an independent object. This means that knowledge is rather separate from people who create and use it. Knowledge as an object is the traditional view of knowledge (Kakihara & Sörensen 2002). Knowledge as access to information is another view of knowledge (McQueen 1998). According to it, organizational knowledge must be organized to facilitate access to and retrieval of content. Knowledge as access to information can be seen as an extension to the knowledge as an object view: In knowledge as access to information, special emphasis is placed on the accessibility of knowledge objects (Alavi & Leidner 2001). Knowledge as capability differs from the first two perspectives in that the focus is on the way in which knowledge can be applied to influence future action (Carlsson *et al.* 1996). Knowledge as knowing and understanding is a more philosophical view of knowledge. It points out that "knowing" and "understanding" only take place in humans, so they can't be mechanized (McQueen 1998) or automated with IT. Instead of trying to store or manipulate knowledge, the role of IT should be to provide new sources of knowledge to individuals (Alavi & Leidner 2001). Knowledge as a process focuses on applying expertise, where knowledge can be seen as a process of knowing and acting (Zack 1999). Knowledge is not possed by any one nor contained in repositories (Schultze 1998). Knowledge as relationship (Kakihara & Sörensen 2002) sees knowledge not only as something that can be possessed and stored but more importantly as a relationship and connectedness with other social actors and structures. Knowledge "can be seen as an interconnected web of relationships in which human interpretative acts (…) shape and maintain, both intentionally and unintentionally" (Kakihara & Sörensen 2002: 52).

Many philosophical scholars have argued that knowledge is inherently associated with human intersubjective interpretation (Kakihara & Sörensen 2002:

52). Winograd and Flores (1986) argue that knowledge is always the result of individuals' mutual interpretive action and linguistic behavior, which depends on the entire previous experience of the interpreter and situatedness in social convention and tradition. This view sees knowledge as interpretation.

There are many different views and perspectives on knowledge. One reason why so many are needed might be due to the contradiction that knowledge resides in a person's mind (Alavi & Leidner 2001) and at the same time it "has to be captured, stored and reported" (Spiegler 2000: 9). Because of this (and the different views and perspectives) defining knowledge is difficult, and the definitions depend on the context in which they are used. For example, Bender and Fish (2000: 126) define knowledge as follows: "Knowledge originates in the head of an individual and builds on information that is transformed and enriched by personal experience, beliefs and values with decision and action-relevant meaning. It is information interpreted by the individual and applied to the purpose for which it is needed. The knowledge formed by an individual will differ from another person receiving the same information. Knowledge is the mental state of ideas, facts, concepts, data and techniques, recorded in an individual's memory."

The purpose of this dissertation is not to go into the philosophical debate on the nature of knowledge. Rather, it is enough to understand that the nature of knowledge (and its exact definition) varies from perspective to perspective.

2.1 Taxonomies of knowledge

Besides different perspectives on knowledge, knowledge has also been classified and characterized in several different ways. Nonaka (1994) (following the work of Polanyi 1966) explicated two dimensions of knowledge in organizations: explicit and tacit. Explicit or codified knowledge refers to knowledge that is transmittable in formal, systematic language. Explicit knowledge can be "articulated, codified, and communicated in symbolic form and/or natural language" (Alavi & Leidner 2001: 110), and indeed, it is often captured in the "records of the past such as libraries, archives, and databases" (Nonaka 1994: 17). Procedure manuals, product literature, and even computer software can be seen as explicit knowledge (Zack 1999).

Tacit knowledge, in contrast, has a personal quality which makes it hard to formalize and communicate. Tacit knowledge is held in people's bodies and heads and it is rooted in action, experience and involvement in a specific context (Nonaka 1994, Polanyi 1966). Tacit knowledge is comprised of both cognitive and technical elements (Nonaka 1994). The cognitive element refers to the individual's mental models which include schemata, paradigms, beliefs and viewpoints that provide "perspectives" that help individuals to perceive and define their world. The technical element of tacit knowledge covers concrete know-how, craft and skills that apply to specific contexts (Nonaka 1994). An example of tacit knowledge could be how to deal with a specific customer.

The tacit–explicit classification of knowledge is the most widely cited one, but there are other knowledge classifications as well. Knowledge can also be viewed as existing in the individual or in the collective (Nonaka 1994). At a fundamental level, knowledge is created by individuals, and different collectives (like organizations) cannot create knowledge without individuals. For example, organizations can support individual knowledge creation or provide a context for individuals to create knowledge. As such, organizational knowledge creation should be seen as "a process that 'organizationally' amplifies knowledge created by individuals, and crystallizes it as a part of the knowledge network of organizations" (Nonaka 1994: 17). An example of individual knowledge could be the insights gained from completed projects (Alavi & Leidner 2001), and an example of collective (or social) knowledge could be norms for project communications.

Some refer to knowledge as declarative (know-about or knowledge by acquaintance) (Zack 1999). Declarative knowledge is the "understanding of concepts, categories, and descriptors" (Zack 1999: 46). An example of declarative knowledge is which drug is appropriate for an illness (Alavi & Leidner 2001). Knowledge of how something occurs or is performed is called procedural knowledge (know-how). Knowledge of why something occurs is called causal knowledge (Zack 1998). An example of procedural knowledge is the understanding of how to administer a particular drug, and an example of causal knowledge is the understanding of why the drug works (Alavi & Leidner 2001). Conditional knowledge is the understanding of know-when (Zack 1998) - for example when to prescribe the drug (Alavi & Leidner 2001). Relational knowledge (know-with) is the understanding of how things relate to each other (Zack 1998).

2.2 Organizational knowledge management

According to Holzner and Marx (1979), organizations can be viewed as "knowledge systems" composed of a collection of socially enacted "knowledge processes" which may be augmented (or impaired) by the introduction of information systems (Pentland 1995). Holzner and Marx identify a set of five knowledge processes. These are (Holzner & Marx 1979):

- Construction
- Organization
- Storage
- Distribution
- Application

Construction is the process "through which new material is added or replaced within the collective stock of knowledge" (Pentland 1995: 3). This construction can create knowledge that is new to all humanity, but in most cases the knowledge constructed is new only to the specific collectivity in question (Machlup 1980). For example, a software company can construct new knowledge to solve existing project management problems but some other company may already know this solution or have an even better one.

Organization is the process "by which bodies of knowledge are related to each other, classified, or integrated" (Pentland 1995: 3). It is not enough for a software company to know how to manage projects: they also need to know the different aspects of software development and development tools and how they relate to each other.

Storage means that constructed and organized knowledge must be stored somewhere so that it can be retrieved when needed. Without storage there would be no "memory" or application of knowledge (Pentland 1995): all constructed knowledge would be lost and forgotten. Today, most knowledge is stored in different information systems. Paper-based files and individual human memory can also storage knowledge.

Distribution refers to the process in which knowledge is "moved" from storage to places where it is needed and can be applied (Pentland 1995). This distribution can be done with the help of information systems, on paper or in face-to-face interaction.

Application is the process in which existing knowledge is used. If existing knowledge is never applied, it might as well be forgotten: all the previous knowledge processes are there so that we can apply knowledge when needed.

Following Holzner's and Marx's (1979) framework, Alavi and Leidner (2001) have developed their own framework to analyze the roles of different information systems in organizational knowledge management. According to this framework, there are four sets of socially enacted knowledge processes within organizations. These processes are (Alavi & Leidner 2001):

- Knowledge creation
- Knowledge storage/retrieval
- Knowledge transfer
- Knowledge application

These processes are very similar to the ones Holzner and Marx (1979) identified. Creation is the same as construction, storage/retrieval corresponds to storage and transfer to distribution, and application is included in both frameworks. The only difference is that Alavi and Leidner (2001) don't see the organization of knowledge as a separate process but rather it is integrated into the storage/retrieval process. Table 2 summarizes Alavi and Leidner's (2001) analysis of the four processes and the potential role of IT in facilitating each process.

Table 2. Knowledge management processes and potential role of IT (modified from Alavi & Leidner 2001).

Knowledge management process	Knowledge creation	Knowledge storage/ retrieval	Knowledge transfer	Knowledge application
Supporting information technologies	Data mining Learning tools	Discussion boards Knowledge repositories Databases	Discussion boards Discussion forums Knowledge directories	Expert systems Workflow systems
IT enables	Combining new sources of knowledge Just in time learning	Support of individual and organizational memory Inter-group knowledge access	More intensive internal network More communication channels available Faster access to knowledge sources	Knowledge can be applied in many locations Rapid application of new knowledge through workflow automation
Platform technologies	Groupware and communication technologies Intranets			

2.3 Personal knowledge management

In Personal Knowledge Management (PKM, see Wright 2005), the focus shifts from organizations towards individuals. PKM tries to understand individuals and their use of technology. It focuses on their knowledge work performance (Wright 2005). The core of PKM is usually formed by (Avery *et al.* 2003, Wright 2005):

1. Problem solving
2. Exploring
3. Learning

These are also in the core of what virtual communities are all about (Wegner 2002). In addition, the above list – and indeed the whole PKM approach – matches the knowledge creation sub-process of comprehension (Oinas-Kukkonen, 2004) well, as PKM involves the individual "constantly interacting with their information-rich environment" (Jones 2009: 228). It also requires individuals to think through problems (Jones 2009), to make sense of information and to decide what to do (Wright 2005). In addition, sense-making is seen as an essential to PKM. In other, words "when a person encounters a situation, they observe it by receiving information about it and applying tacit knowledge to make sense" (Wright 2005: 157).

Avery *et al.* (2003) have identified seven skills that are crucial for PKM. These are:

1. Retrieving information
2. Evaluating information
3. Organizing information
4. Collaborating around information
5. Analyzing information
6. Presenting information
7. Securing information

Retrieving information refers to the skills that help the user gather information from various sources. Using suitable search queries in electronic databases, asking the right questions and in general finding the right information are examples of information retrieving. Evaluating information refers to the skill of filtering out irrelevant pieces of retrieved information and organizing helps in making the connections that link the information pieces together. Collaborating around information is more of a social process, which includes listening, building relationships and developing ideas with colleagues. Analyzing information is a process of converting information into knowledge, and presenting means understanding the audience and communicating the ideas to them. Finally, securing information is an information skill that helps to evaluate the confidentiality, integrity and existence of information (Avery *et al*. 2003).

2.4 Knowledge creation

Knowledge creation (or construction) is the first process in both Alavi and Leidner's, and Holzner and Marx's frameworks. It is the process that is probably researched the most. Many different models and theories try to explain how knowledge is created. Knowledge creation is dynamic (Nonaka & Takeuchi 1995). It is also most often displayed as a spiral, whether we are talking about the SECI model (Nonaka 1994) or the 7C model (Oinas-Kukkonen 2004). The dynamic nature of knowledge creation can be seen in Figure 1 (from Nonaka *et al.* 2000).

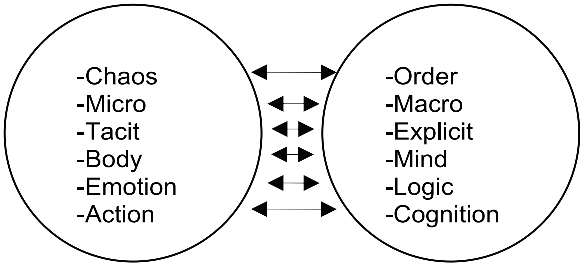

Fig. 1. Knowledge creation is a dynamic spiral (Nonaka *et al.* 2000).

As can be seen from Figure 1, knowledge creation is a constant interaction between the two spheres. Or as Nonaka *et al.* (2000: 7) put it, "knowledge is created in the spiral that goes through two seemingly antithetical concepts such as order and chaos, micro and macro, part and whole, mind and body, tacit and explicit, self and other, deduction and induction, and creativity and control."

The dynamic theory of organizational knowledge creation and the 7C model are discussed next.

2.4.1 Dynamic theory of organizational knowledge creation

The dynamic theory of organizational knowledge creation (Nonaka 1994) explains how new knowledge emerges within organizations. Knowledge creation is a “spiral” that takes place in two dimensions. These dimensions are the epistemological and ontological dimensions.

The epistemological dimension is the distinction between tacit and explicit knowledge. In the ontological dimension we find the levels of knowledge creation entities. These are the individual, group, organization and inter-organization levels. Strictly speaking, all knowledge is created by individuals. Thus, “organizational knowledge creation […] should be understood as a process that ‘organizationally’ amplifies the knowledge created by individuals” (Nonaka & Takeuchi 1995: 59). In essence, “human knowledge is created and expanded through social interaction between tacit knowledge and explicit knowledge” (Nonaka & Takeuchi 1995: 230).

The dynamic theory of organizational knowledge creation has four modes of knowledge conversions that take place when tacit and explicit knowledge interact. The modes are: 1) socialization, 2) externalization, 3) combination, and 4) internalization. (Nonaka 1994).

Socialization is a process of sharing experiences (Nonaka 1994). It creates new tacit knowledge from existing tacit knowledge. For example, by observing a colleague the observer can learn through imitation or practice. Typically, the new tacit knowledge is in the form of shared mental models or technical skills.

Externalization is a process of articulating tacit knowledge into explicit concepts (Nonaka 1994). Externalization is the key process in the theory as it is the process that creates new explicit concepts from the tacit knowledge. One example of this is writing. It can be seen as an act of converting tacit knowledge into articulable knowledge (Emig 1983). The use of metaphors and analogies seems to be a key in externalization as it is typically triggered by dialogue or collective reflection.

Combination is a process of systemizing concepts into a knowledge system (Nonaka 1994). It creates new explicit knowledge from existing explicit knowledge. It is the kind of knowledge creation that happens in formal education or training at schools. The use of large-scale databases could also be seen as an example of combination.

Internalization is a process of embodying explicit knowledge into tacit knowledge (Nonaka 1994). Reading documentations or watching videos is an example of the kind of “re-experiencing” that internalization requires. “Learning by doing” can also be seen as an example of internalization.

On their own these knowledge conversion modes produce only a limited amount of knowledge creation. They must form a dynamic and continuous knowledge spiral for knowledge creation to truly happen. Typically, this spiral starts at the individual level and moves up along the ontological dimension (*i.e.* from individual to group, from group to organizational, and from organizational to inter-organizational level).

The organization usually provides the context that facilitates the knowledge creation, especially from the group level onwards. Organizations can also promote knowledge creation. This requires the following five conditions to be fulfilled (Nonaka & Takeuchi 1995): 1) intention, 2) autonomy, 3) fluctuation and creative chaos, 4) redundancy, and 5) requisite variety.

The organizational intention provides "the most important criterion for judging the truthfulness of a given piece of knowledge" (Nonaka & Takeuchi 1995: 74). Without intention it would be difficult to say anything about the value of the knowledge being created. While organizations usually have strategies and visions that form the intention, individuals are also driven by their own interests. For example when the individuals are using a Web-service, they must judge themselves whether or not the newly created knowledge is important. The intention takes the form of a shared interest or even a passion for a particular topic.

This also means that intention is also found in virtual communities, too. However, as the users all have their intrinsic intentions (*e.g.* somebody needs to install a driver for his PC), this also means that justifying knowledge can be difficult. Each participant can and probably will justify the knowledge by themselves.

Each member of the organization should also be allowed to act autonomously (Nonaka & Takeuchi 1995). Autonomy not only increases motivation but also increases the chances of unexpected opportunities. The wisdom of crowds also highlights the importance of autonomy (Surowiecki 2004). Luckily, when using a Web-based tool autonomy is almost guaranteed as all users are equal (save for the admins or moderators).

Fluctuation and creative chaos stimulate the interaction between the organization and the external environment. For example, employees could benefit from a "breakdown" of routines, habits, or cognitive frameworks. On the Web, the danger is that this goes too far. If users participate infrequently in different discussion forums or Web sites there might be no routines, habits or cognitive frameworks to break down. There might even be a danger of information overload (Maes 1994).

Redundancy as an enabling condition for knowledge creation is defined as "the existence of information that goes beyond the immediate operational requirements of organizational members" (Nonaka & Takeuchi 1995: 80). This helps in knowledge creation by making it easier to sense what others are trying to articulate. Today, the Web is full of redundant information. Discussion forums usually have discussion threads with similar topics. These threads are packed with redundant information. The more the users participate in similar forums, the more redundant information they are likely to possess.

The last enabling condition is requisite variety. Requisite variety can be enhanced by "combining information differently, flexibly, and quickly, and by providing equal access to information" (Nonaka & Takeuchi 1995: 82). The hypertext functionalities (e.g. linking) and the accessibility of the Web seem to support this to a great extent. See Table 3.

Table 3. Web's support for the enabling conditions.

Condition	Support in Web
Intention	Intrinsic as users share a common interest or passion
Autonomy	Everybody has autonomy by default
Fluctuation and creative chaos	Perhaps even too much fluctuation
Redundancy	Web is full of redundant information
Requisite variety	Hypertext functionality and information access is good

Besides the above mentioned enabling conditions, Nonaka and Takeuchi (1995) also provide a five-phase model of the organizational knowledge-creation process. The model consists of the following phases: 1) sharing tacit knowledge, 2) creating concepts, 3) justifying concepts, 4) building an archetype, and 5) cross-leveling knowledge.

As organizations cannot create knowledge by themselves, the knowledge creation starts by harnessing the tacit knowledge residing in the individuals. This phase matches with the socialization mode of the spiral. This is also the phase where the five conditions work best.

The second phase uses collective reflection to verbalize the shared mental models into words and phrases, and finally into explicit concepts. The externalization mode of the knowledge creation spiral is similar to the creation of concepts phase.

As these concepts are being created, the organization must screen them in order to justify the "true beliefs" among the rest. This phase does not have an equivalent in the knowledge conversion modes. The organization needs some sort of criteria for the justification. For example, some concepts may be too expensive or otherwise not feasible. The justified ones can be taken to the fourth phase.

The fourth phase consists of building an archetype of the concept. This can be a prototype of the product under development, for example. As the prototypes are usually built by combining existing knowledge with the newly built concept, this phase is close to the knowledge conversion mode of combination.

The fifth and final phase of the model is the cross-leveling of knowledge. In this phase, the newly created, justified and modelled concept moves onto another ontological level where a new knowledge creation process can begin. The newly acquired knowledge can also be extended to other divisions.

Nonaka, Toyama and Konno (2000) have also talked about the role of Ba in enabling knowledge creation. Ba refers to a shared context. This is crucial as knowledge needs a context to be created (Nonaka *et al.* 2000). Ba is defined as the shared context in which knowledge is shared, created and utilised. The knowledge creation process is a spiral, and the key to leading it is dialectical thinking. In short "using existing knowledge assets, an organisation creates new knowledge through the SECI process that takes place in Ba, where new knowledge, once created, becomes in turn the basis for a new spiral of knowledge creation" (Nonaka *et al.* 2000: 5). They also state that in knowledge creation, the generation and regeneration of Ba is the key, as Ba provides the energy, quality and place to perform the individual conversions and to move along the knowledge spiral.

Ba is a difficult concept as it unifies physical space such as office space, virtual space such as e-mail, and mental space such as shared ideals (Nonaka *et al.* 2000). There are four types of Ba (Nonaka *et al.* 2000). In virtual environments there is exercising Ba and systemising Ba. Systemising Ba is defined by collective and virtual interactions. It mainly offers a context for the combination of existing explicit knowledge, as explicit knowledge can be relatively easily transmitted to a large number of people in written form. Exercising Ba is defined by individual and virtual interactions. It mainly offers a context for internalisation. Here, individuals embody explicit knowledge that is communicated through virtual media, such as written manuals or simulation programs. Exercising Ba synthesises the transcendence and reflection through action, while dialoguing Ba achieves this through thought.

2.4.2 The 7C model for knowledge creation

One conceptual model that aims at describing the knowledge creation process by distinguishing aspects that affect this process is called the 7C model. According to the 7C model, there are seven Cs that affect knowledge creation (Oinas-Kukkonen 2004). These can be described through technology, language and organizational contexts (Lyytinen 1987). In the technology context, the Cs are connection and concurrency. Today, various Internet and mobile technologies provide us with a fluent – and possibly concurrent - connection to information and people. The benefits of this concurrent connection can be realized in the language context by improved comprehension and communication. This in turn supports conceptualization and collaboration in the organizational context. (Oinas-Kukkonen 2004). These six Cs (connection, concurrency, comprehension, communication, conceptualization and collaboration) support the collective intelligence of the organization. This is the seventh and final C of the 7C model.

If we think about knowledge creation using Web and mobile technologies, the first two Cs (connection and concurrency) are somewhat self-evident. Users participating in the knowledge creation need an Internet connection. They also may or may not participate simultaneously. Thus, the emphasis is more on the following four Cs: comprehension, communication, conceptualization and collaboration. Indeed, repeatedly going through these four Cs forms a knowledge creation spiral which over time increases the collective intelligence (Oinas-Kukkonen 2004).

Similarly as in Nonaka and Takeuchi's (1995) dynamic theory, the 7C model relies on epistemological and ontological dimensions. In the epistemological dimension, there is again the distinction between tacit and explicit knowledge. In the ontological dimension, there is individual and social knowledge. New knowledge emerges as existing knowledge is converted from one form to another. The outcomes of the comprehension, communication and conceptualization sub-processes follow the work of Engelbart (1992). The dimensions and the 7C spiral are presented in Figure 2. Note that for simplification purposes the time element – the figure should show a spiral that grows with each iteration - has been omitted from the figure.

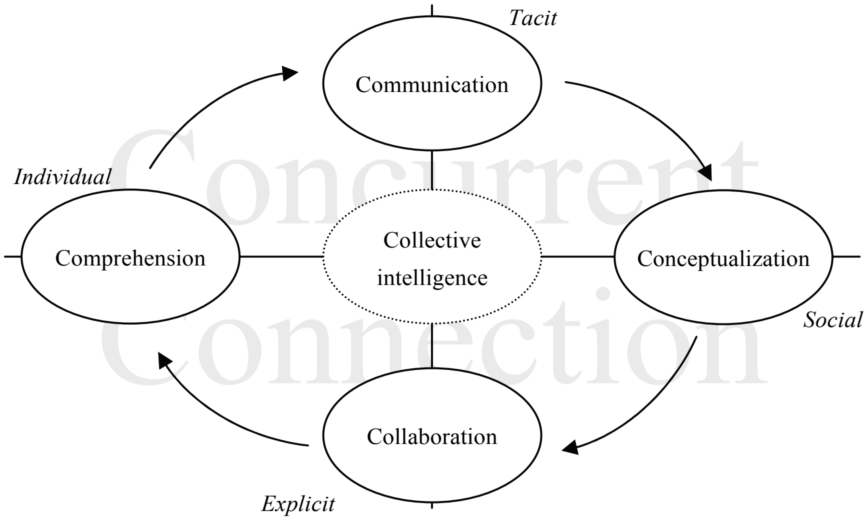

Fig. 2. The spiral 7C model in a nutshell.

