A System Architecture for the 7C Knowledge Environment

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Abstract. This paper presents an information system architecture for the 7C model for organizational knowledge creation and management. The architecture is derived from the requirements that the 7C model posits. The architecture presented here comprises three layers: the conceptual layer, which discusses fundamental principles of the model, the technology layer, which tackles potential implementation technologies for the environment, and the application layer, which describes possible applications in the environment.

1 Introduction

Knowledge management has received great attention both among practitioners’ and researchers’ literature for a longer period of time (see, e.g. [1][19][22][26][30][41]). More recently, collaborative approaches for managing knowledge have been proposed [44], suggesting that new knowledge is being created in group-efforts among many people instead of a few experts only [44]. This paper approaches knowledge management through a conceptual framework known as the 7C model [37]. This model suggests that knowledge is produced through the interaction of individual and social knowledge, as well as explicit and tacit knowledge. As the 7C model puts special emphasis on the social aspects of the knowledge management we will try to identify and analyze those new technologies that offer support for them.

The research approach adopted for this paper is design science [25][20], in which IT artifacts are build and evaluated. March and Smith [25] recognize four types of design science products, namely constructs, models, methods and implementations. This paper describes a construct, namely an overall information system architecture for the 7C model. More specifically, systems development as a research methodology consists of five parts [31]: 1) constructing a conceptual framework, 2) developing system architecture, 3) analyzing and designing the system, 4) building the (prototype) system, and 5) observing and evaluating the system. In line with this definition, the research described in this paper is part of a larger system development research effort. According to March and Smith constructs “form the vocabulary of a domain”, and “they constitute a conceptualization used to describe problems within the domain and to specify their solutions” [25]. The 7C conceptual framework has been originally described in [37]. The contribution of this paper lies in the system architecture, which together with the conceptual framework, may be regarded as a whole construct [25]. Later, following the framework presented here the 7C knowledge environment will be implemented and experimented.

Nunamaker et al. [31] define that system architecture is supposed to: 1) define a unique architecture design for extensibility, modularity, etc., and 2) define functionalities of system components as well as interrelationships between them. They also state that careful system requirements definition should be made and that the requirements should be
measurable. For this reason, we aim at identifying the requirements for the overall 7C architecture, and then present the architecture using layers, integrating the functionalities and interrelationships of system components within the architecture.

The paper is organized as follows. Chapter 2 describes the 7C conceptual framework. Chapter 3 analyses the framework in order to define requirements for the 7C information system architecture. Chapter 4 summarizes the requirements to recognize such concepts that the architecture must implement. Chapter 5 presents possible implementation technologies which are able to meet the concepts. Chapter 6 and 7 discuss example applications and the contribution of the paper. And finally, chapter 8 concludes the paper.

2 The 7C Model in a Nutshell

The 7C model for understanding organizational knowledge creation suggests that the following seven Cs play a critical role in the creation of organizational knowledge: Connectivity, Concurrency, Comprehension, Communication, Conceptualization, Collaboration, and Collective intelligence [37]. Technologically, the benefit is realized through the fluent connectivity that the Internet technology provides with information and people for potentially several concurrent users (the 1st and 2nd Cs). The World Wide Web and its hypertext functionality to promote options and allow freedom of choice with contextual support provides users with a rich environment for comprehending (the 3rd C) and communicating (the 4th C) the information they find. Knowledge is conceptualized (the 5th C) as knowledge artefacts, which serve as a collaboration vehicle through interaction between information producers and consumers, within a team of co-workers or among other stakeholders (the 6th C). All of these six preceding Cs contribute to the growth of “togetherness” or collective intelligence (the 7th C).

The creation of organizational knowledge is not a linear process, but rather a multi-cycle spiral process. See Fig. 1. The framework assumes that connectivity of all stakeholders with the joint information space and people potentially concurrently is provided in a technologically sound manner, e.g. through the Web, Internet, wireless, mobile and other technologies. The 7C model follows Nonaka and Takeuchi [30] in that the integration of individual and social orientations (in their terminology individual and organizational) are emphasized, and that knowledge is assumed to be created through interaction between tacit and explicit knowledge. The model follows Engelbart [13] in the outcomes of the Comprehension, Communication and Conceptualization sub-processes.