The 7C knowledge creation spiral starts when an individual comprehends something new. This creates new tacit knowledge that is stored in the individual. This knowledge can be shared with, for example, co-workers through communication. After this, the tacit knowledge is stored in the social collective. The collective can then create an explicit concept through the process of conceptualization. This converts the tacit knowledge stored in the members of the collective into explicit knowledge. The collective can then apply these concepts (e.g. in their work) through collaboration (Oinas-Kukkonen 2004). The next sections will investigate the four Cs of the 7C knowledge creation spiral as well as collective intelligence more closely.

Comprehension

According to Oinas-Kukkonen (2004: 5), comprehension is “a process of surveying and interacting with the external environment, integrating the resulting intelligence with other project knowledge on an ongoing basis in order to identify problems, needs and opportunities; embodying explicit knowledge in tacit knowledge, ‘learning by doing’, re-experiencing”. As such it is similar to the internalization mode of knowledge conversion (Nonaka 1994).

Comprehension also seems to be similar to sense-making, which is defined as “a motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively" (Klein *et al.* 2006: 71).

From the technologies studied in this dissertation, the Web seems to support comprehension well. Various hypertext functionalities (Bieber *et al.* 1999) allow users to survey, interact and study connections among information and people. An example of how we could support comprehension on the Web could be on-line virtual tutorials, which could help users to better understand and internalize working practices that are related to the design principles (Vaccaro *et al.* 2008).

Communication

Communication is "a process of sharing experiences between people and thereby creating tacit knowledge in the form of mental models and technical skills; produces dialog records, which emphasize the needs and opportunities, integrating the dialog along with resulting decisions with other project knowledge on an ongoing basis" (Oinas-Kukkonen 2004: 5).

Communication is also the sub-process where individual knowledge is shared with the collective. Thus, it creates new social knowledge which is shared by many individuals. While the transfer of codified knowledge (electronic documents or pictures, for example) is easy to support with computerized information systems, supporting the transfer of tacit knowledge is much more difficult.

The sub-process of communication can also be seen as knowledge sharing in which knowledge (*i.e.* information, skills, or expertise) is exchanged among people. And it can be seen as a process through which knowledge is transferred. As such, it is not just a process of two or more people communicating through various media but rather a process where one unit (*e.g.* person, group) is affected by the experience of another (Argote & Ingram 2000).

Conceptualization

After the individual knowledge is shared with others, the collective must reach a shared understanding or a consensus on it. In the 7C model, this is reached through the process of conceptualization, which is "a collective reflection process articulating tacit knowledge to form explicit concepts and systemizing the concepts into a knowledge system; produces knowledge products of a project team, which form a more or less comprehensive picture of the project in hand and are iteratively and collaboratively developed" (Oinas-Kukkonen 2004: 5). These may include proposals, specifications, requirements, computer software and such. (Oinas-Kukkonen 2004).

The common ground theory provides a framework for understanding how people develop shared understanding in a conversation. The process of acquiring a common ground is grounding (Clark & Brennan 1991). It is fundamental to communication and to all collective actions, including argumentation and conceptualization. Grounding takes different shapes depending on the communication media used. For example, grounding is different in face-to-face conversation than in emails.

The factors affecting grounding (Clark & Brennan 1991) are purpose, *e.g.* what two people are trying to accomplish, and the medium of communications. Depending on the medium, there are different techniques available for accomplishing the purpose. Each technique also has various costs associated with it.

The principle of the least collaborative effort also affects grounding. The principle states that in conversation participants try to minimize their collaborative effort (Clark & Wilkes-Gibbs 1986). Indeed, with today's IT tools this principle might be emphasized even more than in, *e.g.* face-to-face communication. This is so mainly because the related costs are lowest in face-to-face interaction (Clark & Brennan 1991). The media also set various constraints on grounding. Some media may impose co-presence (share the same physical environment) or visibility (be able to see other participants), for example (Clark & Brennan 1991).

It is also important to notice that there are various costs associated with grounding. For example, it costs time and effort to formulate a compelling argument. It also costs to produce the argument (*e.g.* to speak or write) as well as to receive (*e.g.* listen or read) it (Clark & Brennan 1991). Certain words and concepts are also more costly to understand than others. For example, the use of smileys or emoticons (Gajadhar & Green 2005) is one way of reducing production costs. Quite naturally, understanding them is easier if there is a common ground with the sender and the receiver. It can also be seen as a way of reducing the costs related to understanding.

After the collective has reached a shared understanding, they must produce the explicit knowledge conceptualizations. These concepts work as vehicles for the actual work that is done.

Collaboration

Oinas-Kukkonen (2004: 5) defines collaboration as "a true team interaction process of using the produced conceptualizations within teamwork and other organizational processes". Thus, it is the process of applying the produced knowledge in the daily work. It is a very important sub-process as the "source of competitive advantage resides in the application of the knowledge rather than in the knowledge itself" (Alavi & Leidner 2001: 122).

Through collaboration, members have also a chance of learning by doing (*i.e.* comprehending), for example by observing other members. This can trigger a new 7C spiral. Indeed, the whole 7C model is a spiral where the sub-processes of comprehension, communication, conceptualization and collaboration happen in a seamless spiral-like way, and going through them in a step-by-step way leads into the growth of collective intelligence (Oinas-Kukkonen 2004).

Collective intelligence

When the four abovementioned sub-processes are repeated in a seamless spiral-like way, it leads into the growth of data, information and knowledge relevant to the organization. This is called organizational memory or collective intelligence (Oinas-Kukkonen 2004). In a way, it represents the organizational knowledge assets that work as inputs and moderating factors for the knowledge creation process (Nonaka *et al.* 2000).

Collective intelligence can be seen, for example, in the skills and know-how of individuals, in the organizational routines and culture, and in the documents, specifications and manuals existing in the organization.

2.5 Summary of knowledge creation

Table 4 presents an analysis of the SECI-model, Nonaka and Takeuchi's knowledge creation process (from now on N&T) and the 7C knowledge creation spiral (called '7C5' in the table as it is formed by the five C's of comprehension, communication, conceptualization, collaboration and collective intelligence). While the SECI model is a theoretical model, the process of organizational knowledge creation describes the processes that "enable individual knowledge to be enlarged, amplified, and justified within an organization" (Nonaka 1994: 21).

Table 4. SECI and knowledge creation process according to Nonaka and Takeuchi (N&T) and the 7C5 spiral.

SECI	N&T	7C5 spiral
Socialization	Sharing of tacit knowledge	Communication
Externalization	Creating concepts	Conceptualization
Combination		
-	Justifying concepts	-
-	Building an archetype	Collaboration
Internalization	-	Comprehension
-	Cross-leveling knowledge	Collective intelligence

The stages of the SECI, N&T and the 7C knowledge creation spiral have many similarities. Socialization, sharing of tacit knowledge and communication seem to be semantically identical. The goal is to share the tacit knowledge with co-workers and other members of the collective. Concept creation seems to be the next step. However, in SECI this is not explicitly so. Yet, through externalization and especially combination new concepts can be created. Next, N&T says that the concepts need to be justified: it determines the "quality" of the created knowledge according to standards and criteria (Nonaka 1994). SECI and the 7C model do not address this issue, even though it could be seen as part of the conceptualization sub-process of the 7C model. Next, the N&T process and the 7C model have a stage for the application of the produced knowledge. N&T calls this building an archetype and 7C calls it collaboration. SECI does not address this. The final step in SECI and the second-to-last in the 7C model is the mode where explicit knowledge is transferred into tacit knowledge. SECI calls this internalization, and the 7C model calls it comprehension. In N&T, the last step is cross-leveling knowledge, *i.e.* the knowledge is shared and extended to others within the collective or to other collectives within or even outside of the company. The 7C sub-process of collective intelligence seems to match this pretty well, even if collective intelligence is more like organizational memory and the cross-leveling of knowledge more like a process through which organizational memory is expanded.

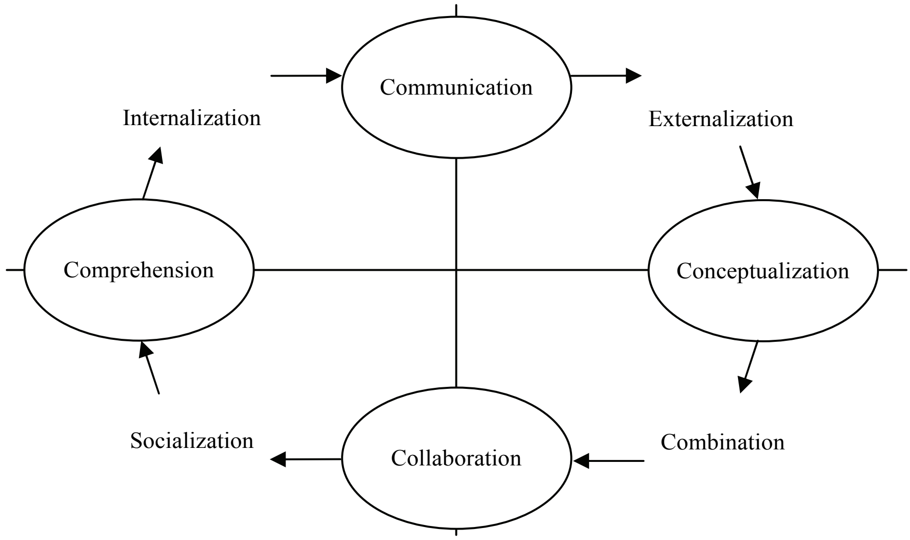

Fig. 3. SECI knowledge conversion works as inputs and outputs for the 7C sub-processes.

We can also compare the 7C model and SECI more closely. While SECI shows the knowledge conversion modes that can take place when explicit and tacit knowledge interact, the 7C model presents the sub-processes that enable this conversion. Indeed, the SECI knowledge conversion works both as inputs and outputs of the 7C sub-processes. For example, if a user comprehends, he or she internalizes explicit knowledge into tacit knowledge. This internalized knowledge then works as an input to the communication sub-process through which it is externalized. Conceptualization then uses the externalized knowledge in order to create new concepts. The output is a combination of the externalized bits of knowledge. Collaboration is based on the combined conceptualizations. Finally, as collaboration is a social activity, socialization (*e.g.* observations) can happen through it. For example, while a team is collaborating, people can compare how other team members perform certain operations. See Figure 3.

3 User participation and content creation

This chapter presents first the concept of Web 2.0 followed by a brief look on mobile technologies. After this user participation and content creation are discussed in detail. Wisdom of crowds approach concludes the chapter.

3.1 Web 2.0

As Web technologies and protocols have evolved, users and developers have invented new ways as well as revised older methods to utilize the Internet. For example, in the early days of email one could only send text-based email messages to each other, while today it is possible to attach any type of content to an email message. The evolution of information technology is very clearly visible on the World Wide Web. Companies such as Microsoft, Google and Yahoo!, among many others competing in online markets, have created new programming environments, paradigms, application programming interfaces and services at an ever growing pace.

Web 2.0 refers to a perceived or proposed “second generation” of Internet-based services (O’Reilly 2005). Different social networking sites, wikis, communication tools, and tagging have enabled Internet users to contribute in novel ways to the services they are using. New forms of online collaboration and knowledge sharing have emerged, and some companies have been able to create significant user populations for their free to use services resulting in few high valuation acquisitions. As a consequence, a buzz around the Web 2.0 phenomenon has emerged.

Web 2.0 has no formal and widely accepted scientific definition because it is not a standard or something revolutionary in a scientific sense. In fact, some researchers see it as normal evolution and development of the Internet and point out that some of these technologies have been invented years ago (Alexander 2006). However, this development has achieved a stage where these Web functionalities are available for the first time to millions of Internet users. Thus, there is a need to describe this development with the term Web 2.0.

According to O’Reilly (2005), some of the key concepts and technologies associated with Web 2.0 are 1) Web as platform, 2) architecture of participation, 3) rich user experience, 4) blogging, and 5) wikis. Following these we have defined Web 2.0 as (Räisänen *et al.* 2008):

> *Web 2.0 is a set of novel technologies and philosophies that use the Web as a platform to deliver information products and services that emphasize user participation.*

The technologies and philosophies related to Web 2.0 continue to change and mature. The understanding of the Web as a platform has also grown and we have seen the rise of many new and novel services. Yet, one of the most important ways that companies try to gain competitive advantage is to harness the end-users with tools to participate in content production. As users start using various services, they form informal Web-based communities where they interact, solve problems and share knowledge with each other (Wegner 2002). However, these communities are usually not restricted (many restricted services exist, too) to just the registered members. Instead, the content (*e.g.* in discussion forums) or knowledge is available to anyone, and thanks to permalinks - *i.e.* a permanent URL that points to a specific blog or forum entry even after it is archived (Blood 2004) - users constantly cross-post funny pictures or videos, or copy-paste related bits of text to other communities they belong to. This helps create redundancy, which provides a vehicle for "problem generation and knowledge creation which follows procedures that are different from those specified by the 'official' organizational structure" (Nonaka 1994: 28).

Another characteristic of modern Web applications is the ability to offer a “rich user experience”. The term rich user experience refers to the fact that in recent years, Web-based applications have started to offer GUI-style application experiences to users (O'Reilly 2005). In essence, the Ajax application “eliminates the start-stop-start-stop nature of interaction on the Web” (Garrett 2005: 1), allowing the web browser to dynamically load new content to the page, thus improving the user experience. One approach to measuring user experiences evoked by the modern Web environment is through the construct of flow (Csikszentmihalyi 1975). Flow has been used particularly to assess users’ experiences in the context of Web-based commerce (Hoffman & Novak 1997). Csikszentmihalyi (1975: 36) describes the construct of flow as “the holistic sensation that people feel when they act with total involvement“. Hoffman and Novak (1996) describe flow as being a state which occurs when navigating in the Web and which is intrinsically enjoyable, self-reinforcing and accompanied by a loss of self-consciousness. As a measurable concept, flow can be inferred from its antecedents and consequences (Oinas-Kukkonen 2000). A primary antecedent condition that is necessary for the flow state to be experienced is that skills and challenges are perceived to be congruent and above a critical threshold (Hoffman & Novak 1996). If the skills of the users are high, but the challenges are low, they may fall into boredom, while if their challenges are high, but the skills are low, they may fall into anxiety. If both the challenges and skills are too low, users may fall into apathy.

In this dissertation we adopt the definition of Oinas-Kukkonen (2000: 80) for modelling the concept of webflow (while this construct is noted as 'webflow', it is equally applicable to mobile or other information systems that require extensive navigation from the user):

> *Webflow is an optimal perceived user experience which improves a system user's orientation and navigational use, as well as vice versa, and which is predicted by balanced user skills and the feeling of the system to be enjoyably challenging, the feeling of being in control of system use, and the perceived ease of use and usefulness of the system. Content and functionality provided by the system help keep user skills and challenges above a critical threshold through focused attention and learning.*

In this dissertation, webflow is applied to studying the user experience of various tools supporting knowledge work. As webflow supports learning (Hoffman & Novak 1996), it should have an impact on knowledge creation as well.

Finally, the Web can also be utilized through mobile devices, such as mobile phones and PDA's. In recent years, this has become increasingly popular. The next section discusses this.

3.2 Mobile technologies and the Web

When the first mobile devices started to have web browsing capabilities (namely a suitable browser) concepts such as "mobile aware" (Chen & Kotz 2000) and "mobile aware Web information systems" (Oinas-Kukkonen 1999) were introduced. The point of the concepts was to make sure that the Web-based information system would be designed with potential mobile usage in mind (Oinas-Kukkonen 1999). Typically, Web-sites had special versions, usually with limited functionality, for mobile devices.

Today, devices like the Apple iPhone and Nokia N900 – to name a few - have fully compatible web browsers, and the browsing capabilities they offer are much closer to a standard web browser. For example, the most successful rendering engine WebKit supports Javascript, CSS, Ajax and even plug-ins (Hernandez

2009). WebKit has also been enhanced with “touch-pad interfaces and zooming capabilities to facilitate viewing and further interface small handsets with full-fledged HTML Web applications” (Hernandez 2009: 83). This means that Web 2.0 applications can update personal mobile Web content. Thus the gap between the mobile and the Web is closing.

Davis (2002) describes four possible beneficial effects of mobile computing on knowledge management activities. The possible effects are:

1. Enhanced capabilities for communication, coordination, collaboration and knowledge exchange.
2. Removal of time and space constraints for doing knowledge work
3. Access to critical decision makers at any time
4. Increased ability to receive and process rich streams of signals about the organization and its environment

While mobile technologies hold great promise, they have some drawbacks as well. These are mainly due to the small size of the devices. For example, as the mobile devices are small, only small displays and keyboards can be fitted onto them.

One use for which mobile devices have been utilized a lot is microblogging (Zhao & Rosson 2009). There are many reasons for this. Micro-blogs must be short so writing them with a mobile device is easy. This is probably important due to the size of the keyboards in mobile devices. In addition, mobile microblogging does seem to match well with the possible beneficial effects of mobile computing described earlier: it enhances communication, removes time and space constraints, improves access and the possibility to receive and process streams. For example, as Twitter “tweets” are short it is easy to read them in a small screen. Thus, mobile device allows us to follow Twitter users in (close to) real-time.

Furthermore, mobile devices have been found to support rich communication and knowledge capture (Zuga *et al.* 2006). As mobile devices are carried around, they can try to benefit from the principles of Kairos – the opportune moment (Kinneavy 1986). When something happens, a mobile phone can be used to take a video or picture of the event, for example.

While mobile devices work well with knowledge capture, they are not so well suited for editing or combining knowledge. For example, editing videos or images is difficult if not impossible with a mobile device. Thus it has been proposed that for knowledge management purposes the use of mobile devices should focus on ”the seamless integration of mobile work into the corporate knowledge management loop, especially where knowledge is associated while performing tasks, tasks necessitate out-of-office work and tasks necessitate communication" (Grimm *et al.* 2005: 58). As such, mobile devices seem better suited for situations where knowledge is utilized rather than situations where knowledge is created.

In short, mobile devices and technologies excel in knowledge capture, *e.g.* taking photos or videos. In addition, they can provide support for knowledge utilization. Through knowledge capture they can also help in content production as well as knowledge creation in general. The next chapter discusses online communities and content production in more detail.

3.3 Online communities and user participation

Today, technologically supported formal and informal social networks are a major domain for fostering the creation and exchange of knowledge (Novak & Wurst 2004). They are often referred to as virtual communities (Rheingold 1993), communities of practice (Wegner 2002), or knowledge communities (Novak & Wurst 2004). These communities are groups of people who share a concern, a set of problems, and who deepen their knowledge and learn by spontaneously interacting on an ongoing basis (Wegner 2002). For example, discussion forums where people discuss about cooking or about strategies on how to play a video game are examples of such communities. They can be physically located, locally networked (*e.g.* via an Intranet), virtual (*i.e.* networked across distance) or a combination of these (Preece 2004).

This dissertation tackles various types of online communities but with an emphasis on healthcare communities. With the growth of the Internet and the World Wide Web during the last ten years, we will use the terms online communities and virtual communities interchangeably. Within these communities, individuals ask and answer questions, and discuss with other members. They also get support, reassurance, insights, and exposure to different value systems and beliefs (Preece 2004). Thus, both explicit and tacit knowledge can be exchanged. As members of the community interact, "gradually shared solutions and insights emerge that contribute to a common store of knowledge that accumulates over time" (Preece 2004: 295). Communities form primarily around people and people's needs to find and use information (Turner & Fisher 2006). In addition, the communities try to (Fisher *et al.* 2003): 1) Exploit the information sharing qualities of the available technology and yield multiplier effects for stakeholders, 2) transcend barriers to information-sharing, 3) connect people and foster social connectedness, and 4) emphasize collaboration among diverse information providers.

In a broad sense, there are two types of users in Web communities: information providers and information users (Fisher *et al.* 2003). Information providers are those users who write Wikipedia articles or upload videos to YouTube. Information users generally only read the articles or watch the videos. Kim (2000) has identified five sequential stages of community participation, these being 1) visitors, 2) novices, 3) regulars, 4) leaders, and 5) elders. Normally, users start to visit a community every now and then. If they ever start participating in the community by taking some actions (like taking part in discussions) they become novices. If they participate actively in the community, they are seen as regulars and some may even become leaders. Regulars are the typical members of the community. They are no longer novices nor are they seen as leaders yet. Leaders make up only a small portion of the users. Yet, they command a lot of respect. Many times all of the other members of the community "immediately adopt what these (…) leaders express" (Füller *et al.* 2007: 64). Finally, elders are a special case of leaders. They have been around for a long time and are proud of it (Golder 2003). There also seem to be different kinds of participators in any online community. Firstly, in most online communities there exists a group of participants who post or otherwise participate in the groups' discussions very rarely. They are called the lurkers (Nonnecke & Preece 2000). In Kim's stages, visitors are typically lurkers, as can be novices especially when they have just "become" novices.

In an online group, more than 90% of participants can be lurkers (Katz, 1998; Mason 1999). Even if lurkers do not take actively part in discussions, they can still benefit the community (Takahashi *et al.* 2003). For example, the more lurkers who contribute every once in a while there are, the more diversity and opinions the group will have. This is one of the key criteria of a smart group (Surowiecki 2004). If only a handful of users contribute to a group's discussion, there is a danger of the group becoming too homogeneous.

Even if a lurker does not post at all, he/she can spend a lot of time reading the discussions in the community. Indeed, reading is in general a much more common activity than writing (Perkins & Newman 1996). Even a very active poster probably reads more than he/she posts (unless he/she produces more than 50% of the content in the community).

Those who actively take part in the community, for example by posting, can also be divided into various groups. Turner *et al.* (2004) classify the following: 1) questioner, 2) answer person, 3) conversationalist, 4) flame warrior 5) spammer, and 6) troll.

Questioners like to ask questions. In most of their posts they look for help or information from other members (Turner *et al.* 2004). Quite naturally, the answer persons are those who like to answer the questioners' questions. What is interesting is the fact that the answer persons rarely get any promise of a return on their investment. Yet they seem content in answering other users' inquiries. Conversationalists come to the community to discuss, conversate, sosialize and evaluate ideas (Turner *et al.* 2004). In doing so they generate social interaction, a sense of belonging and a sense of community, thus being valuable members in the community. Flame warriors are somewhat close to conversationalists. Their primary goal is to win debates, thereby making themselves appear superior to others involved in the conversation (Turner *et al.* 2004). While the flame warriors can offend other members, they can still produce viable content for the community. Spammers do not provide any meaningful content for the community. Rather they post irrelevant content in the same manner as email spammers do. As such they can make it more difficult for the members of the community to find relevant knowledge as it might be lost in the spam. Trolls are users who are seemingly normal users, but who post controversial, inflammatory, irrelevant or off-topic messages to the community with an aim to lure others into useless discussions (Turner *et al.* 2004). These posts not only make it more difficult to find relevant knowledge, but the unwitting users can also spend a lot of time discussing with trolls even though no new knowledge or information can emerge from such debates.

Depending on their expertise, the users can also be classified into novices and experts (Priest & Lindsay 1992). Experts are users with a high level of task related knowledge, while novices are usually lacking this knowledge (Arnold *et al.* 2006). An example of the type of virtual community where the roles of experts and novices are emphasised are virtual communities of healthcare (VCHC) (Dannecker and Lechner 2007). If some member of a VCHC happens to be a physician, he or she can have a very high level of healthcare related knowledge, and his or her value to the community can be great. As a VCHC provides information and support to its members, having experts around would help novice members considerably. Indeed, it seems to be typical that there are trained healthcare professionals (Eysenback *et al.* 2004: 1168) “leading the groups as moderators or facilitators by stimulating discussions, formulating questions, or posting topics of interest or educational material on the bulletin boards.”

Besides different social roles or levels of participation, Web users can also be classified into groups according to their learning orientations (Martinez 1999). They represent how individuals plan and set goals, commit and expend effort, and how they experience learning while attaining these goals. Learning can be roughly categorized into formal and informal learning (Colley *et al.* 2002). Formal learning is the learning offered by, e.g., schools and universities. Informal learning, on the other hand, "happens to everybody from daily life activities related to work, family or leisure" (Drachsler *et al.* 2008: 303). In formal Web-based learning, learner-centered methods have been found to perform better than teacher-centered methods (Khalifa & Lam 2002). This is probably somewhat self-evident, as in learner-centered methods the Web is used not only as a medium (as it is in teacher-centered methods), but also to allow learners the freedom to explore and interact with the information. This is closely related to the constructivist model of learning, which states that knowledge is created or constructed by each learner (Leidner & Jarvenpaa 1995). Emotions and intentions can have an impact on human learning (Martinez 2001). Thus, in informal learning the focus has been on motivating learners to learn (Wellington 1990). Learning orientations try to model the effort and desire that individuals are willing to spend on learning. The following orientations have been identified (Martinez 1999): 1) transforming learner, 2) performing learner, 3) conforming learner, and 4) resistant learner

Transforming learners are highly motivated and enjoy acquiring expertise. They take responsibility and control of the learning process and they are willing to commit great effort to discover, elaborate and build new knowledge and meaning (Martinez 2001). Performing learners approach learning with a little less motivation or desire. They are self-motivated when the content appeals to them, and when the situation is right they will assume learning responsibilities in areas of interest. But when the conditions are not right, they are not willing to expend great effort on learning (Martinez 2001). Even less motivation and willingness to put effort on learning is found from conforming learners. They do not generally think critically, like to make mistakes or give new meanings to knowledge (Martinez 1999). Compared to the first two orientations, conforming learners need more guidance and reinforcement to get the job done. Last and least, the resistant learners do not even try to learn. Indeed, they may find the challenge of not learning to be more interesting than learning (Martinez 1999).

The more motivated the learner is (*i.e.* the closer the learner is to a transforming learner), the greater chances he has to utilize the vast amounts of information found on the Web as well as the existing hypertext functionalities, as transforming learners like to explore, discover and construct their own knowledge. The other (save for the resistant learner) seem to need at least general instructions (performing learners) or even step-by-step guides (conforming learners) (Martinez 2001).

As we can see, there is no one type of Web user. And as such, there is probably no one solution that would fit all users and their needs. In Figure 4, we can see the learning orientations (x-axis) and participation activity (y-axis, the higher on the axis he is, the more actively the user takes part in the community).

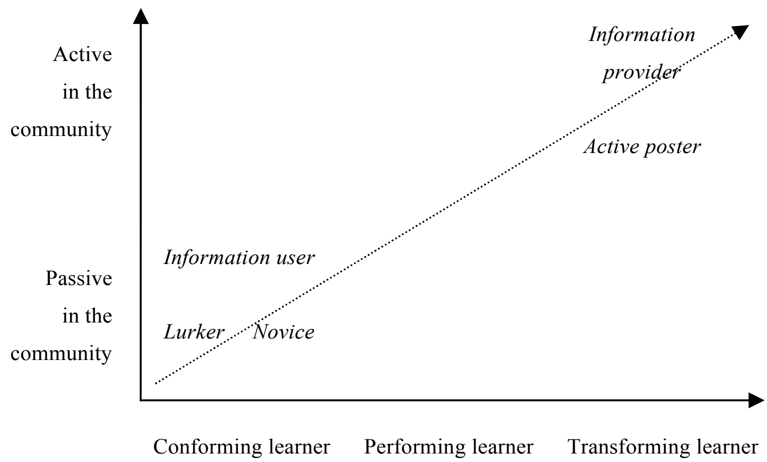

Fig. 4. Learning orientations and activity in the group.

As transforming learners acquire expertise they like to share it. They even often serve as a guide, coach or mentor for others (Martinez 1999). Thus they are well suited to be answer persons. As they also have a strong passion on the topic and a high desire to learn, they can be good conversationalists but they may also fall into being flame warriors. They are probably more active in the community than other orientation types.

Performing learners are sometimes willing to take the effort in the short-term to achieve goals. If they know the answer they may be an answer person, but more often than not they probably are the ones asking questions. Conforming learners probably lurk more, asking questions every now and then. So, as the motivation and desire to learn increases (*i.e.* the learning orientation moves towards the transforming learner), the user becomes more active in the community, and the user may even become a valuable information provider. If the motivation and desire are not there, the user probably will be more of a lurker, or information user. See Table 5.

Table 5. Learning orientations and social roles.

Learning orientation	Social roles
Conforming	Lurker, questioner
Performing	Questioner, answer person
Transforming	Answer person, conversationalist, flame warrior

Many reasons have been identified for why lurkers lurk. Some of these are (Mason 1999; Katz 1998): 1) feeling of incompetence, 2) fear of insult and abuse, 3) unfamiliar terminology and rituals, and 4) lack of language skills. Different solutions have also been proposed to get lurkers to post more. For example, encouragement and rewards (Preece & Maloney-Krichmar 2003) have been suggested. In other words, if lurkers had an incentive to post, maybe they would do so more often.

Besides trying to persuade lurkers to post, the actual lurking could also be made easier by "providing effective tools for reading, finding and browsing community information" (Preece *et al.* 2004: 218). This could also indirectly help lurkers to post more. For example, knowledge gained by lurking could reduce the feeling of incompetence and help understand the terminology and rituals of the community. Given that the users' learning orientation, their social roles and activity on the communities can change depending on the community, it is difficult to design a solution that would work in all circumstances. Luckily, depending on the positive or negative responses, a user may easily move from a transforming learner to a performing learner or from a performing learner to a conforming learner (Martinez 1999). Thus, a solution designed for conforming learners will work at least to some extent with performing and transforming learners. As movement in the other direction (*e.g.* from conforming to performing) requires "greater effort, learner control, and increasingly stronger intentions and beliefs" (Martinez 1999: 16), solutions designed for more motivated users do not fit so well with less motivated users.

3.4 Information providers and users in virtual communities

A user can be both an information provider and an information user in the same community. This is in fact the best case scenario, as the user can gain new knowledge as well as help others gain knowledge. See Figure 5. “VC” represents a virtual community that the user is a member of. The upper arrow emphasises how the user gains new information by interacting with the other members in the community. The lower arrow denotes how the user produces new content for the community, *e.g.* by posting or uploading.

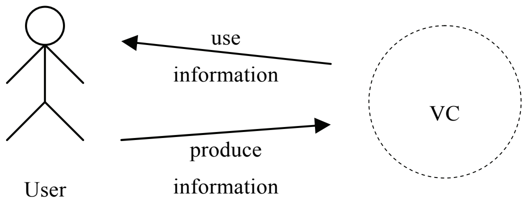

Fig. 5. User as information provider and user.

Typically, those interested in obtaining information and knowledge have several specific concerns. Wagner (2004) states that as the needs are difficult to know a priori (*i.e.* ad-hoc knowledge), virtual communities are a good place to ask questions. If the user cannot get answers, the information must be found in some other way, for example, through search engines. The next thing to do is filtering the relevant pieces of information from the noise. Finally, users have to ensure the quality of the information (Wagner 2004).

Those creating content must be able to 1) maintain dynamically changing knowledge, 2) distribute information, 3) assure quality, and 4) handle publication overhead. Maintaining dynamically changing knowledge is a challenge. Luckily, virtual communities allow information to be created, collected, and disseminated quickly. Thus dynamically changing content can be kept up to date.

Virtual communities offer a great way to distribute information and knowledge. Through posting and interaction with other members, information is shared with all participating members. Virtual communities offer a fast way of self-correcting mechanisms that quickly correct clear errors in the knowledge (Wagner 2004). For example, typos or missing information can be spotted more easily when there are many members observing the information. And the content creators should not have to worry too much about the message presentation or structural issues. Rather, producing should be made as easy as possible.

It should also be noted that the same user can be an information user in one community and an information provider in another. See Figure 6. The user (in the middle) is a member of four different virtual communities (VC 1, VC 2, VC 3, and VC 4). The arrows represent information flows. The flows from the first two communities are directed towards the user. In these communities, the user is an information user: he does not actively take part in the community by posting for example. The flow to VC 3 is bidirectional. The user both uses information from VC 3 and provides new information for VC 3. The flow to VC 4 is again unidirectional but this time the flow is unidirectional towards the community. This would be the theoretical situation where the user would only provide information to the community but would not receive any information back.

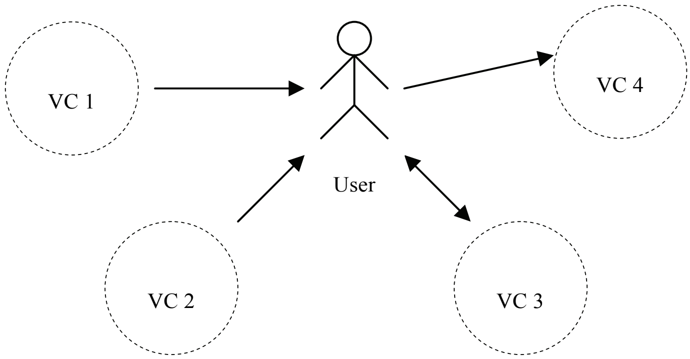

Fig. 6. User is a member in four different virtual communities.

The information that the user is producing for communities 3 and 4 can contain knowledge gained from communities 1 and 2. This way the user works as a proxy between different social networks. In fact, if the communities do not have many common members (*i.e.* users that are members in the some communities), the user forms a bridge between the two communities (Granovetter 1973).

Ease of use (Davis 1989) is one aspect affecting especially information production. For example, the easier it is to upload a video, the more likely users are to do so. Persuasive technology (Fogg 2003) is another field that studies this. In order to use information, users must be able to, for example retrieve, evaluate and analyse the information (Avery *et al.* 2003) before they can put it to use. For example, sense-making (*e.g.* Griffith 1999), comprehension (Oinas-Kukkonen 2004) and learning (Chatti *et al.* 2007) relate to this.

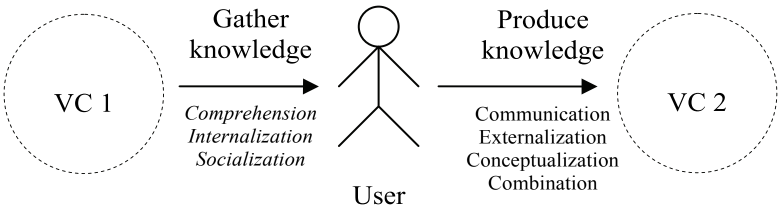

Fig. 7. The user is part of two virtual communities and his knowledge creation skills affect how knowledge flows between the communities.

Finally, Figure 7 shows a user who is a member of two virtual communities (VC 1 and VC 2). From the knowledge creation point of view, the arrows in Figure 7 are very different. The left arrow represents the knowledge that the user gets from VC 1. While reading and taking part in the community, the user comprehends and internalizes new tacit knowledge. The right arrow shows how the user externalizes and combines this knowledge through communication and conceptualization. Thus, information technology should offer support for both of the arrows in the figure. First, technology should allow us to use the information we have at hand. And second, technology should offer support when we are producing new information.

3.5 Wisdom of crowds

One reason why communities are good at producing new knowledge is that they can take advantage of the so-called wisdom of crowds (Surowiecki 2004). Surowiecki (2004: XIII) states that "under the right circumstances, groups are remarkably intelligent, and are often smarter than the smartest people in them". In essence, this means that by aggregating the information in a group, the resulting decisions are often better than any member of the group could have made.

Based on Surowiecki's book, Oinas-Kukkonen (2008) has defined the wisdom of crowds approach as follows:

1. It is possible to describe how people in a group think as a whole.
2. In some cases, groups are remarkably intelligent and are often smarter than the smartest people in them.
3. The three conditions for a group to be intelligent are diversity, independence and decentralization.
4. The best decisions are a product of disagreement and contest.

5. Too much communication can make the group as a whole less intelligent.
6. Information aggregation functionality is needed.
7. The right information needs to be delivered to the right people in the right place, at the right time, and in the right way.
8. There is no need to chase the expert.

This kind of decision making can be applied to problems related to cognition, coordination, and cooperation. Coordination refers to problems such as optimizing the utilization of a popular bar, or not colliding in moving traffic. The cooperation relates to problems that would seem to require some sort of centralized controlling system (Surowiecki 2004). For knowledge creation purposes, the interesting type of problems relate to cognition. Cognition problems refer to things like thinking and information processing. For example, if enough people made a bet on which team wins the Super Bowl, we could see a good estimate of how the game is going to end from the odds.

There are four conditions that a smart group needs (Surowiecki 2004): 1) diversity of opinion, 2) independence, 3) decentralization, and 4) aggregation. Diversity of opinion means that the group's decision cannot be smart without enough diversity. For example, with the Super Bowl example we would not get proper odds if we only got bets from the fans of one team playing in the match. The independence means that each individual should make their decision by themselves. Decentralization helps with diversity and independence. If the bettors are located all over the country, they can take the local knowledge into account in their betting (in contrast if they were situated locally, their local knowledge would be similar) and there would be no one to tell them how to bet (*i.e.* their betting decisions would be independent). Finally, there needs to be a way to aggregate the decisions of individual users (Oinas-Kukkonen 2008). In sports, the odds do this, as the odds are determined by how the bettors bet (*i.e.* each decision can change the odds one way or another even if this change is usually marginal).

If a crowd can make good decisions, they may have the potential to generate valuable knowledge as well. As the individual decisions are based on individual knowledge, the aggregated group decisions are based on the cumulative knowledge of all group members. Indeed, most of the knowledge creation theories note that new knowledge emerges from the interaction of individual and social knowledge. Thus, by comparing his or her decisions with the aggregated decisions of a group the individual has a chance for comprehension.

Virtual communities can be very diverse and decentralized (*i.e.* members can be from all around the world, from all age groups and with different backgrounds), and independent. Thus, the wisdom of crowds approach could be utilized to the fullest. Aggregation is the one aspect that should be supported more. In the online communities, users discuss, disagree and share their ideas. The most common way for this is text-based posts that can be found in discussion forums and blogs, for example. But for example for aggregation, there seems to be only indirect support in the form of voting. When some posts (or pictures or videos) receive a lot of plus votes they can be suggested, and the ones receiving minus votes can be ignored by the system. Mobile technologies allow users to stay connected while on the move. This can help especially smaller communities to stay diverse.

Crowds are not always smart. Sometimes a phenomenon called groupthink (Janis 1972) happens. Janis (1972: 9) defined it as a "mode of thinking that people engage in when they are deeply involved in a cohesive in-group, when the members' strivings for unanimity override their motivation to realistically appraise alternative courses of action."

The most important antecedent of groupthink seen by Janis (1972) is group cohesion. Indeed, if a group is too cohesive, it might lose some diversity and independence and, more importantly, its decision might no longer be the result of disagreement and contest. In a cohesive group, members might wish to avoid being seen as foolish, or avoid embarrassing or angering other members of the group.

In addition, Janis (1972) states that cohesion will only lead to groupthink if one of the following antecedents is also present: 1) structural faults in the organization, or 2) a provocative situational context. A structural fault could be, *e.g.* isolation of the group from outside influences. Stress and past failures are examples of provocative situational contexts. (Janis 1972). Thus, when utilizing virtual communities as a knowledge creation tool, special attention should be paid to ensuring that groups do not fall victim of groupthink. Rather the conditions of a smart group should be pursued.

4 Related research

This chapter will present related research regarding Web and mobile technologies as knowledge management tools. The aim is to highlight the opportunities of a new generation IT tools for knowledge management. Firstly, conversational knowledge management is discussed. Then, Web and mobile technologies are presented from the knowledge management point of view. The next section focuses on sense-making and comprehension. Finally, the last section summarizes the related research.

4.1 Conversational knowledge creation

In recent years, there has been a shift from a knowledge repository approach to a conversational collaborative foundation of knowledge management (Lee & Lan 2007). One reason for this is that knowledge residing in the repositories has not been accumulated or integrated to generate new intelligence. The conversational approach to knowledge management is based upon the knowledge network infrastructure but in a collaborative manner (Lee & Lan 2007). Keyes (2006) states that this is the kind of knowledge creation that happens in communities of practice where users discuss and share ideas and information.

Wagner (2004) has identified several benefits of conversational knowledge creation:

1. Economical and technology undemanding. Many on-line communities are built on little more than a listserv or a (freely available) Web-based discussion forum.
2. Fast, taking potentially only as long as is required for one person to post a question and others to post or e-mail a response. Speed makes conversational technologies particularly useful for environments where ad-hoc knowledge creation is required.
3. Suitable for environments where the knowledge is not centralized, but resides with multiple owners who may be located far apart.

Conversational knowledge management (CKM) relies heavily on questions and answers (*e.g.* some users like to ask questions, others like to provide answers). Especially answers are crucial. They provide the knowledge. If new questions are asked based on given answers, the knowledge can be further developed. In some cases, a common ground and grounding are also important (Clark & Brennan

1991). All in all, conversational knowledge creation is a good starting point in supporting knowledge creation in Web. In recent years it has also been supported by the growing number of available communication technologies.

Today, there are many different information and communication technologies that can be used to discuss, share and conversationally create knowledge. For example, Voice over IP (VoIP) allows people to speak to each other and their voice is sent over the Internet in IP packets. The ability to hear one another in conversation is valuable (Sellen 1995), mainly because speaking is easier than writing and listening is easier than reading (Brennan & Clark 1991). For the purpose of knowledge transfer, the ability to hear one another can facilitate tacit knowledge transfer (Roberts 2000). Indeed, for most of us it is easier to express our experiences by voice than by written text.

Video conferencing (and other types of virtual project rooms) may suite the transfer of tacit knowledge even better (Roberts 2000), as such technologies try to simulate face-to-face meetings. In the transfer of tacit knowledge face-to-face contact is often a prerequisite as communication is much more than just an exchange of verbal messages (Sellen 1995). For example, gaze, posture, gestures and facial expression can contain some elements of tacit knowledge in them.

The communication medium used may impose some constraints on the communication – or knowledge transfer – between people. Some of these are (Brennan & Clark 1991): 1) copresence, 2) visibility, 3) audibility, 4) cotemporality, 5) simultaneity, 6) sequentiality, 7) reviewability, and 8) revisability.

In copresence, communicators must share the same physical environment. For example, in face-to-face communication the participants are usually in the same surroundings. Visibility means that the participants must be able to see each other, and audibility means that they must hear each other (*i.e.* they communicate by speaking) (Brennan & Clark 1991). Today, copresence is difficult to achieve via information and communication technologies (ICT) but visibility and audibility are usually achieved, *e.g.* via teleconferencing.

Cotemporality means that the participants receive the communication roughly at the time it is produced. For example, a slow Internet connection or excess net traffic can increase the time it takes for the message to travel from the sender to the receiver (called lag). Simultaneity means that the participants can send and receive at the same time, and sequentiality means that the messages cannot get out of sequence. ICT generally supports both simultaneity and sequentiality, even if excess lag can hamper especially sequentiality.

Reviewability refers to the fact that the participants must be able to review the messages. For example, emails can be reread until they are deleted. Revisability means that the producer can rewrite the message many times before sending it. For example face-to-face this is not possible. ICT seems to offer great support for both reviewability and revisability.

All of these constraints are especially important for the 7C sub-process of Communication, and tacit knowledge transfer in general. For example, sharing the same surroundings (copresence), being able to see (visibility) and hear (audibility) each other helps by allowing the participants to observe what the other is doing or looking at as well as taking notes on timing and intonations of speech. Being able to review the messages can also help in comprehension. This is especially true with complex issues that require more thinking.

According to Novak and Wurst (2004), solutions supporting knowledge creation and sharing can be roughly classified into three main approaches: 1) internalization models based on individual reflection on the discourse conducted in the community, 2) socialization models based on direct interaction with the community mediated by technology, and 3) externalization models based on the explicit construction of a shared conceptualization.

Socialization is the process whereby new tacit knowledge is converted through interaction between individuals (Nonaka 1994). Two possible sources are participation in communities (*e.g.* discussion boards, social networks), and computer-mediated communication (Walther 1996).

According to Nonaka and Takeuchi (1995), the socialization mode starts with building a field or space for social interaction. On the Web there are the various communities that the users take part. Indeed, social media offer great promise for socialization spaces (Chatti *et al.* 2007).

The other aspect of socialization is sharing experiences (Nonaka & Takeuchi 1995). As Angeli *et al.* (2003) have found out, computer-mediated communication (CMC) helps because the discourse that the users take part in through CMC tools is mostly an exchange of personal experiences. In addition, as imitation and observation are crucial for socialization, tools like videoconferencing can help by providing visual and auditory cues.

While CMC helps in socialization, it is even more useful in externalization. Via open participation, dialogue and discussion, users can try to express themselves, and oral communication can verbalize tacit knowledge (Chatti *et al.* 2007). Blogs, for example, can support externalization by allowing users to immediately write down their thoughts, and allowing others to comment on the posts. These comments and trackbacks give context to the codified knowledge.

Internalization can be triggered by games, simulations, learning-by-doing (Chatti *et al.* 2007), reading discussion forums (Novak & Wurst 2004), and innovation support tools (de Carvalho & Ferreira 2001). In addition, the concept of sense-making is closely related to internalization. Multi-player games can also help in socialization. See Figure 8 for a summary of how Web 2.0 tools help SECI-based learning (Chatti *et al.* 2007).