![Figure 1: Organizational knowledge creation [37].](attachment://image.png)
The four most central sub-processes in the knowledge creation are:

- **Comprehension** – 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.

- **Communication** – 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.

- **Conceptualization** – a collective reflection process articulating tacit knowledge to form explicit concepts and rationale and systemizing them 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; may include proposals, specifications, descriptions, work breakdown structures, milestones, timelines, staffing, facility requirements, budgets, etc.; rarely a one-shot effort.

- **Collaboration** – a true team interaction process of using the produced conceptualizations within teamwork and other organizational processes.

Each of the sub-processes may also be regarded as the building of an artifact and reasoning why it has been built the way it has, i.e. capturing the knowledge rationale. Repeatedly going through these phases in a seamless and spiral-like way leads into the growth of collective intelligence. Support for capturing deep individual thinking and recording the dialog between team members may help create truly innovative knowledge products. The learning involved in the comprehension and communication processes is closely related to the attitudes of the participants, i.e. whether they understand their weak points in the sense of individual learning styles, for example.

In spite of receiving a lot of attention recently among practitioners, relatively little organizational knowledge management research has discussed the evaluation of the suggested solutions [38]. Evaluating may be carried out at the individual, work unit (group, team, or department), or overall organizational levels. The 7C model shares the view of King and Ko [22] to knowledge in that knowledge surpluses data and information, and thus even if it emphasizes knowledge content, it also addresses the link from knowledge back to re-shaping data and information (cf. [41]).

The evaluation of the Comprehension and Communication sub-processes means, for instance, whether the following goals will be achieved: Better understanding of the current and potential future customers, the key organizational business processes, the product portfolio, product features and potential future products, as well as markets in general. Quite naturally, improvement of any of these will lead into either increase of new ideas or achievement of better ideas for future business, and it may also help solve some of the problems the organizations face with over time (by being more capable of defining the core processes and their key challenges) or to even avoid some of the pitfalls they might fall into.

The increase of sharing and dissemination of information and the increase in varied interpretations are obvious and, as a matter of fact, by no means the most important measures for the success of knowledge management solutions. The truly important measure is the identification of underlying non-obvious, complex problems and issues. This may help better formulate the problems and issues the organization is facing, has faced or will face. Naturally, means for solving these problems are urgently needed. By emphasizing the identification of the key organizational issues and focusing more clearly on solving these instead of something else, the organization also becomes less dependent on its individuals.
At the same time the corporate or collective intelligence grows by the transfer of ideas, experience and best practices, and the individuals become more confident at their daily work. An example of these, in particular Collaboration and Conceptualization, is the role of argumentation or design rationale in systems development (cf. [34]).

3 Requirements for the 7C Information System Architecture

The purpose of this paper is to develop an information system architecture that follows the 7C conceptual framework. According to Nunamaker et al. [31], system architecture should be designed for extendibility and modularity. This is supported by presenting the architecture in three layers: application layer, technology layer and conceptual layer. Extendibility is supported by separating possible applications and technologies from the key concepts presented in the conceptual layer. The key concepts provide those underlining principles upon which the architecture, and the 7C model, builds upon. Modularity is supported by defining the structure of each layer. As new technologies are developed, they can be included in the technology layer if they support the identified key concepts.

First, to recognize the key concepts for the system architecture, we will aim at identifying requirements posed by the 7C model itself.

3.1 Connectivity

The fluent connection provided by Internet technology is the basis of the 7C model. The users must have access to the system whether they are working at home or in the office. For example, language context processes of Communication and Comprehension rely heavily on Internet technology to provide a connection. This connection can be to people (Communication) or to knowledge (Comprehension). The connection to the Internet provides users a space in which they can communicate and interact regardless of time or place.

3.2 Concurrency

Concurrency refers to the fact that the system may have several concurrent users, which, in some cases, may be interested to work with the exact same knowledge artifacts. Thus, proper concurrency control must be taken care of. Internet technology provides a good start for the Concurrency. However, Concurrency may be supported to a greater extent through providing another access point to the system. For example, a mobile access to the system for those on the move may enhance their participation for the knowledge creation processes. Providing mobile access should require no client application to be installed for the mobile device (and, in a matter of fact, for the desktop either). The system should be able to be used with any device that has a modern browser.