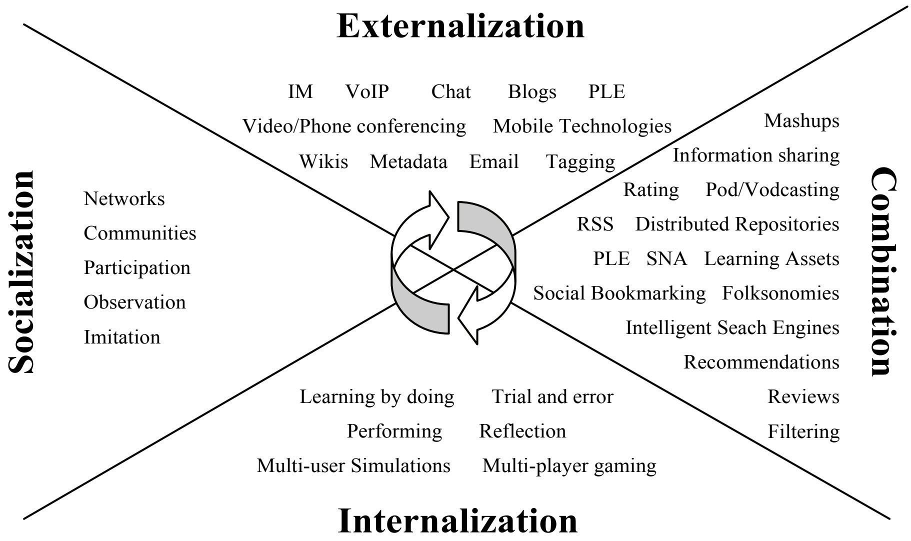

Fig. 8. Web 2.0 tools and SECI-based learning (adapted from Chatti *et al.* 2007).

Novak and Wurst (2004) have studied how existing, but not explicitly formulated knowledge structures can be discovered, visualized and made usable for the collaborative discovery of knowledge. They argue that this would support knowledge creation and sharing in communities. They propose a model of personalised learning knowledge maps (Novak & Wurst 2003). A knowledge map presents a semantic structuring of an information pool and consists of two elements. These are (Novak & Wurst 2004) documentMap and conceptMap. DocumentMap structures information space into clusters that consists of semantically related documents (Novak & Wurst 2004). This provides an overview of the topic as well as showing the relationships in the information space. ConceptMap on the other hand is used to visualize the concept-network. In addition it provides a navigation structure as well as the criteria for determining this structure (Novak & Wurst 2004).

Besides the conversational knowledge creation that takes place as users interact, the Web has some inherent features that support knowledge creation, too. The next chapter discusses these.

4.2 Hypertext and the Web

The Web allows many hypertext functionalities, such as linking, annotation, and navigation, to be easily integrated as parts of information systems (Oinas-Kukkonen 1995). This allows "contextual, navigational access for viewing information and that it represents knowledge in a form relatively close to the cognitive organizational structures that people use." (Bieber *et al.* 1997: 35). Bieber *et al.* (1997) also state that this kind of knowledge representation supports understanding.

Kolb (2005) asks the question how hypertext helps in the process of developing the order and connection of ideas in claims and arguments. For this, he distinguishes four kinds of hypertext. These are: 1) page-and-link, 2) stretchtext, 3) link mapping, and 4) spatial hypertext.

Page-and-link hypertext is what we see on the Web: a web page that has both content (*e.g.* text and images) and links to other content. Stretchtext is the kind of hypertext which can extend to offer more detail. The difference in page-and-link and stretchtext is that whereas page-and-link will replace the original content (or be opened in a new window), stretchtext will display the new content embedded in the original page. Link mapping "provides a spatialized overview of linked networks, most often in the form of boxes linked by arrows" (Kolb 2005: 13). Spatial hypertext would allow us to, *e.g.* drag-and-drop a paragraph of text into another place in a document. It is also a kind of spatial overview, but when you change something, it can change the relationship and meaning of it (Kolb 2005).

Kolb (2005: 17) concludes that "for the analytic phase of intellectual work, the best tools would seem to be ones that combine the multiple presentations of stretchtext, the precision of page-and-link structures, and flexible link maps".

The Web as a hypertext system offers great promise for knowledge creation, even if some high-level hypertext features could make it even better (Bieber *et al.* 1997). Thus expanding the functionalities of the Web as a hypertext system has been studied a lot (see, *e.g*. Farzan & Brusilovsky 2008). Content annotation has been one of the most popular topics of research. Research has shown that with the ability to share annotations with others (Xin & Glass 2005) users can learn from each other. Brush *et al.* (2002) showed that users will leave more comments if they can be made contextual. Contextuality refers to the ability of associating the comment to any part of the page. Thus contextual comments could help learners even more. Guided tours (Bieber *et al.* 1997) and adaptive navigation support (Farzan & Brusilovsky 2008) are other functionalities typically used.

The problem with expanding the hypertext functionalities of the Web is that the different solutions are usually not compatible. In addition, existing projects usually focus on advancing Web hypertext in only one area (Farzan & Brusilovsky 2008). Some solutions, for example AnnotatEd (Farzan & Brusilovsky 2008), try to integrate multiple functionalities into a single value-added service.

One way to add value to existing functionalities or services is to combine them to create new functionalities. These combinations are called mashups (O'Reilly 2005). They have also been suggested to be potential tools for knowledge management, especially when the user himself bonds data and services thus increasing the usability of such systems and supporting knowledge intensive processes (Bitzer *et al.* 2008).

Mashups seem to complement standard KMS (Bitzer *et al.* 2008). For example, combining Google Maps with housing information allows the mashup to provide a much better results set by showing only those houses that are close by. Without mashup this would require separate searches. Mashups seem to be a good way of building high level tools since combining different information sources allows the integration of "the resulting intelligence with other [...] knowledge" (Oinas-Kukkonen 2004: 5).

Bieber *et al.* (1997: 39) state that semantically typing nodes and links "help authors organize information more effectively and lend context for readers." Argumentation-based systems demonstrate this well. Typically in argumentation-based systems like gIBIS (graphical issue-based information system; Conklin & Begeman 1996) the nodes have types like 'issue', 'position' and 'argument' (or 'question', 'answer', 'argument' in QAR; Oinas-Kukkonen 1998). The links between the nodes can be typed, *e.g.* 'responds to', 'objects to', or 'supports' to name a few.

Graphical notations to support argumentation and communication have been studied a lot over the past years (Buckingham Shum *et al.* 1997). Argumentation seems to provide the most support when elaborating on poorly understood topics, but are a distraction when evaluating well-constrained topics (Buckingham Shum *et al.* 1997).

For some reason, argumentation-based solutions have not been very popular in recent years. Buckingham Shum (1996) has analyzed the usability of a design rationale notation. He found out that the users must learn to manage four interleaving cognitive tasks. These are: unbundling, classification, naming, and structuring.

Unbundling is "identifying and separating constituent elements of ideas which have been 'bundled together' when they were initially expressed, but which from an argumentation perspective need to be teased apart" (Buckingham Shum *et al.* 2006: 108). Classification is deciding whether a contribution is a Question, Option or Criterion. Naming is labelling the new contribution succinctly but meaningfully, and structuring is linking in a new element to other ideas (Buckingham Shum *et al.* 2006).

So it is not surprising that argumentation requires extra work. In fact, Buckingham Shum *et al.* (1997: 275) note that "on reflection, reports of cognitive overhead should not be surprising. The basis on which [concept mapping tools] work is that deeper understanding of a domain comes through the discipline of expressing knowledge within a structural framework, working to articulate important distinctions and relationships." So effort must be invested to get the benefits of rationale systems. However, this seems to be in conflict with the ease-of-use paradigm popular with Web 2.0.

Baumer *et al.* (2008) have studied the role of the reader in blogging. They were mostly interested in the role, contributions, and significance of the reader, as previous research has been focusing on the blog itself or the blogger. They argue that the reader (*e.g.* an Internet user) is not a passive recipient of content but rather an active interpreter (Baumer *et al.* 2008, *c.f.* Davis & Womack 2002). Reality and meaning exist neither in the text nor in the reader. Rather, they are constructed by a dialectic interaction between the two (Baumer *et al.* 2008). Thus, the tacit knowledge created by the readers emerges from the active interpretation of and interaction with the content on the Web (*e.g.* blogs, wikis).

4.3 Knowledge creation in the Web and mobile settings

User participation in virtual communities (VC) has been studied a lot. For example, Cheng and Vassileva (2005) have studied how motivation and persuasion strategies can affect user participation in peer-to-peer communities. In the study, they introduced a set of hierarchical memberships into the community. For example, users are given different memberships, such as “bronze”, “silver”, “gold”, and so on, depending on their own contributions to the system. They found out that they could increase users' contributions and participation through this. Persuasive solutions like this - in this case a reward, see Fogg (2003) - could support knowledge creation too, as users who would contribute and participate more would make the system better (*e.g.* produce more content).

Similar finding were found by Tedjamulia *et al.* (2005), who found out that extrinsic rewards can increase users’ intrinsic motivations under some conditions. Sangwan (2005) identified three key motivators for VC use. They are functional needs, emotional needs and contextual needs. Functional needs refer to things like the users’ perceptions of the quality and quantity of content received and processed. Emotional needs refer to social interaction, self expression and personal use. Finally, contextual needs relate to individual user specific expectations and experiences. (Sangwan 2005).

Web 2.0 and how it is used also affects how users generate new content. Lee and Lan (2007) provide a list of features that may be considered as the objectives of knowledge contents development via Web 2.0. These are:

1. Contribution – every Internet user has the opportunity to freely provide their knowledge content to the relevant subject domains.
2. Sharing – knowledge contents are freely available to others. Secured mechanisms may be enforced to enable knowledge sharing amongst legitimate members within specific communities.
3. Collaboration – knowledge contents are created and maintained collaboratively by knowledge providers. Internet users participating in the knowledge contents can have conversations as a kind of social interaction.
4. Dynamic – knowledge contents are updated constantly to reflect the changing environment and situation.
5. Reliance – knowledge contribution should be based on trust between knowledge providers and domain experts.

Lee and Lan (2007) state that wikis, blogs and discussion forums can benefit from the above listed features. In fact, conversational knowledge creation seems well suited for this kind of knowledge development.

Dannecker and Lechner (2007) have studied knowledge creation in virtual communities of health care (VCHC). VCHCs provide information and support to their members. The information shared in such communities includes experiences about the disease, how it was contracted, how it affects the daily life and how to cope with the disease (Dannecker & Lechner 2007). Their study focuses on information quality, or more precisely on the rating of relevant medical information. They also claimed that the rating is part of a knowledge creation process within VCHCs.

Dannecker and Lechner (2007) also provide us with a 5-phase knowledge creation process that happens within a VCHC. The phases are: 1) identification, 2) preparation, 3) definition, 4) initial event, and 5) ongoing rating. First, the relevant and interesting topics in the VCHC have to be identified. As discussions in a VC can be about anything, it is important to find the topics that are most important to the members. The second phase is about preparing information related to the chosen topic. In a VCHC this can be medical studies, expert interviews, personal experiences and so forth. The third phase is the definition of the rating criteria for a specific part of information. The initial event phase is the first ratings of the information. This creates attention and helps in reaching a critical mass of ratings. The final step is the ongoing rating phase, which contains all the ratings the information will have after the critical mass has been achieved. (Dannecker & Lechner 2007). By examining the ratings of the information, users can assess the quality of it.

Eysenbach *et al.* (2004) made a systematic review of VCHCs and electronic support groups to see their effect on health and social outcomes. While they found out some evidence for social support and support for depression, no robust evidence for the benefits or harmful effects were found. They also indicated that the quality of the studies was low. The absence of robust evidence made them suggest that future research should concentrate on finding out about the conditions and factors influencing the outcomes.

Hemetsberger and Reinhardt (2004) have studied knowledge sharing and creation in virtual open source communities. They advance the perspective that knowledge in online communities is shared and co-created by the members through the establishment of processes and technologies that enable re-experiencing (Hemetsberger & Reinhardt 2004). They found several ways to enable re-experience. These were: 1) Enabling re-experience by decreasing complexity and transactive group memory, 2) enabling re-experience by guidance, openness and legitimate peripheral participation, and 3) enabling re-experience by asynchronous communication and virtual experimentation.

Recently in Web-based knowledge management tools, the conversational knowledge creation and collaborative knowledge management approaches have received the most attention. Virtual community members can also use knowledge discovery to help deal with the amount of information. For this, Jenkin (2008) has identified some general characteristics. They are divided into three levels. The first level tools help to automate the information foraging process. For example, search engines locate information and assess its usefulness for the individual based on the search terms provided. These tools rely on the user to come up with the search terms, requiring intuition and induction (Jenkin 2008). The second level tools help to organize and display results in clusters and knowledge maps. This helps the users to find relevant and interesting results, thus automating the foraging process. This also offers some support for interpretation by making it easier for the users to understand the topic, sub-topics and their relationships (Jenkin 2008). As such, the second level tools do seem to offer some support for comprehension, too. The third level tools help discover novel knowledge. They direct the individuals' attention to what they should do or learn next based on what is indirectly connected, yet related to the search terms. Whereas level 1 and 2 tools tend to bury the user in information overload, level 3 tools should provide a smaller list of search results. How this is done is not described. The third level tools should also support the interpreting process by pattern recognition (Jenkin 2008). It is quite clear that knowledge management tools should be third level tools.

Mobile technologies and tools have their merits and problems related to knowledge management. Fagrell (2000) has pondered about how we can provide mobile workers with timely knowledge. With timely knowledge he means knowledge that is relevant to the task at hand. Fagrell (2000) found out that the current perspectives for knowledge management are not appropriate in mobile context. He proposed the following main requirements for a mobile knowledge management architecture (Fagrell 2000):

1. Support evolving tasks and notify users of interdependencies
2. Offer an overview of records, including annotations
3. Suggest available expertise
4. Filter information based on task and long-term interest
5. Enable adaptation to user preferences and mobile device capabilities

What is interesting here is that most of these requirements aim at simplifying the knowledge work tasks. For example, overviews make it easier to view records, suggestions simplify the decision making process, and filtering rules out (hopefully) unimportant information.

Zuga *et al.* (2006) have studied mobile knowledge management and mobile learning. They point out that mobile learning and mobile knowledge management are similar in nature, and they are in fact merging at a fast pace. Furthermore, the tools used for mobile learning are often the same ones that are used for mobile knowledge management (Zuga *et al.* 2006).

Such tools typically support (Zuga *et al.* 2006): 1) rich interactive communication and knowledge capture, 2) context awareness for content creation and delivery, 3) out-of-office learning situations, and 4) permanent connectivity. For content creation, context awareness is important. For example, if a mobile device knows its location it can store, *e.g.* GPS coordinates with pictures taken with it.

Anytime, anywhere (*e.g.* Perry *et al.* 2001) is a concept often used when talking about mobile devices. One of the major premises of mobile technology is that it removes “the bindings between a fixed space and a person’s information and communication resources” (Perry *et al.* 2001: 324). Indeed, permanent connectivity means that workers can access relevant information and communication resources if they have suitable tools or applications. This is important for knowledge creation as well (for example in the 7C model, one C is named “connection”).

4.4 Sense-making on the Web

Sense-making can be defined as a process of bridging gaps in knowledge that prevent a user from moving forward in a time-space situation (Dervin 1998). Russell *et al.* (1993: 269) define it as “a process of searching for a representation and encoding data in that representation to answer task-specific questions.” It is closely related to comprehension, which is one of the central sub-processes of knowledge creation (Oinas-Kukkonen 2004).

Hypertext supports sense-making "through the enriched context that comes from sophisticated navigation support and supplemental relationships" (Bieber *et al.* 1997: 33). By seeing the context (*e.g.* other documents which link to the content), the user can see how the content relates to other topics.

Some go as far as saying “knowledge cannot be transferred; it can only be enacted, through a process of understanding, through which people interpret information and make judgements on the basis of it” (Leadbeater 2000: 29). Okada *et al.* (2008: 28) claimed that “users need intuitive, powerful tools to manage, share, analyse and track information, ideas, arguments and the connections between them."

Selvin and Buckingham Shum (2009) have studied sense-making in the context of participatory media practice. They have found out that the concepts of coherence, engagement and usefulness can contribute to the understanding of sense-making. Coherence refers to the fact that the information display and the interaction of the participants should be kept understandable, clear, evocative, and organized (Selvin & Buckingham Shum 2009). Otherwise, a lot of time and effort must be spent to do so. The Web allows both coherent and incoherent hypermedia presentations, so special emphasis must be on keeping the visual and textual elements of the display clear for the users. However, as most of the content in Web 2.0 services is generated by the users, this can be difficult. Engagement refers to the degree that the participants are engaged with the system or service they are using (Selvin & Buckingham Shum 2009). The deeper the engagement, the better the chances are for sense-making to happen. The concept of engagement relates closely to the concept of flow, which is a state where a person is fully immersed or fully involved in what he or she is doing (Csikszentmihalyi 1975). Finally, usefulness is the extent to which the system, service or piece of information appears to be adding value for the participants, and helping them to fulfil their goals (Selvin & Buckingham Shum 2009).

Uren *et al.* (2006) have developed various sense-making tools. Their first tool is an argument sketching tool. With it users can enter arguments into the system. These arguments are stored in another tool, which is a Web server. The server also allows users to search for, visualize and discover arguments stored in it. For sense-making, visualization can indeed be a key, especially if it can show how various concepts relate to each other. The discovery service can also be important as it allows users to, *e.g.* extend a set of concepts by adding positively linked concepts from other topics, or find other concepts associated with the original concept (Uren *et al.* 2006). One of the closing remarks by Uren *et al.* (2006) was that future research should aim at developing the functionalities of browsing tools and improving the clarity of outputs to help users forage as effectively as possible.

Buckingham Shum *et al.* (2006: 117) have noted that "novices can gain value from the [design rationale] tool as a personal concept mapping aid within days, while confident, effective use in meetings takes longer." However, this learning curve of days makes a big difference when organizations are compared to virtual communities. Whereas organizations can make it mandatory that employees learn to use such a system, in virtual communities the members participate voluntarily.

Members of a virtual community might not have the time to spend days learning a system that may or may not be helpful to them.

Ravis *et al.* (2008) have suggested that visualization tools as well as synchronous communication tools can help in collaborative sense-making. They say that visualization helps by making important information more accessible and easier to remember and process, and synchronous communication tools help in creating social awareness and bringing virtual communication closer in quality to face to face interaction.

Finally, Savolainen (2006) states that there are a myriad of ways to make sense rather than a single "right" way. Yet, "means of externalizations and available operations are essential elements in people's creative knowledge work" (Nakakoji *et al.* 2005: 64). In addition, because knowledge creation tools are cognitive tools, they affect how a user understands and solves a problem. Thus, the interaction design of a knowledge creation tool "guides or distracts, encourages or discourages, and permits or prohibits a user in and from taking certain courses of actions and states of mind" (Nakakoji *et al.* 2005: 64). Since knowledge creation is very cognitively intensive intellectual work, tools need to be very carefully designed.

Nakakoji *et al.* (2005: 43) acknowledge that "creative knowledge work (...) is a cognitively intensive human activity, and yet cognitive resources have limitations." So we need tools "to generate representations and interact with them, but using tools consumes some of the cognitive resources, which then becomes a cognitive overhead" (Nakakoji *et al.* 2005: 43). So, in essence, the more cognitive resources are demanded by the tools, the fewer cognitive resources we can spend on our own creative thinking (Streitz *et al.* 1989). Thus, as Okada *et al.* (2008: 28) have claimed, we "need intuitive, powerful tools to manage, share, analyse and track information, ideas, arguments and the connections between them."

4.5 Summary of related research

Knowledge management is a topic that is researched a lot in the field of information systems (see, *e.g.* Alavi & Leidner 2001, Argote & Ingram 2000, Bender & Fish 2000). In order to understand knowledge creation, conversational knowledge management offers a good starting point. Especially Web applications utilize this to a great extent. For example, Web users discuss and share ideas in Web-based communities, thus creating new content – and knowledge.

New knowledge is formed in the minds of individuals and it is being developed in social interaction between individuals (Nonaka 1994). In other words, communities of interaction "contribute to the amplification and development of new knowledge" (Nonaka 1994: 15). For organizations this means that they can utilize this to refine the knowledge stored in its employees. Communities of practice can bring together employees that normally work on different projects. Through conversations and sharing of experiences they can generate knowledge that would not emerge otherwise.

Conversational knowledge creation does match the 7C sub-processes of communication well. It also provides a basis for the sub-process of conceptualization: through conversations concepts are created. Conversations can also support collaboration, at least indirectly. However, conversational knowledge creation does not match comprehension so well. Naturally, users can comprehend and internalize knowledge through conversations, but the support for this is limited. Conversations are also not optimal for utilization purposes.

Luckily, Web as a hypertext tool is better suited for supporting comprehension. The hypertext capabilities of the Web allow "contextual, navigational access for viewing information" (Bieber *et al.* 1997: 35). This is a good starting point in supporting comprehension as it "represents knowledge in a form relatively close to the cognitive organizational structures that people use" (Bieber *et al.* 1997: 35).

Hypertext capabilities can also support the "gap bridging" required by sense-making. Users can combine information and knowledge, link them together and make important information more accessible and easier to remember and process (Ravis *et al.* 2008). Knowledge creation tools must not distract, discourage or prohibit users from taking certain actions.

Thus, as Okade *et al.* (2008) concluded, we need intuitive and powerful tools. In the constructive part of this dissertation, such tools are investigated. The utilization of knowledge seems to have also received somewhat less scientific attention. This is especially so for mobile settings. This is fascinating, as the competitive advantage gained from knowledge resides in its applications rather than in the knowledge itself (Alavi & Leidner 2001). Thus, information systems should concentrate on supporting the creation of applicable knowledge. This will be another focus of this dissertation.

5 Method of research

The chapter will discuss the overall research approach of this study.

5.1 Research approach

This study includes both conceptual analysis and empirical observations. It has elements that are both theory testing and constructive in nature. The observations (see Figure 9) are based on two different case studies, and the experiment part on two different constructions. Based on the observations, constructions and experimentations were made. As a whole, the research problem is approached with a constructive research method. Figure 9 shows the research process and the publications of this study.

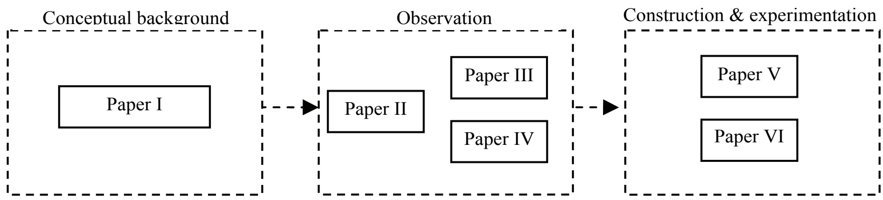

Fig. 9. The overall research process.