3.3 Comprehension

Comprehension is a process of “surveying and interacting with the external environment, integrating the resulting intelligence with other (...) knowledge” [37]. It is the process of embodying explicit knowledge into tacit knowledge. Different knowledge artifacts are created and stored for gaining collective intelligence. The user must be able to browse these artifacts and organize them as (s)he sees fit. Through browsing and organizing existing
explicit knowledge, the user is able to “identify problems, needs and opportunities”, and thus learn by doing [37]. This interaction should go deeper than just browsing and organizing. The user should be able to ‘play with’ the existing knowledge. For example, the user 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 any case the interaction should go deeper than just browsing of static Web pages or the generation of dynamic Web pages through user defined queries.

Another way to support deeper understanding would be to allow users to see (potentially any kind of) similarities between knowledge artifacts, in particular between different pieces of knowledge. An associative link [6] between two knowledge objects would explain the user that these objects are somehow related or that they have something in common. Providing this information may trigger the user to understand something totally new. Links may also be typed and they may have attributes [6]. Typed links may help users organize information more effectively and, more importantly, “lend context for readers” to boost Comprehension [6]. Guided tours or paths [6] are examples of providing such a context.

3.4 Communication

Communication is the process of “sharing experiences between people and thereby creating tacit knowledge in the form of mental models and technical skills” [37]. Tacit knowledge an individual possesses may be transferred to other individuals or to a group of 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. Asynchronous communication must be supported: users are not always online at the same time, but they must still be able to discuss issues through the knowledge support system.

In the 7C model controlling concurrency means supporting the co-presence of users in the virtual space. Even though the knowledge workers may be located in different places, they can still be connected to the same work processes. Co-presence may require some support for synchronous communication, in which knowledge transfer may be enhanced through real-time communication.

Marwick [26] argues that in text-based chats, people use such a kind of informal dialog that can help the emergence of new tacit knowledge. Another aspect that speaks for text-based communication is the fact that we can relatively easily search, navigate, and visualize previous text-based communications. We can also add structure for text-based conversations: summarize, highlight, link and annotate them [14]. For example, discussion stored in a XML file may include meta-information on it (i.e. metadata such as date, topic, participants etc.), as well as the actual content of the discussion. Annotating a certain part of the conversation can be done simply by adding a new tag into a specific spot in the file. With structure visualizations these discussions become relatively lively, and annotations and links between discussions may be displayed when needed. For communications stored in video or voice, this becomes much more difficult.

Nevertheless, video, voice and pictures are important in tacit knowledge transfer. Tacit knowledge is often deeply rooted in visual and other bodily senses [29]. According to Nonaka [29] tacit knowledge can be acquired without language, through observations, imitations and practice. Tacit knowledge gained through visual observation may be impossible to articulate and transfer without some visual stimuli to trigger and help the transfer process. Thus it should be possible to use different kinds of multimedia objects (video, sound, pictures etc.) to enrich text-based discussions.
After all, the things that are communicated are more important than how they are communicated. The 7C model states that Communication is a process of sharing tacit knowledge, particularly experiences. Typically, information communication technologies provide a means for communication, but they also have an effect on what users communicate [40]. According to the 7C model users should be encouraged, or even persuaded, to share their knowledge and experiences with co-workers in organizational settings. Information systems can be regarded as tools, social actors, or as media [16]. As a tool, an information system may persuade by making the sharing of knowledge easier. As a social actor, it may reward the user and provide social acceptance. And as a medium, it may provide people vicarious experiences that motivate them to share information.

One problem for tacit knowledge sharing and formation is the potential lack of trust among participants [26]. Especially in virtual environments where the lack of past or future association (face-to-face meetings, for example) decreases the potential existence of trust [21]. One solution for building trust online is to create online communities [4]. Virtual environments may help share some experiences. If a past experience was “learned the hard way” (which may have seen an embarrassing or even humiliating personal experience) sharing such a lesson requires not only trust, but personal courage as well. If no past or future connections among participants exist, sharing such experiences might be easier. On the other hand, if the users know each other, there should be a way to share experiences anonymously.