The dissertation comprises of the following publications:

PAPER I:
Räisänen T & Oinas-Kukkonen H (2007) A System Architechture for the 7C Knowledge Environment. In: Jaakkola H, Kiyoki Y & Tokuda T (eds) *Information Modelling and Knowledge Bases XIX*, IOS Press: 217–236.

PAPER II:
Oinas-Kukkonen H, Räisänen T & Hummastenniemi N (2008) Patient Relationship Management: An Overview and Study of a Follow-up System. *Journal of Healthcare Information Management* 22(3): 24–29.

PAPER III:
Oinas-Kukkonen H, Räisänen T, Leiviskä K, Seppänen M & Kallio M (2009) Physicians' User Experiences of Mobile Pharmacopoeias and Evidence-Based Medical Guidelines. *International Journal of Healthcare Information Systems and Informatics* 4(2): 57–68.

PAPER IV:
Räisänen T, Oinas-Kukkonen H, Leiviskä K, Seppänen M & Kallio M (2009) Managing Mobile Healthcare Knowledge: Physicians' Perceptions on Knowledge Creation and Reuse. In: Tan J & Olla P (eds) *Mobile Health Solutions for Biomedical Applications*: 111–127.

PAPER V:
Räisänen T (2009) Supporting the Sense-Making Processes of Web Users by Using a Proxy Server. Proc *42nd Annual Hawaii International Conference on Systems Sciences*, Waikoloa, Hawaii, IEEE Computer Society Press.

PAPER VI:
Räisänen T & Oinas-Kukkonen H (2010) Making Sense of Argumentation-based Knowledge: The Lost on the Moon Experiment. Proc *IADIS International Conference on Information Systems 2010 (IADIS-IS 2010)*, Porto, Portugal.

5.2 Observation phase

A multi-method approach was used in the observation phase. The reason for this is that complex social phenomena such as organizational knowledge creation "can be usefully understood through multiple methods of inquiry" (Rossman & Wilson 1994: 315). Thus, the observation phase combines both qualitative and quantitative methods.

The purpose of a multi-method approach has been defined as (Rossman & Wilson 1994, Greene *et al.* 1989): corroboration, elaboration, development, and initiation. Corroboration is "classical triangulation where different methods are employed to test the consistency of findings from one method to another" (Rossman & Wilson 1994: 319). It is expected to "pinpoint the values of a phenomenon more accurately by sighting in on it from different methodological viewpoints" (Brewer & Hunter 1989: 17). The second purpose of a multi-method approach is elaboration, which can provide new details that would often be lacking if just one method were employed (Rossman & Wilson 1994). The data from different sources can enhance, extend and even help interpret the data from one source. To achieve this, qualitative methods can be used to enrich the quantitative findings. For the purpose of development, multiple methods can be used to shape the subsequent method (Greene *et al.* 1989). For example, a qualitative study could provide findings that are used to generate a questionnaire for quantitative study. The final purpose is initiation. It "suggests alternative ways to pose the research questions, and generally challenge the original conceptual framework of the study" (Rossman & Wilson 1994: 323).

The reason that a multi-method approach was used in this dissertation was elaboration. By combining qualitative and quantitative data we could deepen the understanding on knowledge creation and the 7C model. This was necessary as the studies in the observation phase alone would not go deep enough into the knowledge creation phenomena.

In addition, the dissertation focused on the creation and utilization of knowledge. By combining multiple methods in the observation phase, the qualitative data could concentrate more on the creation of knowledge while the quantitative data could put special emphasis on the utilization of knowledge. More importantly, by analysing the results of the two methods we can see how the knowledge creation and utilization relate to each other. It is not enough to create new knowledge if it cannot be applied. Thus, the role of the usability of knowledge was emphasised.

A multi-method approach can be applied to research design or analysis (Rossman & Wilson 1994). In the observation phase, the multi-method approach was used in the analysis. But at the same time, as the results of this analysis work as inputs for the constructive phase of the dissertation, some elements of the multi-method approach for research design exist as well. The next chapter discusses the constructive phase.

The first data source in the observation phase (Paper II) was a qualitative case study conducted in a large hospital containing several different units. Yin (1981b) defines case study as:

- an empirical enquiry that examines a contemporary phenomenon in its real-life context, especially when
- the boundaries between phenomenon and context are not clearly evident.

Case study research can be positivist, interpretive, or critical (Myers 1997). In this dissertation, we used an interpretive approach. The overall goal of the case studies was not in-depth investigation but rather to gain some validation of the 7C model and to understand knowledge utilization better. The use of multiple cases could have provided more rigour by allowing replication and confirmation of the results (Yin 1981b). As we could not find several suitable cases, a single case was used. The data collection was done through interviews. The goal of the case study was to gain a deeper understanding of the 7C model and new knowledge on how different knowledge creation sub-processes can be supported. The case also provided evidence that supported the use of the 7C model to study knowledge creation and utilization.

The second data source (Papers III and IV) in the observation phase was a quantitative study of knowledge utilization in a virtual healthcare organization. The data collection was done using a questionnaire emailed to each member of the virtual organization. Quantitative analysis was then performed. The case was selected because the virtual organization utilized a mobile healthcare information system that supported physicians' knowledge utilization. This allowed us to study it in a real-life context and gain knowledge on what kind of knowledge and functionalities support both knowledge utilization and the 7C sub-processes (and thus knowledge creation).

Paper I identified technologies and solutions suitable for supporting knowledge creation on the Web. The observation phase (Papers II, III and IV) revealed how some of these solutions work, especially in the mobile context. In addition, a lack of support for comprehension and conceptualization was observed. Thus, the construction and experimental part of the research focused on finding ways to offer support for the comprehension and conceptualization sub-processes of knowledge creation.

5.3 Constructive phase

The constructive phase is a combination of design science and experimental research. The results of the observation phase were used as inputs for designing tools and research. The constructive phase consists of two studies where prototype tools supporting 7C knowledge creation sub-processes were implemented. The first study (Paper V) puts special emphasis on individual sense-making (*i.e.* comprehension in the 7C model) while the second (Paper VI) puts more emphasis on aspects of collaborative sense-making.

Natural science is aimed at understanding reality. It tries to explain how and why things are the way they are (March & Smith 1995). This is done by theories and models that explain parts of the reality. For example, the 7C model could be seen as a way of explaining how social collectives generate new knowledge.

Natural science is typically viewed as consisting of two activities: discovery and justification (Kaplan 1964). In discovery, the theories and models are created or proposed, and in justification they are being evaluated. As this dissertation relies on existing models, in particular the 7C model, discovery is not emphasised. In parts of this dissertation, justification for the 7C model (or parts of it) is offered. This justification also works as an input for the later parts of the research. The next section discusses the design part of the thesis.

Instead of trying to understand reality, design science attempts to create things that serve human purposes (March & Smith 1995).

Iivari (2007: 43) states that the "primary interest of Information Systems lies in IT applications." He identifies seven archetypes of IT applications. See table 6. Iivari states these seven archetypes are ideal and may not occur in practice in their purest form, and typically an IT application has several roles or functions. For example, a word processor is both a tool intended to augment text production and a tool that automates some aspects of text production such as spelling (Iivari 2007).

Table 6. Archetypes of IT applications (Iivari 2007).

Role/function	Metaphors	Examples
To automate	Processor	Many embedded systems Many transaction processing systems
To augment	Tool (proper)	Many personal productivity systems; computer aided design
To mediate	Medium	E-mail, instant messaging, chat rooms, blogs Electronic storage systems (*e.g.* CDs and DVDs)
To informate	Information source	Information systems proper
To entertain	Game	World of Warcraft
To artisticize	Piece of art	Computer art (*e.g.* ASCII art)
To accompany	Pet	Digital (virtual and robotic) pets

March and Smith (1995) also identified four design artifacts or outcomes and two design processes. The possible research outputs are constructs, models, methods and instantiations. Whereas natural science is interested in theorizing and justifying the research output, design science processes are focused on building and evaluating them. Thus we have the research framework displayed in Table 7.

The observation phase of this dissertation can be seen as justification of the 7C model, and the constructive phase as building and evaluating instantiations.

Table 7. Design science research framework.

	Build	Evaluate	Theorize	Justify
Constructs				
Models				X
Methods				
Instantiations	X	X		

Nunamaker *et al.* (1991: 89) state "that systems development and empirical research methodologies are complimentary to each other". They also define the following steps for a systems development research process: 1) Construct a conceptual framework, 2) develop a system architecture, 3) analyse and design the system, 4) build the prototype system, and 5) observe and evaluate the system. Finally, Hevner *et al.* (2004) provide us with seven guidelines on how to conduct design science research. These are displayed in Table 8 with a description and explanation of how this research tackles them.

Table 8. Design science research guidelines (adapted from Hevner *et al.* 2004).

Guideline	Description	Explanation
1. Design as an Artifact	Design science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.	Artifacts were produced in Papers I, V and VI; a system architecture in Paper I (close to a model), and instantiations in Paper V and Paper VI. The findings of Papers III and IV can also be interpreted as being parts of a method.
2. Problem relevance	The objective of design science research is to develop technology-based solutions to important and relevant business problems.	Knowledge management and in particular the Web and mobile environments are growing trends in both academia and business world.
3. Design evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.	Part of the architecture presented in Paper I is implemented in Papers V and VI, which are then evaluated interpretively (Paper V) and empirically (Paper VI).
4. Research contributions	Effective design science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.	Research gave us a deeper understanding of knowledge creation and utilization, and provided some viable ways to support it using IT tools. The findings are described in detail in the next chapter.

Guideline	Description	Explanation
5. Research rigor	Design science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.	In the building process we used W3C standards and programming tools (Java, Javascript, HTML). We used both qualitative and quantitative methods of analysis.
6. Design as a search process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.	Instantiations are implemented in Papers V and VI, which are then compared to find the best solutions.
7. Communication of research	Design science research must be presented effectively both to technology-oriented as well as management-oriented audiences.	The research is published in scientific forums (Paper I being more technical, while the others are more on the management side).

5.4 Evaluation and validation

In order to validate and evaluate the designs we used different approaches. In Paper II we also used an interpretive approach to gain insights into the knowledge creation processes. The main approach used was a positivistic approach which was used with both quantitative and qualitative data. Indeed, Orlikowski and Baroudi (1991) suggest that multiple approaches can provide new knowledge on the researched phenomena.

Information systems research is usually concerned with the "social processes surrounding the introduction, creation, use (…) of information technology" (Orlikowski & Baroudi 1991: 7). The focus in this dissertation is on the use of IT: How can organizations use Web- and mobile-based tools to create and utilize knowledge? In addition, Benbasat and Zmud (1999) claim that the relevance of IS research is directly related to its applicability in design. We try to structure our findings in such a way that this could be possible.

Chua (1986) has classified three assumptions that constitute the philosophical stances that researchers adopt towards the world. These are researchers' beliefs about: 1) physical and social reality, 2) knowledge, and 3) the relationship between theory and practice (Chua 1986). The next two chapters discuss these aspects for positivistic and interpretive approaches.

Positivistic approach and quantitative data

Positivism generally assumes that reality is objectively given and that it can be described by measurable properties which are independent of the researcher (Myers 1997). In the positivistic approach, the social and physical world are objective and exist independently of humans, and their nature "can be relatively unproblematically apprehended, characterized, and measured" (Orlikowski & Baroudi 1991: 9). Positivist studies also generally attempt to test a theory in order to increase the predictive understanding of the phenomena (Myers 1997).

Quantitative positivistic research uses statistics like T, F, and Chi-square tests to reject the null hypothesis. From a positivistic point of view, the objective of statistics employed by the quantitative positivistic research methods is to falsify the null hypothesis, which is based on the assumption that the data in the dependent variable are not affected by the data in the independent variable or variables (Straub *et al.* 2004). When the null hypothesis cannot be rejected, presumably the theoretical hypothesis is supported. Orlikowski and Baroudi (1991) classified IS research as positivist, if there was evidence of formal propositions, quantifiable measures of variables, hypothesis testing, and the drawing of inferences about a phenomenon from the sample to a stated population.

Quantitative positivistic research is the most commonly used approach in IS research (Kaplan & Duchon 1988, Schultze & Leidner 2002, Mbarika *et al.* 2005). In positivistic research, there is also the possibility of generalization and causal linkages (Lincoln & Gabe 1985). For example, results concerning a sample can sometimes be generalized into the whole population.

In positivistic research, the physical and social reality exists independently of humans, and its "nature can be relatively unproblematically apprehended, characterized, and measured" (Orlikowski & Baroudi 1991: 9). The role of the researcher is then to discover the objective physical and social reality by measuring and detecting those dimensions of reality that are of interest. With knowledge, the positivistic approach is concerned with the empirical testability of theories, and the relationship between theory and practice is primarily technical (Orlikowski & Baroudi 1991).

Exclusive reliance on the statistical testing of hypotheses has been criticized (Cook & Campbell 1979). Firstly, some researchers have argued that scientific knowledge cannot proceed by incremental gains achieved through the statistical significance testing of hypotheses (Kaplan & Duchon 1988). Secondly, controlling all possible variables is more difficult in natural settings that it is in controlled environments (Cook & Campbell 1979). And if researchers do try to control all possible variables "the simplification and abstraction needed for good experimental design can remove enough features from the subject of study that only obvious results are possible" (Kaplan & Duchon 1988: 572).

Thus, combining quantitative methods with qualitative methods has been proposed (Orlikowski & Baroudi 1991). This is generally done by, *e.g.* combining interviews and observations with a survey questionnaire (Kaplan & Duchon 1988).

Interpretive approach and qualitative data

With qualitative data, an interpretive approach was used. The interpretive approach was chosen in order to attempt to understand phenomena through the meanings that people assign to them (Myers 1994) with the aim of "producing an understanding of the context of the information system, and the process whereby the information system influences and is influenced by the context" (Walsham 1993: 4). In addition, as interpretive research does not predefine dependent and independent variables, but rather focuses on the full complexity of human sense-making as the situation emerges (Kaplan & Maxwell 1994), it seemed suitable for a study related to sense-making (Paper V).

The interpretive approach attempts to “understand the way others construe, conceptualize, and understand events, concepts, and categories, in part because these are assumed to influence individuals’ behaviour” (Kaplan & Duchon 1988: 572). The interpretive approach allows the researcher to immerse in the context in order to gain a deeper understanding of what actually is occurring.

Interpretive research assumes that reality is a social product and hence incapable of being understood independently of the social actors that construct and make sense of the reality (Orlikowski & Baroudi 1991). As for knowledge, understanding social reality requires understanding how practices and meanings are formed by the language and tacit norms shared by humans working towards some shared goal, and the relationship between theory and practice is that “the researcher can never assume a value-neutral stance, and is always implicated in the phenomena being studied” (Orlikowski & Baroudi 1991: 15). Kaplan and Duchon (1988) state that the positivistic and interpretive perspectives, when combined, provide added value to research.

6 Research contributions

The research question for this dissertation was stated as:

> *How can organizational knowledge creation and utilization be supported using Web 2.0 and mobile tools?*

The research question is answered in the six papers of the dissertation.

6.1 Published papers

The contributions of the papers are summarized in the following sections.

6.1.1 Paper I: A System Architecture for the 7C Knowledge Environment

This dissertation process started with the aim of defining a system architecture for the 7C knowledge environment. The architecture was divided into three layers: conceptual layer, technology layer and applications layer. As comprehension and conceptualization were identified as the sub-processes that have received the least attention in research literature, special emphasis was put on them.

Knowledge and how it is represented is crucial for any knowledge creation model. Paper I proposed that for the 7C architecture, the rationale behind knowledge, *i.e.* the knowledge rationale, should be treated as equally important as the knowledge itself. This means that any produced concept of knowledge is stored with argumentation for it. In the 7C model, the knowledge rationale is embedded in the comprehension, communication, conceptualization, and collaboration sub-processes. Each of these may produce new artifacts and new knowledge. For example, in conceptualization, the produced concepts can be seen as explicit knowledge in the form of proposals, specifications, descriptions, work breakdown structure, *etc.* and the rationale behind the knowledge. The knowledge rationale is at the very heart of 7C architecture, and all of the processes deal with it in one way or the other.

The interaction capabilities provided by hypertext functionality are also important for the 7C model. They provide the means for "surveying and interacting with the external environment, integrating (...) intelligence (...), identify problems, needs and opportunities" (Oinas-Kukkonen 2004: 5). Without the ability to interact with knowledge objects we lose some of the ability to "learn by doing" and re-experiencing (Oinas-Kukkonen 2004). As such, the hypertext functionality is very important for the comprehension. To allow the users to truly interact with the existing knowledge, hypertext must be provided in a richer way than with static web pages or even dynamic web pages (*i.e.* web pages are created according to the users' actions). The users should be able to edit, comment, link and create the web pages as they see fit. With this kind of functionality we may facilitate the comprehension even further.

Hypertext functionality is useful for conceptualization and collaboration, too. We can use linking and annotation to help the use of metaphors, for example. As another example, a structure-based query can support the knowledge rationale. As knowledge is saved with its reasoning, a knowledge-based search is not enough: there also has to be the capability to investigate the rationale. Annotations (Bieber *et al.* 1997) attached to knowledge can be used as the rationale. In collaboration, we can interact with the produced concepts to perform the work at hand and use them in teamwork (Oinas-Kukkonen 2004).

The concurrent connection is realized through the concept of a mobile aware Web information system (Oinas-Kukkonen 1999). A mobile aware Web information system (MAWIS) is a Web information system that has been designed for potential use through wireless interfaces. A wireless interface refers to different mobile devices such as PDA's, mobile phones, etc. With the concept of MAWIS, we can improve the connectivity as well as the number of concurrent users. In doing this, the separation of content from its presentation becomes essential.

In the technology layer, Web 2.0 technologies were identified to suit the requirements of the 7C model well. The reason for this is that one core competency of Web 2.0 is to harness the collective intelligence (O'Reilly 2005). As new knowledge can emerge from the interaction among people, Web 2.0 was seen as a more natural way to support it than, *e.g.* Semantic Web. Nevertheless, Semantic Web could help users find knowledge they are looking for.

Tagging and metadata were identified as important for the 7C model, especially as tagging provides a way to associate bits of information together. This could support comprehension. AJAX (Asynchronous Javascript and XML) was another key technology, as it allows for much deeper interaction with information and knowledge than static or dynamic web pages would. Perhaps quite naturally, wikis and blogs were also identified as means to support the needs of the 7C model. Communication technologies would also be useful, and to utilize the knowledge rationale, the Question-Answer-aRgumentation structure of the QAR-method was identified as a way to capture argumentation.

The key concepts and technologies recognized implicitly suggest a set of tools to be used with the 7C model. A wiki was identified to be suitable as a knowledge repository. It allows knowledge to be stored and retrieved, and it should enable removing unnecessary or gratuitous knowledge, when seen fit. A wiki would also work as a virtual place for collaboration.

Users also need the capability to write down their own thoughts and ideas about different knowledge objects. This may be done with a tool such as a blog. Blog entries should be able to link with anything within the system. Writing and reading blog entries may facilitate communication, in particular when users comment on other users' blog entries.

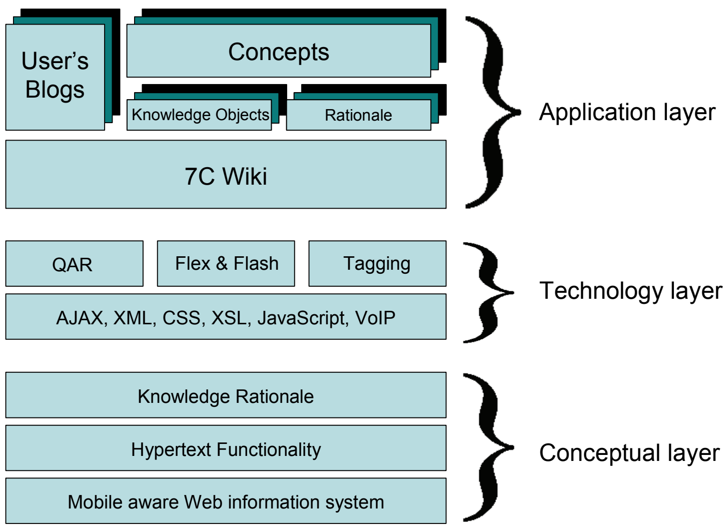

Fig. 10. 7C Information System architecture.

The suggested 7C knowledge architecture can be seen in Figure 10. In its simplest form, the 7C environment is a wiki that consists of users' blogs and concepts produced as knowledge rationale. Users blog for communication purposes. To further facilitate real-time communication additional tools, such VoIP-based tools, may be implemented.

Blogs can also support comprehension as the users may write down their thoughts and ideas. Yet, most of the comprehension support is provided by browsing, searching and categorizing the concepts. Tagging is a key technology for comprehension, as it enables associative links between the concepts. Comprehension is also supported by allowing users to read the rationale behind knowledge objects. Conceptualization is supported through a wiki, where users collectively debate (argue) over the produced knowledge objects using QAR. The wiki also works as a vehicle for collaboration.

Table 9 presents the key 7C sub-processes and how they are supported by the 7C Knowledge Environment.

Table 9. Support of the proposed architecture for the subprocesses of the 7C model.

7 Cs	How they are supported
Connection	The system is designed as a mobile aware Web information system.
Concurrency	The wiki handles concurrency control. Mobile access improves the chances for concurrent users.
Comprehension	The users can interact with the knowledge and arguments stored in the environment, *e.g.* by editing, linking (including tagging), commenting on, and combining existing knowledge.
Communication	Users can blog to communicate about their experiences and to read other users' experiences.
Conceptualization	The users can use QAR to argue for and against a question to define the explicit concepts in the form of knowledge rationale.
Collaboration	The 7C Wiki can be used as a platform for collaboration, where users divide the work among them and use the produced conceptualizations to perform collaborative knowledge work.
Collective intelligence	All the created knowledge is stored in the environment and it can be retrieved whenever needed, *e.g.* in the collaboration process.

In sum, the paper identified Web 2.0 technologies to be suited for supporting knowledge creation. For the 7C model, the most crucial parts are the comprehension and conceptualization sub-processes. In the future, special emphasis should be put on implementing and testing tools supporting these sub-processes. In addition, the capture of the knowledge rationale through the QAR-method should be investigated.

6.1.2 Paper II: Patient Relationship Management - An Overview and Study of a Follow-Up System

Paper II focused on the 7C model of knowledge creation. We wanted to study both how the model works in healthcare settings and what kind of tools, information and knowledge would support the sub-processes. In the paper, a patient follow-up system's effect on the knowledge work of physicians was investigated. The results seem to indicate that the follow-up system supports the knowledge work performed by the physicians. The system seemed to support physicians' comprehension mainly in issues related to patient/treatment information (*e.g.* patient satisfaction, wound inflammations), self-awareness, and the patient care process (*e.g.* why a patient had to wait for a long time in certain parts of the process). Physicians also felt that with a follow-up application, they may understand the actual patient care process at their hospital better.

The follow-up system can support comprehension by allowing the physicians to understand which treatments have worked with certain symptoms or diseases. The physicians felt that it is important to gain deeper insight on patient satisfaction after a patient's release from the hospital. The physician may acquire quantitative evidence about his/her skills which may help him/her become a better physician in the clinical setting. This information may also help a physician's self-awareness. A physician may think and reflect upon the treatments and operations (s)he assigned and/or performed for a patient, and even self-question whether (s)he had made the right diagnosis in the first place.

Communication between medical staff was also improved through the follow-up system. There seemed to have been more communication between the medical staff through the application and the communication had been clearer. Communication between medical staff and the patients was also improved through the application. The patients who had already been sent home could provide feedback for physicians on how the treatments had really worked on them.

Most of the communication that was increased "… has been one-way, from them to us," *i.e.* from patients to the medical staff. The physicians felt that they can gain new insights from patients to carry out their work. Yet, a follow-up system could also improve communication towards patients. For example, "we can explain [better] to patients, what is part of the treatment and what is not. (...) When all goes normal, the patient does not need a control visit".

The functionalities of the system do not seem to support conceptualization. Yet, the information provided by the system does seem to offer some support. This seemed to be so especially at the unit level. The system could help medical units discuss and reach a consensus on issues related to the unit's tasks and also on issues related to other units. For example, one interviewee said that a kind of shared understanding on nosocomial infections was achieved by a hospital unit.

The follow-up system seemed to support understanding and it could also allow users from different specialties to make decisions on various measurements and treatments (*e.g.* what measurements are needed and when to take them). Decisions like this seem to require a consensus between a few members participating in the decision-making, which is central in the conceptualization efforts.

Hospitals are very hectic places, as there can be many things happening all the time, and physicians have to deal with vast amounts of information every day. The follow-up system provided a way to handle some of this information (*i.e.* feedback) better. However, introducing a new system means extra work – at least in the early stages when people are still learning how to use the system - which can be a hindrance.

The case system also improved collaboration to some extent. While the main benefits for collaboration come through improved communication (the staff can, *e.g.* coordinate their work better), some direct support for collaboration was also found. For example, meetings where feedback and improvements of the treatment processes were discussed were easier to conduct. Some of the collaboration was perceived as being negative. Especially in the early parts of system adoption, there was a lot of collaboration that concentrated on getting the system to work.

The system also affected the collective intelligence of the physicians' working community. This seemed to be especially true among nurses, as the information was more useful for them than for the physicians. The nurses seemed to have understood many issues better through the system and become "more prepared" for carrying out their tasks. The hospital unit was also able to concentrate on those patients who need the care the most.

A follow-up system is designed to improve the relationships between hospital staff and the patients. It can also help to track down how the treatments are working. Thus, it is essential that the communication between patients and the staff is working as the information (*i.e.* are they satisfied, are there any setbacks) comes from the patients. This information helps hospital staff better understand the patients and how the treatments are working. The feedback seems to be a good source for improvements in the hospital's collective intelligence. Due to the fact that hospitals are able to store the feedback they get, they can compare how user satisfaction as well as the overall performance of the hospital has developed over time. Table 10 summarizes benefits of the system.

Table 10. The main benefits of the follow-up system.

7C sub-process	Main benefits
Comprehension	1. Patient/treatment information
	2. Self-awareness
	3. Patient care process
Communication	1. Feedback from patients
	2. Improved communication within medical staff
Conceptualization	1. Improved at the unit level
	2. Between specialties
Collaboration	1. Improved between management and units
Collective intelligence	1. Nurses “more prepared”
	2. Concentrate work on patients that have the biggest need for treatment

In more general terms, a physician working in a management position expressed the main reason for using the system: “Actually nothing else than better treatment [for the patients] may be the final target.” Another physician stated that the system was used to “help understand sick leave reasons, how our treatment affects patients and whether we are able to reduce complications”. With a non-PRM application, it can be difficult to pinpoint the reasons behind sick leaves. For example, reoccurring sick leaves may be a symptom of something else besides what was originally treated. A follow-up system can indicate this to physicians and they may try to find the real cause of the problems. The system can also reveal some complications that might otherwise stay unrevealed. In one unit, the system was mainly used to figure out “what kinds of troubles patients undergo after the treatment and how big the risk for complications is”. One of the units utilized the system to express to the patients what kind of harm they may encounter after a specific treatment process.

The follow-up treatment system seems to be a tool to create and maintain better communication with the patients, rather than just a technological solution. It may help the users to better understand and analyze both individual patients and patient groups. For individual physicians, it provides a way to reflect on their professional skills. In a way it allows the kind of reflection-in-action that leads to learning-by-doing. As users use the system and perform their work, they will accumulate evidence on their performance. This evidence can be used to reflect on and improve the skills of the user.

6.1.3 Paper III: Physicians' User Experiences of Mobile Pharmacopoeias and Evidence-Based Medical Guidelines

While Paper I focused on the concepts of Web 2.0, and Paper II focused on the 7C model, Papers III and IV put special emphasis on the mobile context and the usability of knowledge. Paper III studied physicians' mobile user experiences with evidence-based medical guidelines and drug information databases with the concept of flow as the research vehicle. Data was collected from 352 members of a virtual organization who all used a mobile medical application. The hypotheses of the study are in Table 11.

Table 11. The hypotheses of the study.

Hypotheses	Description
H1	The higher the perceived learning, the higher the webflow.
H2	The higher the perceived focused attention, the higher the webflow.
H3	The higher the perceived skills of the user, the higher the webflow.
H4	The higher the perceived feeling of control, the higher the webflow.
H5	The higher the perceived challenges, the higher the webflow.
H6	The higher the perceived ease-of-use of the system, the higher the webflow.
H7	The higher the perceived usefulness of the system, the higher the webflow.
H8	The higher the perceived orientation, the higher the webflow.
H9	The higher the perceived navigation, the higher the webflow.

The results provide some support for the claim that mobile applications may not only be beneficial for patient safety but for improving the professional skills of the physicians as well. The use of the system improves physicians' computer skills as well as the feeling of being in control of system use and the perceived ease of use. These may help, at least to some extent, in navigation and orientation, which will make it easier to find relevant knowledge and information. Finding the relevant pieces of knowledge is crucial for utilization. Balanced orientation and navigation within the system and a feeling of being challenged have a direct effect on webflow, *i.e.* gaining an optimal user experience. Surprisingly, ease of use and usefulness did not have a direct effect on user experience. Figure 11 displays the supported hypotheses, *i.e.* the prerequisites for a positive user experience.

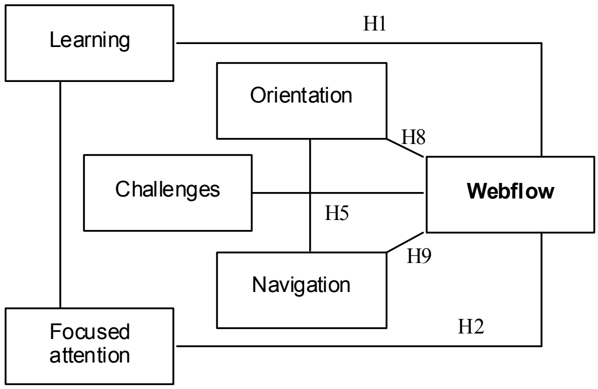

Fig. 11. The prerequisites of a positive user experience.

Learning seemed to correlate strongly with webflow. The reason for this might be that the knowledge work of physicians is mainly cognitive. It is related to areas such as diagnosing and making decisions over treatments or medication. Physicians use multiple different kinds of information systems for fulfilling these tasks and they seek support and evidence for their reasoning. Thus, ease-of-use per se is not a virtue. More importantly, the information provided by the system has to be helpful. The optimal user experience is closely related to such information that actually helps the physicians perform their job better. In other words, information that helps the physician to learn is new and potentially helpful.

Finding relevant pieces of knowledge becomes essential. This also implies that within the knowledge work context, learning may play a greater role for creation of the overall user experience than is often suggested. For using the knowledge, relevancy is also a key issue. The use of evidence-based medical guidelines and drug interaction guides increased the perception of both webflow and learning.

The Acute Care Guide was perceived as highly useful and its usage also improved learning. This may be explained by the critical role that it may play in emergencies. The knowledge it provides may sometimes save lives. Even if the Acute Care Guide improved learning, it did not affect webflow. Perhaps the nature of acute medical situations is different from situations where evidence-based guidelines or drug interaction information are needed. Even if physicians learn more deeply what to do in specific emergency situations, they do not necessarily have the time to reflect on their actions in those situations. Thus, the user experience in acute situations may not always be as enjoyable as it may be in a more peaceful setting. Table 12 displays the different parts of the system under study as well as their impact on the user experience (the Drug Information Database is excluded from the Table as results concerning it are inconclusive). In Table 12, ** denotes a p-value smaller than 0.01, and * denotes a p-value smaller than 0.05.

Table 12. Different databases and their effect on the user experience.

Prerequisites and webflow Database	Lear-ning	Focused attention	Skills	Chal-lenges	Control	Ease of use	Useful-ness	Orient-ation	Navi-gation	Web-flow
-Evidence-Based Medical Guidelines	**	**	*						*	**
-ICD-10 Classification			*		*				*	
-Acute Care Guide	**						**	*		
-Drug Interactions	**						*		*	**
-Medical Pictures	*		*			*				
-Contact Information			**	*						

Previous research has shown that learning is a consequence of flow, *i.e.* people who perceive flow have better learning outcomes than people who do not perceive flow (*cf.* Hoffman & Novak 1996, Choi *et al.* 2007). The findings in this research point out that the interplay between webflow and learning truly is crucial in the knowledge work context. When a knowledge worker learns, (s)he perceives webflow, and when (s)he perceives webflow, (s)he learns. Webflow seems to have a dual role both as a consequence and as an antecedent.

This finding also seems to imply that the traditional causal models of flow do not capture the dynamic nature of the phenomenon well. Most of the current flow models regard flow as a state which occurs when certain conditions are met. In contradiction to this, Pearce and Howard (2004) have demonstrated that flow may change rapidly during computer-human interaction. It could indeed be that a physician who has used the system continuously for some time will slowly “fall out” of flow if (s)he does not have some additional stimuli to keep him/her in flow. Our findings suggest that learning could be that kind of a stimulus.

Summarizing, the results demonstrate that instead of usefulness and ease of use, it is the orientation and navigation within the system in par with perceived challenges, focused attention, and learning that led to a positive user experience. Finding relevant pieces of information becomes essential in the utilization of the system. Frequent use was noted to improve physicians’ computer skills, the feeling of being in control of the system, and their perception of the system’s ease of use. Moreover, learning may play a greater role for knowledge work than is often suggested.

6.1.4 Paper IV: Managing Mobile Healthcare Knowledge: Physicians’ Perceptions on Knowledge Creation and Reuse

In paper IV, physicians’ usage of a mobile system is analysed through a knowledge management framework known as the 7C model. The study was conducted in a virtual healthcare organization. The members of the organization are all healthcare professionals. The data was collected through the Internet from all the 352 users of the mobile system.

The four Cs of the knowledge creation spiral correlated with each other strongly. Interestingly, the highest correlations were between comprehension and communication, *i.e.* the individual side of the model, and conceptualization and collaboration, *i.e.* the social side of the model. This supports the individual-social dichotomy in the knowledge creation model. The next strongest correlations were between communication and conceptualization, comprehension and conceptualization, and communication and collaboration while the lowest correlation was between comprehension and collaboration.

To investigate the knowledge creation spiral, a sum variable was constructed, representing the comprehension, communication, conceptualization and collaboration sub-processes (referred to later simply as the “sum variable”). We used the sum approach, as each of the 7C sub-processes may be treated as equally important. Since five responses had one or more missing data items related to these sub-processes, the missing data were replaced by means from similar respondents. The sum variable has a high reliability and it correlates strongly with collective intelligence. This seems to indicate that the interplay among the four Cs, *i.e.* the spiral, indeed leads to the growth of collective intelligence.

A comparison between those who used the system daily and those who used it less frequently indicates that daily use improves all knowledge creation sub-processes as well as the sum variable. This seems to indicate that it actually helps physicians to perform their jobs better and it may eventually increase the collective intelligence of the whole work community. This is an important finding and provides some empirical evidence for the usefulness of mobile information systems in healthcare in general. Thus, a mobile healthcare information system would be of benefit not only for patient safety (Honeybourne *et al.* 2006) but for the professional skills of the physicians as well.

From the five Cs addressed in this study, comprehension was improved by the use of the Acute Care Guide and the Drug Interaction Database. The Acute Care Guide was used slightly more often by the less experienced physicians. Quite obviously, the less experienced physicians still have more to learn and comprehend. Maybe this is especially true in acute medical situations. The fact that the Drug Interaction Database improves comprehension seems feasible too, since there exists such a large number of different drugs and their combinations that it is practically impossible to know all of their interactions. Thus, an easy way of checking these interactions should indeed help physicians, and over time they may comprehend something new. Interestingly, EBMGs did not affect comprehension. This might be because most of the physicians were experienced and thus familiar with the guideline information. On the other hand, most of the users had specialized in certain medical domains, which implies that their knowledge needs might have been more specialized than what is provided through the evidence-based medical guidelines.

Communication was improved by the EBMGs and the Acute Care Guide, which are both well-structured (meaning that each guide follows the same structure) and evidence-based. Thus, they contain guideline information that is relatively easy to deliver. For example, all guidelines in the Acute Care Guide are organized in the same format, *i.e.* pathogenesis, causes, symptoms and differential diagnosis.

Conceptualization was improved by the EBMGs, the Acute Care Guide and the Drug Interaction Database. Indeed, evidence-based information may help a group of physicians reach a consensus in making medical decisions.

Collaboration was improved by the EMBGs, the Acute Care Guide, the Drug Interaction Database and Contact Information. It seems natural that guidelines help physicians to collaborate. Similarly, providing Contact Information helps find the right people.

Collective Intelligence was improved by ICD-10, the Acute Care Guide and Drug Interactions. Interestingly, the specialists used ICD-10 more than the general practitioners. This could mean that specialists have a greater need for ICD-10 than the general practitioners, but as such it does not explain why the use of ICD-10 improves collective intelligence. One reason for this could be that hospitals are very bureaucratic by nature, and these classifications of diseases are needed in many situations, *e.g.* when a patient checks in, when a patient's treatments are entered into hospital records, or when a patient is discharged. The use of a mobile ICD-10 application can provide practical support in these situations. See Table 13 for a summary (the Drug Information Database is excluded from the Table as results concerning it are inconclusive).

Table 13. Usage of the different parts of the system and their impact on the 7C processes.

Duodecim database	Collective intelligence	Compre-hension	Communi-cation	Concept-ualization	Collabo-ration	Sum variable
-Acute Care Guide	X	X	X	X	X	X
-Drug Interactions	X	X		X	X	X
-Evidence-Based Medical Guidelines			X	X	X	X
-Contact Information					X	X
-ICD-10 Classification	X					X
-Medical Picture Database						X

Of the different subsystems, the Acute Care Guide improved all knowledge creation sub-processes. Mobile applications such as the Acute Care Guide combine the "anytime, anywhere" possibilities of mobile applications with actual needs in acute medical situations, where knowledge must be acquired and applied swiftly. Thus, instead of concentrating on anytime and anywhere mobile applications in a knowledge work context, we might need to concentrate more on the exact situations where the knowledge is needed, *e.g.* in healthcare at the point of care.

Of the other subsystems, Evidence-Based Medical Guidelines and Drug Interactions seem to support the knowledge creation sub-processes to a greater extent. Overall, guideline information seems to provide a good fit with knowledge creation. Guidelines contain information about diagnostic procedures that may be used with certain symptoms as well as suggestions for which drugs might work best for different illnesses. Physicians may also find them helpful when consulting other physicians, as the guideline information may provide a basis for communicating and collaborating. A general practitioner may first check the information found in the mobile HIS, for example, and then use it as a reference when consulting a specialist.

As a summary, frequent use of the system seemed to improve individual physicians' knowledge work as well as the collective intelligence of the work community. The guide for acute care, evidence-based medicine guidelines and information related to drug interactions supported the knowledge creation to a large extent. Mobile healthcare information systems may be capable of supporting the different sub-processes of knowledge creation and the knowledge work of individual physicians, and through this also improve the collective intelligence of the work community. The easiest sub-process to support through the system seemed to be collaboration between the physicians. Comprehension and, quite surprisingly, communication were the most difficult aspects to support. All parts of the case system helped improve the knowledge creation spiral.

These findings go hand in hand with some of the previous findings on the usefulness of healthcare information systems, especially in acute medical situations where decisions have to be made swiftly. The findings also hint that the daily use of such a system may indeed over time be of benefit, not only for patient safety, but for the professional skills of the physicians as well. Overall, knowledge management seems to be a prominent approach for studying healthcare information systems and their impact on the work of physicians.

6.1.5 Paper V: Supporting the Sense-Making Processes of Web Users by Using a Proxy Server

The constructive part of the dissertation focused on Web 2.0 even though the proposed solutions were designed with the potential mobile use in mind. Paper V presented a study on how we can support knowledge creation and reuse in a Web 2.0 environment. Particular emphasis was on the comprehension sub-process.

The problem with supporting comprehension is that there is no single right way to make sense or comprehend. Thus, providing solutions that work every time is difficult. A suitable solution should be extendable to fit different learning styles. The concurrent connection required by the 7C model also means that, *e.g.* browser plug-ins are not the best solution. Thus, the study proposes that a proxy server is a viable way to provide new functionalities to users of existing Web services. To demonstrate the solution, three example tools were implemented into the system. The first two tools experimented with enriching user interaction capabilities – in the form of annotation – with the existing knowledge. The ability to annotate has been considered a basic tool for collaboration and the exchange of ideas. The last tool utilized the concept of flow. More precisely, it aimed at allowing users to stay in flow, *i.e.* to not disturb them if they perceived flow. The tool provided enhanced translation functionality to the users (in short the tool translated every word that the user double-clicked). Using a proxy-server the tools were added to Wikipedia, which was used as a knowledge repository.

The study was conducted among six foreign visitors of an American university. They all used the system for fifteen minutes while the authors observed, after which interviews lasting another fifteen minutes were conducted. The aim of the study was to evaluate the proxy server solution and the tools as a way to enhance the sense-making possibilities of users. Figure 12 displays a high-level description of the solution.

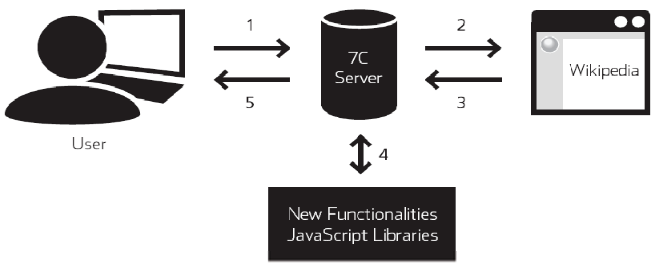

Fig. 12. High-level description of the framework.

The first result of the study was that the proof-of-concept implementation of the system works. It is quite simple to include new JavaScript code in the 7C server and enhance the functionalities of Wikipedia, or any other Web service that uses normal W3C standards. Problems can arise when we try to include new functionalities in a service that is mostly scripting based (*e.g.* Facebook, www.facebook.com).

The users' impressions of the translation tool were that it is great. One of the main benefits seemed to be its speed. There is no need to copy and paste the word to a separate translator. As the content of Wikipedia is mostly text-based, the translation service was seen as a great addition to it. Quite naturally, it works best with non-native English speakers. Maybe more importantly, it might be the simplicity of the tool that provides the best benefits. In addition, double-clicking seemed to be a natural way of "doing things" on the Web.

One participant also indicated that the double-click translation might not disturb flow. If indeed this is so, this could indicate that the translation tool causes less distraction and would not reduce the user's chances of flow, which should help in comprehension.

There were a few possible problems, especially when the literal translation of the word is not the same as the meaning in which it is used in the context of the article. However, allowing the user to stay in the Wikipedia article while translating the word might indeed help him to understand the context – and thus the article - better. He can see the sentence and the translation on the same page. He can then translate the whole sentence and continue reading the article. Sometimes the words might be too difficult, so that even a translation does not work. This happened when one of the participants tried the system with medical Wikipedia articles. Maybe the system should show the definition of the word as well or offer a link to some service providing definitions.

Participants were used to annotating papers that they read. They also felt having the ability annotate Wikipedia would be useful. Writing annotations could help users as they have to think about what they write. In a way, the annotations could be used to store new ideas and the articles the annotations are attached to could provide the context. This ability to link user annotations to the article probably supports comprehension or at least remembering what the annotations were for.

Perhaps more useful than writing would be the ability to read annotations that the user himself or someone else had written. Having someone else's annotations would speed up reading the article. However, if the annotations were from someone whom the reader did not know, it might cause trouble. For example, a programmer might not gain the best benefits from comments made by a healthcare professional. So, sharing annotations with colleagues could be more useful than sharing annotations with strangers.

Highlights helped people to re-read articles. This speeds up remembering articles read previously. It probably also allows users to recall things. Users also indicated that many benefits of the annotations also apply to highlights. For example, the ability to share highlights would be great.

Seeing what others have highlighted would allow participants to understand each other. On the other hand, they can also disturb the users, especially if the other user's highlights would differ greatly from one's own. Thus, there should be a way to hide the highlights. In any case, highlights could indirectly help communication and conceptualization, if users knew the things they had highlighted differently, *e.g.* why somebody sees some part of the text as important and someone else another part.

All of the participants said that annotation and highlight services could help them. It was not always so clear if or how they actually improved comprehension. The participants did feel that they could help but as they did not use the system in real situations, they could not be sure how.

The integration of our solution worked well with Wikipedia and it should work well with most existing web pages that follow W3C standards. However, there can be some problems with certain web pages, *e.g.* those that are mostly scripting based or rely heavily on Flash. Some possible drawbacks of this solution are:

- If someone in Wikipedia changes something, we can lose some relevant information (*i.e.* a note is linked to a specific point in the Wikipedia article, and if that point is changed, we link to the wrong place).
- Download time is increased (connection goes through a proxy server).

With fast connections, download time is not a big issue. However, if we use the system with a mobile device, the increase in download time could be crucial as download times are already longer with mobile devices. To tackle the first drawback, the annotations and highlights must be attached to certain versions of the article. This way when someone, for example, deletes a sentence we have highlighted, we can still find the highlight in the previous versions of the article. Still, keeping annotations and highlights up to date can be a challenge. For example, do users have to transfer the annotations manually from older versions of the article to a new one?