Even though the Communication process is probably the easiest C to support, there are still potential problems with it. The sharing of tacit knowledge is more complicated than the sharing of explicit knowledge. A critical, social requirement for the environment such as discussed in this paper is to ensure that users end-up sharing their knowledge and experiences. Special emphasis should be put on such knowledge and experiences that other users do not know. Another important requirement is that the communications are stored in a well-defined, text-based format, such as XML or its variants. In this manner, the communications can best support the full 7C knowledge creation cycle, and information may be reused in the Comprehension and Conceptualization phases more easily and to a larger extent than if they were in some other formats, such as audio.

3.5 Conceptualization

Conceptualization is the “collective reflection process articulating tacit knowledge to form explicit concepts and systemizing the concepts into a knowledge system” [37]. It is the process of transforming tacit knowledge into explicit, and it is probably the least researched area of the 7C processes. This may also be why the existing systems and tools offer little support for it.

According to Nonaka [29], the first step in transforming tacit knowledge into explicit knowledge is the use of metaphors. Moreover, the use of 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” [29]. It 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” [29]. Nonaka also states that contradictions incorporated in metaphors may be harmonized through the use of analogies. Association of meaning by metaphors is mostly driven by intuition and involves images, whereas association of meaning through analogy is more structural and functional, and is carried out through rational thinking.
Conceptualization is a collective process and it requires some sort of consensus about the explicit concept being formed and systemized. This might mean that people have different opinions and ideas about the concept at hand. In that case, reaching a consensus (or compromise if the ideas are too far apart) might need a strong argumentation. If we are to get others to accept a radical idea (or at least to accept the existence of differing opinions) we must show why they should do so.

Capturing design rationale in systems development may be used to accomplish just this. Design rationale means the understanding of why an artifact has been designed the way is has [34]. Capturing the rationale behind explicit concepts may lead to “clarity of thinking and augmentation of (…designer’s…) memory” as well as to better communication [34]. With argumentation, we may try to understand the specific elements of each others’ concepts, and perhaps even try to persuade others into accepting our viewpoints, or in other words to conceptualize “knowledge rationale”. If we can argue the explicit knowledge created in the Conceptualization process, we then have a chance of understanding the tacit knowledge behind it. In this way the arguments behind the knowledge help us in Comprehension, Communication and Conceptualization, making knowledge rationale one of the key concepts of the 7C architecture.

The outputs of the Conceptualization process are the explicit concepts (basically this can be any explicit knowledge object) backed up with rationale arguing (against or for) the concepts. Visualizing and linking these concepts to each other may help in Comprehension and Collaboration.

In the 7C model Conceptualization is a collective process, and the use of metaphors and analogies could facilitate the formation of explicit concepts. Visualization of metaphors and linking them through analogies may provide a way for new concepts to emerge. By utilizing knowledge rationale one may help others to understand his/her reasoning, thus helping Comprehension, Communication, and Conceptualization (and indirectly also Collaboration).

3.6 Collaboration

7C Collaboration process is a “true team interaction process of using (…) conceptualizations within teamwork” [37]. As discussed in the Communication process, a shared virtual environment must be provided for the team to work in. The most important aspect of Collaboration process is to support the coordination and distribution of work. Users should be able to know who is doing what and with whom. An essential aspect for the Collaboration process is that it must provide ways to utilize the produced conceptualizations. Thus, the users should be able to decide who works with whom and with what conceptualization. The actual outcomes of the Collaboration may vary depending on the job at hand but the shared virtual environment provides a good starting point for teamwork. Browsing previous cases, e.g. conceptualizations in use, and reusing the work already accomplished should also be possible.

3.7 Collective intelligence

Going through the Conceptualization, Communication, Conceptualization and Collaboration phases several times in a seamless spiral-like way leads into the growth of Collective intelligence [37]. While organizations create new knowledge, they also forget it [1][3][11]. That is why the storage, organization, and retrieval of organizational knowledge are important [42].
In the 7C architecture, it is important that all the knowledge artifacts created in any subprocess are stored. These knowledge artifacts can be anything between discussions in the Communication process and metaphors in the Conceptualization process. Equally important is that the stored knowledge artifacts can be retrieved whenever needed.

4 From the requirements to the architecture – key concepts

In the discussion above, 22 requirements for the 7C architecture were identified. The requirements are summarized in Table 1. With these requirements we aim at capturing the essence of the 7C model and identifying the key concepts underlying the C’s.