In addition to these drawbacks, using a proxy server might also disturb the actual knowledge creation that happens within Wikipedia. Those users who did not use Wikipedia through the proxy would not see the annotations made by other users. However, if the proxy users comprehended something they could probably better contribute to Wikipedia articles. However, if some new tool were especially beneficial it could always be implemented as part of Wikipedia, too.

In summary, the contribution of this paper is twofold. Firstly, a framework for providing new functionalities is presented. Secondly, a prototype Web service is implemented and evaluated. The prototype uses Wikipedia as an example and as a knowledge repository. The emphasis was on the prototype, a service that allows users to 1) insert sticky notes in Wikipedia articles, 2) enhance the translation capabilities of Wikipedia, and 3) highlight texts in Wikipedia. The analysis of the prototype service showed that we can provide new functionalities to Web users with a proxy server and that the implemented tools offer some support for the knowledge creation process called comprehension.

6.1.6 Paper VI: Making Sense of Argumentation-based Knowledge: The Lost on the Moon Experiment

Paper VI presented a study on how to support the sense-making of argumentation-based knowledge by contemporary Web users. The paper used the QAR-method to capture the rationale. In previous research, Buckingham Shum (1996) has analyzed the usability of a design rationale notation and he found out that the users must learn to manage four interleaving cognitive tasks. These are (Buckingham Shum 1996): unbundling, classification, naming, and structuring. So, in order for a user to produce valid argumentation, he has to learn the above mentioned tasks. And to make matters even more difficult, the reverse is usually true when the rationale is to be used. The idea has to be bundled again into explicit form so that it can be applied to the problem at hand.

In this paper, we exposed the participants to argumentation-based knowledge after which we compared their answers to find out the similarities in them. This worked relatively well, as we have explicit answers from each participant and can measure how much they differ in each group. In a way, we measure if each individual has understood the knowledge they were exposed to in the same way, and whether specific functionalities affect this understanding.

We used a Lost on the Moon experiment in the study. In the experiment, users have to rank 15 items in order of importance in a crash landing on the moon. After the users had ranked the items, they were exposed to argumentation that tried to argue for a certain ranking. After this treatment, the users ranked the items again. In an ideal case, each member would answer in exactly the same way (for example, each member would rank matches as 15th). For this reason, we will measure the shared understanding within the group by calculating the variance of the group's answers. The more variance there is in the answers, the worse the shared understanding within the group. For testing this, we will use tests for equality of variance (Levene 1960). We divided the participants into four groups: a control group and three experimental groups. The groups are displayed in Table 14.

Table 14. Different versions and their descriptions.

Version	Description
Control	Displays only the argumentation
Experiment A	Displays the argumentation and the mean of the answers
Experiment B	Displays the argumentation and the voting information
Experiment C	Displays the argumentation with one argument against one answer

All of the experimental versions did manage to produce smaller variances than the control version. Experimental version A seemed to have the biggest effect, followed by B and C. While the standard Levene's test shows a much greater reduction of variances, the modified test is stricter in this sense. By combining both tests, we can conclude that there are small improvements with some of the items. These seem to exist items that are not easy to rank; in other words they are more open for debate. However, this is not always the case as there can also be an increase in the variance.

Experimental version A displayed the mean of the answers for the participants. The success of this experimental version is consistent with the ease-of-use habits of Web 2.0 users: the easier it is to do something, the more likely it is that users will do it. In this case, the participants could see what other people had answered (on average) and they could easily copy that answer. To confirm this, we could implement an even more persuasive version of the experiment. For example, we could say to the users "Others have answered xx to this question so maybe you should too." This way users' cognitive work could be reduced as the "social proof" would allow them to just copy what others have answered. However, this would somewhat defeat the point of creating a space for arguments and consensus. Thus, a balance between how much we can influence the users and how much work is required from them should be found.

Experimental version B allowed the users to vote for and against the arguments. This seems to work well in the Web 2.0 communities as only a handful of users will actually produce content, but many more of them are likely to click the plus or minus buttons to vote. It should be also noted that this is information about the content. There might be something in the content receiving a lot of plus votes worth reading, whereas content receiving a lot of minus votes might be ignored.

The third version displayed some extra information in the form of a counter-argument. The argument for an answer that was present in the other versions was placed in juxtaposition to another answer. This version did reasonably well in reducing the variance, and it performed well when comparing the answers to NASA rankings. At the same time, to some extent this version points out the possible problems with argumentation and with other Web applications that are not so easy to use. Nobody was willing to use the arguments against – even if they would improve performance. Persuasive system design (Oinas-Kukkonen & Harjumaa 2009) could help with this. For example, the system could utilize various primary task and social support principles to get users to contribute.

We compared each group's answers to NASA's expert ranking of the items. In the control version, participants had an average of 32 error points (*i.e.* if an item should have been ranked 5th and it was ranked 6th, the participant would get one error point). The results showed that the experimental versions did not improve the overall performance of the participants. The experimental groups did have fewer errors than the control group, but the difference was not statistically significant.

The experimental version that did worst in terms of errors was the one displaying the means, while the other two versions were equal in their error points. This seems logical, as the first version did not provide any new knowledge to the users, whereas the other two versions did: Version two provided the voting information and version three provided the extra arguments against some of the answers.

We also conducted usability tests and compared the answers from the control group to the experiment versions. The users of experimental version A perceived that they did not comprehend or learn by using the system as much as the control group. If they answered according to the mean information displayed to them, this seems logical. Instead of thinking by themselves, they may have just copied what the group had answered. Thus, they would not have learned much. The users of version B perceived that the system did not support communication or orientation as much as the control version. This experimental version allowed users to vote on the arguments. Perhaps this made the lack of communication between the users more explicit than in the control version. No logical explanation of why orientation was not supported was found. The users of version C perceived that they learned less than the users of the control version. This might relate to the fact that many users felt that the usage of arguments against an answer was difficult.

The new functionalities seemed to make the system perform a little better in terms of the users' results. But quite surprisingly, they also made the users perceive the system as being worse than the control version. This might relate to the importance of ease-of-use. Even if the new functionalities do make the system perform better, users might perceive it as being worse due to the new functionalities requiring more effort from them. In other words, the new functionalities can increase relevant cognitive costs, *e.g.* when a user had to think how to define compelling arguments and how to separate arguments from the answers. Even if many system features were beneficial, they may actually reduce use of the system. There seems to be a heavy emphasis on ease-of-use in the era of Web 2.0.

This could indicate that perhaps better sense-making for contemporary Web users does not come through functionalities supporting deeper thinking (*i.e.* from solutions requiring high understanding costs) but rather from low-cost and easy to use solutions (such as versions A and B in this study). It could be the constant exposure to the content, *i.e.* repeated usage of the system, that could trigger sense-making. And for users to use a system repeatedly, the system must be very easy to use. This is indeed at the core of the Web 2.0 phenomenon. Such solutions could also better take advantage of the wisdom of crowds (Surowiecki 2004) principles, as easy to use solutions are more likely to gain larger user populations than high-cost solutions requiring deep thinking. Confirming this will require more research, though.

As a conclusion, the results indicate that sense-making can be improved at least in some issues, such as for those items that are more open to debate in the Lost on the Moon exercise. Sense-making was improved to some extent in all of the different experimental versions. By comparing the actual answers with a post-experiment questionnaire, we found out that the versions that were most useful were not perceived as useful. This may be related to one of the core ideas behind Web 2.0, namely the ease-of-use. For example in Web 2.0 learning applications, ease-of-use has been identified as absolutely necessary (Ebner *et al.* 2007). The same might be true of knowledge creation, too This could also suggests that rather than building tools that require deep thinking, it might be the easy to use and simple solutions that are more suited to support the creation of new knowledge in

Web 2.0. In addition, easy to use and low cost solutions can also probably be used through a mobile device. This highlights the importance of such solutions.

The next section summarizes the results concerning knowledge creation and utilization. Special emphasis is put on the comprehension and conceptualization sub-processes as they were identified as the ones receiving the least practical and scientific attention.

6.2 Summary of the contributions

This dissertation utilized the 7C model to understand how new knowledge is generated using various Web and mobile tools. This summary will aim at generalizing these findings. First, figure 13 shows how the contributions of the different papers relate to the Web and to mobile environments, and to the knowledge creation and utilization processes.

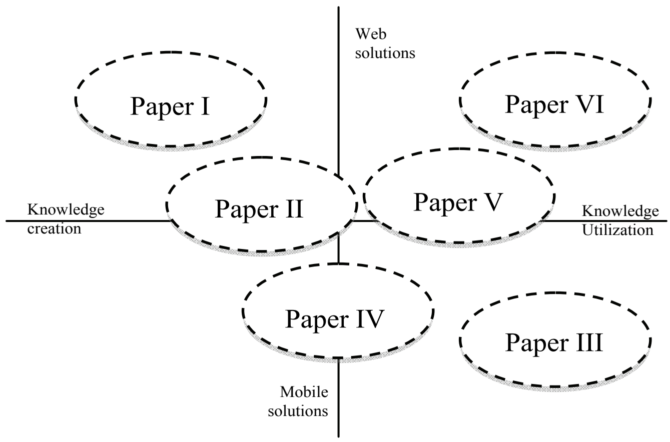

Fig. 13. The papers tackle both Web and mobile solutions as well as knowledge creation and utilization.

The upper part of the figure shows the papers related to Web technologies, while the lower part presents the papers related to mobile technologies. Further, the left side of the figure shows the papers related to knowledge creation while the right side shows the papers related to knowledge utilization. As can be seen from the figure, some papers (Papers II, IV and V) address two or more aspects.

Through the observations it was soon clear that the comprehension and conceptualization sub-processes have received the least scientific attention, while collaboration and especially communication have been researched a lot. This is interesting as communication is the sub-process where ideas already comprehended are shared with others. So without comprehension, sharing becomes difficult or even meaningless. And after sharing and debate, the ideas are refined into concepts through conceptualization. In fact, comprehension and conceptualization are key knowledge creation sub-processes because they produce new tacit knowledge and explicit knowledge, respectively. Thus, this dissertation put special emphasis on the comprehension and conceptualization sub-processes.

In the conceptual part of this doctoral dissertation, Web 2.0 technologies were identified to be well-suited for supporting knowledge creation (Paper I). This is mainly due to their collective features as new knowledge can emerge from the interaction of individual and social knowledge. Capturing the "knowledge rationale" was also identified as a feasible way to support knowledge creation (Paper I). Observations of healthcare information systems revealed that evidence-based guideline information was very good in supporting the 7C knowledge creation spiral (Paper IV).

In the constructive part (Papers V and VI) of this doctoral dissertation, the QAR method was used to capture the rationale. Even if users found out it would help them, they preferred simpler approaches (Paper V). In the last experiment (Paper VI), it was found out that the perceived ease-of-use of the argumentation approach is perhaps not high enough. Indeed, argumentation – or the knowledge rationale - works for some people who are willing to spend time and effort, but for thousands of other people there should be easier ways to aggregate the information.

Argumentation seems to work better for transforming learners than for performing or conforming learners because transforming learners are more willing to spend the time and effort required by the approach. In other words, it seems to work for those who are highly self-motivated and willing to commit great effort to discovering, elaborating, and building new knowledge. Alas, most Web users seem to be closer to conforming learners than transforming learners. Thus, in order to support knowledge creation, a careful balance of simplicity and complexity must be found: too simple a tool and no new knowledge will emerge; too complex a tool and users will not use it. Instead of complex functionalities supporting deep thinking, in the era of Web 2.0 new knowledge might emerge from constant exposure to the knowledge. The exposure to knowledge can work as a trigger for comprehension. In other words, the more users will use the knowledge management system the more chances there are for comprehension to take place.

By examining the papers focused on the Web technologies (Papers I, V and VI) we can see that the Web-based tools offer great support for both knowledge creation and utilization purposes. Web-based tools such as wikis and Google Docs among others have advanced text-editing capabilities. Web-based tools can also store large amounts of data, and this data can be used *e.g.* to filter and display relevant information.

By looking at the papers focusing on the mobile technologies (Papers III and IV) we can conclude that the mobile technologies might be better suited for knowledge utilization than knowledge creation. Editing existing information and knowledge can be tricky through a small screen of a mobile device. By comparison reading documents or watching YouTube videos works to some extent (depending on the device screen size this can work to a great extent). Also one aspect that this dissertation did not address is knowledge capture which mobile technologies seem to support well. Through knowledge capture mobile devices can provide excellent support to content creation and thus to knowledge creation.

Information providers and information users also have different types of needs. For example, for providers it helps if there is a template (*i.e.* a specific structure) that the user can just fill in. Structure can also help information users, as once the user is familiar with the structure he or she can more easily make sense of other pieces of information with a similar structure. However, this aspect of knowledge creation was not in the main focus of this dissertation.

In the next two sections, comprehension and conceptualization are discussed in more detail.

6.2.1 Support for comprehension

Oinas-Kukkonen (2004: 5) defines comprehension as "a process of surveying and interacting with the external environment, integrating the resulting intelligence with other project knowledge on an ongoing basis in order to identify problems, needs and opportunities; embodying explicit knowledge in tacit knowledge, 'learning by doing', re-experiencing." In this thesis, the following ways to support comprehension were found (the findings in the conceptualization section also support comprehension, at least indirectly):

1. Deeper interaction
2. Improved linking
3. Reflection
4. Guidelines
5. Webflow
6. Repetition
7. Decision aids

As identified in Paper I, the interaction should go deeper than just browsing static web pages or generating dynamic web pages via queries. Users should be able to "play with" the knowledge and information. For example, users should be able to "integrate and link different pieces of knowledge, to edit or highlight texts and graphics, or to take an audio file and embed it within a video".

In Paper V, a proxy server based solution was designed and implemented for deeper interaction. In the solution, the interaction functionalities were implemented with Javascript. As the web pages were downloaded via proxy the new functionalities were embedded into the HTML code of the web page. This way new interaction functionalities that can support comprehension can be included to existing Web tools. In the paper, a prototype version of the proxy server was implemented.

The prototype used Wikipedia as a knowledge repository, and three tools were implemented. Two of them were annotation tools in the form of sticky notes and highlighting. They both offered some support for comprehension. Quite interestingly, the tool that received the best attention in the study was a simple tool that allowed the users to double-click a word. The double-clicked word was then translated into another language. While the possible benefits of annotation tools can be argued to be greater, users prefer simpler tools. This is probably because the production costs of annotation are much higher than those of double-clicking. However, this could indicate what kind of tools users want: low-cost tools that are almost overly simple.

Another way to support comprehension would be to provide improved linking capabilities. For example, users could be allowed to see (potentially any kind of) similarities between knowledge artifacts, in particular between different pieces of knowledge, via associative linking. An associative link indicates that there is something similar in the two objects that are linked together. Various other links might work as well. Defining link attributes or typing them might help users organize information more effectively and, more importantly, "lend context for readers” to boost comprehension (Paper I). Guided tours or paths are examples of providing such a context.

Reflection was also found to support comprehension to a great extent (Paper II). If a user has tools to reflect, he/she can “look back” and see how his/her previous actions led to the current state. An analogical situation to this is if a physician can see how his/her patients are doing after he/she has treated them. This way he/she can reflect and maybe change something the next time he/she treats a patient with similar symptoms. This could also mean a tool to compare oneself to other users in order to see where one differs from them.

Information in guidelines seems to work well in supporting comprehension. Guides can provide steps that need to be performed to get something done. This is the kind of learning by doing that the 7C model refers to (Oinas-Kukkonen 2004). On the Web there are various ‘how-to’ guides and also FAQ (frequently asked questions) lists that contain this kind of information. If the guides have certain steps (as is usually the case), this can help in breaking down the knowledge into understandable steps. Or in other words, these steps can reduce a complex behavior into simple tasks that help users perform the target behavior. This way the user has a chance to learn-by-doing. As the steps help in breaking down the knowledge the user can also comprehend the knowledge step by step.

The step-by-step structure that the guides have seems to be a great way to support comprehension. When all of the material has a similar structure, the users know where to find relevant pieces of information. For example, scientific articles usually have a results section where the results of the paper can be found. Wikipedia articles also seem to have the same kind of structure. The reason why this works is probably the fact that it reduces the costs related to receiving. This not only works in comprehension but in a similar manner with conceptualization, too. Producing understandable information and knowledge is also easier (or at least faster) when there is a format to follow.

Allowing users to stay in webflow – *i.e.* not disturbing them if they are in a state of webflow – would seem to help in learning (Papers III, V). Learning seems to also induce webflow. Thus, there is a chance for a self-fuelling spiral to occur: webflow induces learning which induces webflow. If such a spiral exists, it would also support comprehension to a great extent. The results concerning this are inconclusive, however. Allowing users to stay in webflow could support comprehension as users did not lose their trail of thought. In the mobile environment, navigation and orientation play a key role in the process of flow (Paper III).

One interesting finding of this thesis was that in the era of Web 2.0, users seem to try to minimize their various costs and efforts related to communication, and indeed to the whole browsing experience. If this is so, there is possibly a big dilemma with most Web-based services that rely on user generated content. Luckily, users seem to be willing to expend more effort in discovering information than producing it. In any case, instead of offering users few high-cost experiences it might be more feasible to offer users many low-cost experiences. This way the experiences are more likely to be repeated, and this repetition might then trigger comprehension. Or in other words, the comprehension might be triggered by constant exposure to the knowledge. The use of decision aids relates to this. Decision aids provide users with information that helps them in decision-making process. While a one-time use of such a tool might not help produce new tacit knowledge, constant use could make the user more confident if the decisions are systematic and consistent.

Constant exposure relates to ease-of-use as well. The more users use the service, the more exposure to the content there will be. And if indeed the perceived ease-of-use of the service correlates with how often and for how long the users will use the system, it is imperative that knowledge management tools are perceived easy enough.

6.2.2 Support for conceptualization

Oinas-Kukkonen (2004: 5) defines conceptualization as “a collective reflection process articulating tacit knowledge to form explicit concepts and systemizing the concepts into a knowledge system”. In this dissertation the following aspects were found to supporting this process:

1. Metaphors and analogues
2. Decision aids
3. Evidence-based information
4. Capturing the knowledge rationale
5. Ease the process of grounding and reaching shared understanding

The reason why conceptualization is a challenging sub-process to support is that it requires tacit knowledge to be articulated. Following the work of Polanyi (1966), Nonaka (1994) classifies knowledge into tacit knowledge and explicit knowledge. While explicit knowledge is transmittable in formal, systematic language, tacit knowledge is not. Metaphors and analogues can offer support for this (Paper I).

The use of metaphors is the first step in transferring tacit knowledge into explicit knowledge. Indeed, using metaphors "constitutes an important method of creating a network of concepts which can help to generate new knowledge about the future by using existing knowledge" (Nonaka 1994: 21). First, metaphors can be used to recognize contradictions, as using them is a creative, cognitive process which relates concepts that are far apart in an individual's memory. When two concepts are presented in a metaphor, "it is possible to (…) make comparisons that discern the degree of imbalance, contradiction or inconsistency involved in their association" (Nonaka 1994: 21). When possible contradictions are spotted, analogues can be used to harmonize them, as association of meaning through analogy is more structural and functional, and is carried out through rational thinking.

The problem with metaphors and analogues is how to incorporate them into the tools. Associative linking offers some support for this, tagging being an example of this. While tagging as a solution is easy enough that users actually use it, its value for supporting metaphors should be studied. While it seems to work well for analogues, other solutions might be needed for the use of metaphors.

Decision aids can help conceptualization by supporting the decision making process of the users (Paper IV). Being a social process, conceptualization has issues like coordination and cooperation. Thus, according to Surowiecki (2004) and Oinas-Kukkonen (2008), information aggregation can help in decision making. The decision aids (like voting) can work as such information aggregation tools.

But as conceptualization also requires thinking and the creation of new explicit knowledge, it has a cognitive side, too. The possible problem could be that too much aid can lessen the amount of thinking that the users need to do. This can be bad for the creativity needed in producing new knowledge. One form of aid for decision making that was found helpful was evidence-based information. Indeed, evidence-based information was found to be excellent support for various knowledge creation processes. This is probably a somewhat trivial finding. Nevertheless, if we can provide information with evidence, the conceptualization process is supported to a great extent.

Capturing and exploring the knowledge rationale – capturing the rationale behind knowledge objects – would seem to support the 7C model and knowledge creation to a great extent (Paper I). Understanding the reasons why an artifact is built they way it is is very beneficial for knowledge creation. The knowledge rationale has a drawback, too. Using a rationale or argumentation provides support for knowledge creation but this support comes from the deep thinking required by the users. For example in small Web communities only a handful of users seem to be willing to take the required effort.

The knowledge rationale would also support the process of grounding and reaching a shared understanding. Reaching a common ground on the issue at hand is critical for the process of conceptualization and the following process of collaboration. The knowledge rationale could, for example, depersonalize conflict, allowing issues to assume a more neutral, less personal tone. This way important issues (instead of persons who are stating the issues) would get the attention they need. If the community is prone to having its discussions turn into verbal wars, using a rationale could help. Further, if the community consists of flame warriors or conversationalists, the benefits of using a rationale could outweigh the cost associated with it.

The important issue is that while the knowledge rationale would support the creation of new knowledge to a great extent, it also increases most of the costs related to grounding, like formulation and production costs. The key here might be to utilize the knowledge rationale while keeping the costs to a minimum. Decision aids combined with argumentation would seem to be one such way to keep costs low while reaping the benefits of argumentation (Paper VI).

The costs related to understanding seem to be other important issue. While argumentation does allow users to find answers to "wicked problems" (Buckingham Shum *et al.* 2007), its cost-benefit ratio might not be optimal for more mundane problems.

6.2.3 Knowledge utilization

The source of competitive advantage resides in the utilization or application of knowledge, not in the knowledge itself (Alavi & Leidner 2001). In order to support the utilization of knowledge, we must help the users to retrieve, evaluate, and apply the knowledge (*e.g.* Avery *et al.* 2003).

Retrieving knowledge means that user must be able to locate the knowledge and gather bits and pieces of it from various sources. For this, the knowledge should be in explicit form, for example in the form of conceptual knowledge assets or in systemic knowledge assets. Examples of such knowledge include product concepts and design (conceptual knowledge assets), and documents and specifications (systemic knowledge assets). This way knowledge is much more applicable than if it would be in tacit form. If the knowledge had to be extracted from discussions threads, it would be much more time consuming and tedious. The second thing to do is to evaluate the knowledge, *i.e.* does it fit and help with the problem or issue at hand? Without any explicit information about the value of the knowledge, the users have to decide this relying on their own expertise. They can do this, for example, by using their experiential knowledge assets like skills and know-how. The last part is the actual application of knowledge. This usually happens outside the community, most often in real life situations. Typically, the user might have a problem that he needs to solve or he or she is interested in exploring the contents or trying to learn something new.

The following ways to support knowledge utilization were found:

1. Guidelines
2. Decision aids
3. Providing evidence
4. Reflection

Guides were found to be a good solution for knowledge utilization (Paper IV). The knowledge conceptualized in them can be applied by following the guide. Guides can be seen as systemised and packaged explicit knowledge. This way the knowledge can also be stored and transferred easily. This would also help in retrieving the knowledge, as guides conceptualize the knowledge in retrievable objects (*e.g.* compare a guide to a discussion thread).

In the 7C model, the collaboration sub-process is the process where knowledge is applied. The "inputs" of the collaboration sub-process are the explicit concepts created in conceptualization. Again, guides can be seen as such concepts. In a way, they conceptualize the knowledge into applicable steps. They also typically have a structure (in the form of steps) which helps in evaluating the guides.

A guide (Paper IV) can also sometimes be followed through without too much prior knowledge of the issue at hand. This helps in problem solving but comprehension would probably be supported more if the user had some prior knowledge of the task at hand. Nevertheless, for utilization purposes, prior knowledge is not always required.

Decision aids (Paper VI) support utilization by reducing possible information overload and clarifying the choices that need to be made. For example in healthcare, the number of possible combination of drugs is so large that a physician has to be careful that he or she will not administer drugs that have bad side effects when combined (*e.g.* one drug affects the absorption of another). So, decision aids help in applying the right knowledge. Evidence works in a similar fashion as decision aids. The point is not to make the actual utilization any easier but to provide information that the user is using the right knowledge (Paper IV, VI).

Reflection helps users to comprehend (Paper II). Once the user has solved a problem, he or she can look back on his or her performance and think where he or she did good and where there are possibilities for improvements. Reflection-in-action provides chances for learning-by-doing. However, for the most part tools supporting this are still missing.

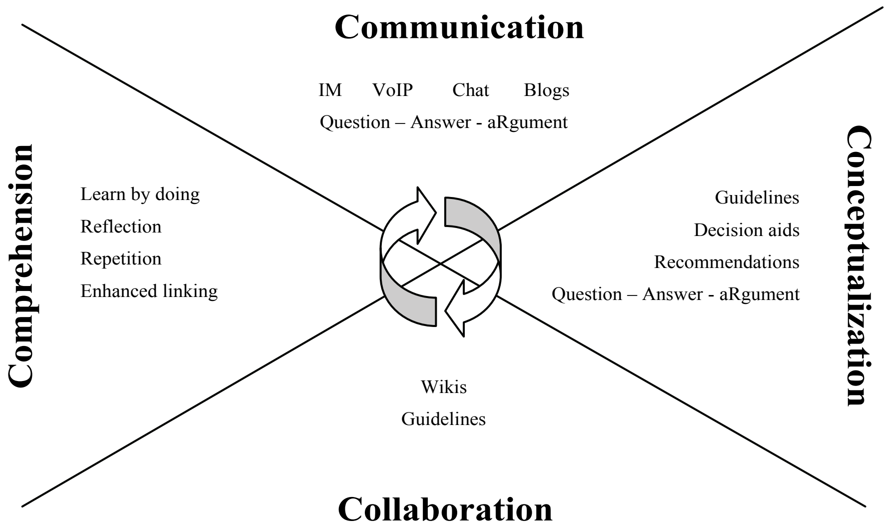

Fig. 14. Solutions supporting the 7C model.

Lots of new knowledge is generated in Web 2.0 through conversational knowledge creation that happens in discussion forums and other social media services. But as the power of knowledge resides in its usage, the knowledge should be in such a format that can be used and applied. Figure 14 shows some solutions that would support both the creation of new knowledge and its utilization.

Mobile technology has one distinctive advantage related to knowledge utilization. Mobile technology allows “anytime, anywhere” access to relevant information and people. For knowledge utilization, the point is not so much anytime, anywhere but rather at specific points in time and space (Paper III, Paper

IV). For example in healthcare, such a situation could be when a physician is by the bedside making decisions on treatments, *i.e.* at the point of care.

For the context of knowledge utilization, too, the knowledge needs to be actionable. Ten pages of prose support deep thinking (and thus knowledge creation) but are not so easily applied in practice. For example, decision support systems seem well suited for knowledge utilization.

Thus, instead of concentrating on anytime and anywhere mobile applications in knowledge utilization contexts, we might need to concentrate more on the exact situations where knowledge is needed and provide the knowledge in actionable form.

7 Discussion

Modern Web and mobile tools offer a tempting basis for knowledge creation. They allow users to capture and generate new knowledge for the services they are using. The conversational knowledge creation that happens between users in discussion forums, blogs and wikis helps people share knowledge and refine their ideas. As more and more content gets produced, the amount of available information in the communities grows day by day. As a result, users will face the problem of evaluating and making sense of the vast amounts of information and knowledge found online. Even if the Web's hypertext capabilities - like allowing freedom of choice, associative linking and navigational support to name a few - offer a good basis for comprehension, it would need even more support.

Since comprehension is a cognitive process and there is no "right" way of doing it, providing solutions that work every time is difficult. For example, to take full advantage of solutions like the QAR method, users' formulation and production costs will be increased, as users have to unbundle, classify, name and structure the information in an unfamiliar and time consuming way (Buckingham Shum *et al.* 2006). Making users learn a complicated way of doing things is a hard task. And even if they learn such a way, the complicated nature of the task might keep user participation low. Yet, if we want to support the deep thinking of users, complicated solutions are needed. At the early stages of this research the idea was to study solutions like annotation and QAR to see if they enable users to gain new knowledge by identifying important bits of information (*e.g.* by highlighting text) and arguing for different opinions. The interesting thing is that while solutions like these work in theory, users do not seem to adopt them into active use. This would indicate that a careful balance must be found on how useful the tools are and how much effort is needed from users to use them. Solutions like the knowledge rationale would be useful only if users used them. Solutions like double-click translation are a little less useful but users are much more likely to use such tools.

In Figure 15, the ascending arrow shows how as the effort to gain benefits from a tool increases, so does the potential usefulness of the tool. The descending arrow shows users' willingness to use these solutions. If we provided users with useful and easy to use (requiring little effort to use) tools (Davis 1989), they would probably use such tools. As the perceived usefulness decreases and the required effort increases, the users' willingness to use the tool decreases.

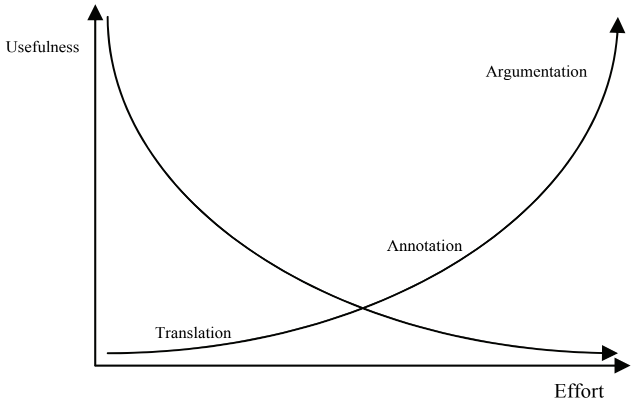

Fig. 15. Users' willingness to use a tool decreases as the effort to use the tool increases.

Of course, there might be users that would use argumentation-based solutions (like QAR). Yet, most users very likely would not use them, or would use them only sparingly. Thus, we would have a hard time taking advantage of the wisdom of crowds approach. As can be seen from Figure 10, there might be a sweet spot for when a tool would require too much effort for the benefits it brings. Thus, knowledge rationale probably has its uses but simpler solutions should also be offered. The drawback of course is that if the solution is too simple, it will help knowledge creation very little or not at all.

7.1 Outputs of knowledge creation

Knowledge assets can be defined as "firm-specific resources that are indispensable to create values for the firm" (Nonaka *et al.* 2000: 20). If Ba is the place where knowledge creation happens, the knowledge assets are the inputs, outputs and moderating factors of the knowledge creation process. According to Nonaka *et al.* (2000), there are four categories of such assets: 1) experiential knowledge assets, 2) conceptual knowledge assets, 3) routine knowledge assets, and 4) systemic knowledge assets. These are described more closely in Table 15. The table is ordered by the importance of the knowledge asset for the purpose of knowledge reuse as found in this dissertation.

Table 15. Knowledge assets in the order of importance for knowledge creation in the Web-based communities.

Knowledge asset	Description	Example
Systemic knowledge assets	Systemised and packaged explicit knowledge	Documents, specifications, manuals
Conceptual knowledge assets	Explicit knowledge articulated through images, symbols and language	Product concepts, design, brand equity
Experimental knowledge assets	Tacit knowledge shared through common experiences	Skills and know-how of individuals Care, love, trust, security, passion
Routine knowledge assets	Tacit knowledge routinised and embedded in action and practices	Know-how in daily operations Organizational routines and culture

Some knowledge assets, such as experiential knowledge assets, are difficult to grasp, evaluate or trade, while others, with like systemic knowledge assets, this can be done more easily. Together these assets form the basis of the knowledge creation process. For example, as users utilize various IT tools they can form virtual communities and interact with other users. These communities accumulate experiential knowledge assets like trust over time. Some assets can also be increased "outside" the community. For example, skills and know-how can be increased through formal education. Conceptual knowledge assets are also accumulated over time through discussions and the exchange of information (like pictures and links). Routine knowledge assets are embedded in the behaviour of community members, for example. Finally, systemic knowledge assets can be stored, *e.g.* in wikis.

However, systemic knowledge assets can often be missing in virtual communities, as they are more concerned with discussions and problem solving. If the outputs of a community's knowledge creation were systemic knowledge, they could more easily be used and reused by the members.

In fact, for reuse purposes the outputs of knowledge creation should most often be explicit. It is much more difficult and time consuming to observe routines or skills than a picture or a document. Indeed, by definition, some of the tacit knowledge possessed by participants cannot even be articulated. Both routine knowledge assets and experiential knowledge assets are transferred over time.

7.2 Usability of knowledge

Oinas-Kukkonen (2000) has defined webflow as an *optimal perceived user experience* which improves a system user's orientation and navigational use, as well as *vice versa*, and which is predicted by balanced user skills and the feeling that the system is enjoyably challenging, the feeling of being in control of system use, and the perceived ease of use and usefulness of the system. In addition, the content and functionalities provided by the system help keep user skills and challenges above a critical threshold through focused attention and learning. Previous research has shown that learning is a consequence of webflow, *i.e.* people who perceive flow have better learning outcomes than people who do not perceive flow (*cf.* Hoffman & Novak 1996; Choi *et al.* 2007). Thus helping users to stay in webflow could also help them in comprehension.

The relationship between webflow and learning could also be the other way around, as seen in Paper III: sometimes learning can cause webflow. This actually matches well with the idea of the flow state being intrinsically rewarding. If learning helps to achieve webflow and webflow helps in learning, then learning can be part of the intrinsic reward.

The issue with webflow is that if and when users are in the flow state, they should not be disturbed. Pearce and Howard (2004) have shown that users can flick in and out of flow. Indeed, Pearce and Howard (2004) have also demonstrated that flow may change rapidly during computer-human interaction, and that the concept of flow can relate to the use of the artefact (artefact flow) as well as to the primary task at hand (task flow). For example, a user can have a fun time playing with a simulator *vis-à-vis* learning about a specific topic. Task flow can be supported or hampered by any tool used to support the primary task. For example, if a user is writing a report any problem with the word processor can hamper flow. The less intrusive the tool is, the better the chances for flow are. If we think about the conversational knowledge creation that happens on the Web, new tools should be "compatible" with the existing behavior of users.

As users have different learning styles (see, *e.g.* Fleming 1995), these should be taken into account. For example, for a user who is a visual learner a tool should support data visualization, and for an auditory learner aural information should be provided. It is quite clear that it is difficult to have one tool that would support all the different learning styles. If we take into account the various learning orientations (*i.e.* users' emotions, motivation and intentions towards learning), the situation can get even more complicated. Luckily, solutions designed for conforming learners work to some extent with more motivated learners as well.

An example of an easy-to-use and simple, non-intrusive, systemised and explicit knowledge solution is guides and guidelines. To utilize them, the community members should be encouraged to produce knowledge in guideline or instructive format. Indeed, sometimes this already happens. If a community has its content in such a format, using and reusing it is more feasible than with discussions or argumentation-based information. For example, argumentation-based knowledge usually needs to be visualized in order to support comprehension, while guides and guidelines can be tried without much effort as they do not always require much previous knowledge.

Using guidelines would also indicate that there would be more "learning by doing", which in turn could trigger comprehension. A guide about how to boil an egg could help a nerd not only make breakfast but also gain relevant skills. In a way, this lowers understanding costs, as guides can be followed without a full understanding of the knowledge behind the guide.

While guidelines in and of themselves do not support conceptualization, they do provide a certain goal for it: what are the easiest and fewest steps to get the problem at hand resolved? This also allows conceptualizations to be compared with each other.

In addition, if at the end of a long discussion thread the conceptualization would be summarized into a guide (indeed any summarization would help), it would help lurkers and visitors find information they need. This way they would not have to read through the whole discussion. Instead, suitable information would be provided in a short and compact format.

Knowing that the solution to a problem should be provided in guideline form could help in structuring the answer, thus reducing formulation costs. This benefit is probably only gained with time, as at first formulation costs might increase.

Guidelines can also help in reflection. This is especially so if the guide helps in solving a problem or "getting something done". After the problem has been solved, the user can look back at the process and reflect on how he or she did.

In some cases, the guides can also be applied to different problems than they were originally designed for. An existing guide can tell how to install a printer driver for a selected printer. With little extra effort the knowledge of the guide could be tried with a Canon printer or a different version of the HP printer. There is already so much information in various Web-based communities and on the Web in general that many problems would be solved by applying that information.

Another way to look at the problem is to take a more persuasive approach. Persuasive technology is defined as interactive computing systems designed to change people's attitudes or behavior (Fogg 2003). While usability is more concerned with the easy to use aspects of a tool, persuasion is more about issues like providing users with the motivation to do something. This could be for example the motivation to spend more time in learning to use solutions like the QAR method. The Persuasive Systems Design model (Oinas-Kukkonen & Harjumaa 2009) also recognizes issues like reduction through which the cost/benefit ratio of using a tool could be increased. This could ideally move the sweet spot a little bit higher in Figure 15.

Fogg (2003) has identified three functional roles through which technology can be persuasive. These are the tool, the medium and the social actor. As a tool, technology can increase human capabilities, making things easier to do. It could be argued that this is what knowledge creation tools are made for, and they do seem to work to some extent. The problem is that as users have different learning styles, it is difficult to design a single solution that would support, *e.g.* comprehension. So maybe knowledge creation tools work better as a medium. As a medium, the tools provide experiences (Fogg 2003). They could, for example, provide experiences and help rehearse behaviour. Comprehension could be supported with experiences, *i.e.* by re-experiencing. And rehearsing could help in learning-by-doing. Utilizing an information system as a social actor could motivate people to share knowledge by rewarding and providing social support. But most importantly an IS could help learning-by-doing by modelling target behaviour. For example, an information system as a social actor could show the user how to boil an egg.

Another persuasive aspect that would fit well with knowledge creation is dialogue support. Suggestions work like decision aids and can support users' decision making and problem solving. Paper VI scratched the surface of the use of persuasive design to support knowledge creation. The interesting question regarding this is how much individuals' knowledge creation processes can be persuaded? In any case, the role of persuasive design in knowledge creation should be studied more.

7.3 Theoretical implications

This dissertation advances our understanding of knowledge creation and utilization using Web and mobile technologies. First, it highlights the need for better support for the comprehension and conceptualization sub-processes. Through comprehension, users internalize new tacit knowledge. This is a crucial step for the emergence of new knowledge. But it is also a difficult sub-process to support, as there is no right way of doing it (Savolainen 2006). Even if hypertext capabilities do offer a good starting point for ”surveying and interacting with the external environment” (Oinas-Kukkonen 2004: 5), there does not seem to be many functionalities besides linking that offer much direct support for comprehension. As such, one major implication of this research is that because users comprehend in different ways, maybe solutions that expose the users to knowledge should be considered. This indirect support for comprehension means that users learn and internalize knowledge gradually, over time. Guides are an example of this. With a guide, the user can get the job done. And over time while using similar guides, the user’s understanding, confidence and task related knowledge increases.

The big theoretical implication here is that the knowledge creation tools can be simple, yet effective. They must be closely integrated into the daily routines and working of the users so that their usage will not disturb the users too much. A careful balance must be found in how much cognitive effort is required from the users and how simple and easy to use the solutions are. If too much effort is needed, the usage of the system is low. And if the solutions are too simple and do not need any cognitive effort, new knowledge might not emerge.

Another under-researched sub-process was conceptualization. As with comprehension, conceptualization is supported indirectly by allowing for better and richer communication. Both Web and mobile tools are very well suited for this. However, conceptualization requires a shared understanding of the topic at hand. While communication tools do offer some support for this, in the early part of this dissertation argumentation was seen as viable way of offering better support. This is especially so with more difficult and sometimes even controversial issues.

The constructive part of this dissertation revealed that users were reluctant to use argumentation. Persuasive system design did provide some assistance for argumentation. This could imply that if we want to have argumentation-based services, the role of persuasive design principles such as reduction, tunneling and suggestion should be studied more. The interesting part is how much we can persuade while still allowing users to be creative and contribute to knowledge creation: too much persuasion and no new knowledge might emerge; too little and users will not use the system.

Mobile information systems were found to support knowledge utilization to a great extent. The “anytime, anywhere” capabilities of mobile devices mean that knowledge can be utilized at the point where and when it is needed. For example in healthcare, knowledge could be used by the bedside, at the point of care. Thus, research should focus not on the anytime, anywhere part but rather on the exact time and place where knowledge is to be applied.

And finally, research should keep in mind the usability of the knowledge. Solutions like QAR might produce new knowledge but applying such knowledge is difficult compared to solutions like guidelines, for example. This means that knowledge creation systems – be they Web-based or mobile – should aim at producing explicit, applicable knowledge.

7.4 Practical implications

The practical implications of this research mean that managers should have a clear understanding of various knowledge creation processes that are taking place in organizations. Any knowledge creation system must take these processes into consideration, as users need tools that fit well into their daily routines and organizational practices. This way, users will actually use the system. This also means that the tools can be quite simple, as long as they offer support for some part of the knowledge creation spiral. Furthermore, if we could offer low cost solutions that still supported knowledge creation and utilization processes, managers could better promote the usage of the knowledge management system. This would have a great effect on organizational capabilities over time. The key is to keep the solutions simple enough while still supporting knowledge creation sub-processes.

For comprehension support there is probably no golden bullet, as each individual can have somewhat different techniques for comprehending things. Rather than one big solution, several smaller ones could be considered. This way the offered solutions do not mess up the users’ existing ways or habits of doing things.

For conceptualization, the support is more complicated. What managers can do is aim at easing grounding and shared understanding efforts. This way, time can be used more efficiently instead of spending it on verbal wars. The information systems used should support rich communication to help in grounding. If argumentation-based solutions are used, a lot of effort must be spent on educating the users on the use of argumentation notation, as well as on explicating usable knowledge out of the argumentations.

Knowledge creation using Web and mobile-based tools has a good chance of utilizing the “wisdom of crowds” principles. The principles point out that a group is sometimes smarter than the smartest individual in it. As a practical implication, a manager should pursue the conditions of a smart group. The one thing that one must watch out for is the possibility of groupthink. The chances for this increase over time as groups become more cohesive.

One of the key practical implications is that users using a tool should produce knowledge in an explicit and applicable form. This way, even if the users leave the organization, the knowledge stays behind. Furthermore, as the knowledge is applicable, other users can apply it to future problems and situations.

8 Conclusion and future research

Over the past years business spending on knowledge management was estimated to rise from $2.7 billion in 2002 to $4.7 billion in 2007 (Babcock 2004). Yet many of the knowledge management initiatives fail or are unable to demonstrate success (Weber 2007). The reasons for these failures are plenty. One major reason is that knowledge management approaches often fail when they do not integrate or take into account humans, processes, and technology well enough (Abecker, Decker & Maurer 2000). As such any proposed technology-based knowledge creation solutions must pay special attention to both organizational knowledge creation processes as well as individuals within the organization.

Web- and mobile-based tools offer a good basis for new knowledge creation. The major drawbacks in tool support relate to supporting comprehension and conceptualization. While the hypertext features like linking do support comprehension to some extent, and various communication technologies offer support for conceptualization, very little tool support exists thus far.

Argumentation-based solutions seem to fit knowledge creation models very well. They may help capture the different viewpoints in a conversation, and help explain why knowledge artifacts are designed the way they are. Later on, this knowledge rationale can be investigated and explored to gain a deeper understanding of the problem at hand. However, the problem with argumentation-based services is that the costs of producing and comprehending the rationale are high. This would indicate that for casual users, other solutions may be found that are more appropriate.

Based on the results presented here, the IT tools should focus on producing procedural knowledge or "know-how". This kind of knowledge is applicable and adjustable. It supports the needs of information users and lurkers, and it fits well with the question-answering type in conversional knowledge creation. In addition, it is well suited for the 7C model discussed in this study. This also emphasizes the "knowledge as a process" view where knowledge is about how something occurs or is performed. It can also be seen as the applying of expertise (Alavi & Leidner 2001, Zack 1999). If we can create such knowledge, there are good chances that it is applicable.

As for future research, the role of persuasive design in knowledge creation should be studied more. Special emphasis should be put on finding out how much we can persuade the users to work efficiently for the good of the organization without hampering the creative side of knowledge creation. Since persuasion is about changing users' behavior and attitudes (Fogg 2003), the question is can we increase the users' exposure to knowledge and make them more responsive to it (*i.e.* more willing to receive the knowledge). For example, can we utilize the principles of suggestion and reward to help users comprehend?

Using persuasive design can also cause some ethical problems, so even if we could support knowledge creation using persuasive principles, the important question is, should we? And in general, how much can we persuade the knowledge workers' cognitive processes that relate to knowledge creation?

In sum, rather than solutions that would focus on supporting deep thinking only, low-cost and easy to use solutions should also be considered. The existing communication technologies already offer a good basis for the communication sub-process. Individuals have multiple ways and a myriad of solutions to discuss and share knowledge. Synchronous communication and video capabilities may help in transferring tacit knowledge, while tools like wikis may help in collaboration. Special attention should be placed on comprehension and conceptualization, which have received the least scientific and pragmatic attention.

Oftentimes new knowledge creation takes place through deep thinking. However, this dissertation emphasizes the role of repetition and constant exposure to information and knowledge. Furthermore, guides can serve as a basis for creating highly applicable knowledge. Davis (1989) has proposed that ease-of-use and usefulness are key in IS adoption. Maybe this holds true for the utilization and creation of knowledge, too: the goal of the knowledge creation should be easy-to-use and useful knowledge. This way such knowledge will be usable, too.

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