Requirements R1 and R3 state that the 7C architecture must be designed as a Web information system that also takes into count possible mobile users. In this way the architecture can provide the best possible support for Connectivity and Concurrency. Without it much of the potential of 7C may be lost. Multiple users working on the same knowledge artifact requires concurrency control (requirement R2).

Comprehension requires that the users must be able to interact (browse, search, read, requirements R4-R6) with existing knowledge artifacts and their metadata in order to comprehend or learn from them. This is essential for new tacit knowledge to emerge as merely providing static information is not enough to truly support Comprehension.

Communication requires that the users can share their experiences or tacit knowledge (R7). Without it no transfer of knowledge will take place. The feeling of community could be used to further enhance this (R10). Much of the knowledge transfer should be text-based so that the previous communications may be easily stored, visualized and searched (R8). To further increase tacit knowledge transfer synchronous communication may be used (R9). Sharing of past experiences “learned the hard way” could be facilitated by allowing users to do it anonymously (R11).

Table 1. Requirements for the 7C information system architecture.

<table>
<thead>
<tr>
<th>7 C’s</th>
<th>Requirements</th>
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<tbody>
<tr>
<td>Connection</td>
<td>R1: must be designed as a Web information system</td>
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<tr>
<td>Concurrency</td>
<td>R2: must provide concurrency control for managing simultaneous users working with the same knowledge artifacts</td>
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<td></td>
<td>R3: should be designed mobile aware</td>
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<tr>
<td>Comprehension</td>
<td>R4: must provide a way to interact, browse and search the knowledge artifacts and metadata concerning the knowledge artifacts</td>
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<td></td>
<td>R5: must provide a way to reorganize stored knowledge artifacts</td>
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<td></td>
<td>R6: should provide a way to interact with the knowledge rationale</td>
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<tr>
<td>Communication</td>
<td>R7: must enable the sharing of knowledge and experiences</td>
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<td></td>
<td>R8: must support asynchronous text-based communication</td>
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<td></td>
<td>R9: should support synchronous communication</td>
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<td></td>
<td>R10: should support user communities and increase of trust among users</td>
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<td></td>
<td>R11: should be able to share experiences anonymously</td>
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<tr>
<td>Conceptualization</td>
<td>R12: must support the definition of knowledge concepts</td>
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<td></td>
<td>R13: must support the capture of rationale behind the explicit concepts</td>
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<td></td>
<td>R14: should support the use of metaphors to recognize contradictions</td>
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<td></td>
<td>R15: should support the use of analogies to resolve the contradictions</td>
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<td></td>
<td>R16: should support the visualization of concepts</td>
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<td></td>
<td>R17: should support the linking of concepts</td>
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<tr>
<td>Collaboration</td>
<td>R18: must provide a shared virtual working environment</td>
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<td></td>
<td>R19: must support the coordination and distribution of work</td>
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<td>R20: should support the use of visual conceptualizations</td>
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<tr>
<td>Collective Intelligence</td>
<td>R21: must store all knowledge artifacts created in any 7C process</td>
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<td></td>
<td>R22: must provide a way to retrieve stored knowledge artifacts</td>
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</tbody>
</table>
Conceptualization means definition of explicit concepts (shift from tacit to explicit). The architecture should support this by defining the knowledge concepts (R12). Resolving between differing opinions or ideas about concepts becomes important (R13). Argumentation behind explicit knowledge is also vital for Comprehension (reading the argumentation might help the reader to understand the tacit knowledge behind the argumentation). Conceptualization might also be enhanced with the use of metaphors and analogies (R14, R15). All this might be facilitated by allowing the visualization and linking of concepts (R16, R17).

Collaboration requires a shared working environment (R18). Without it doing any collaborative work is impossible. Collaborative work also requires coordination and distribution of work tasks (R19), so that work is efficient and users know what they should be doing. Also the users should be able to collaborate by using the conceptualizations in their work (R20).

Finally, the processes produce knowledge artifacts that must be stored and retrieved as needed (R21, R22). Without the ability to store and retrieve the knowledge, there would be no organizational memory and the knowledge created would be quickly lost.

From the requirements, we can recognize key concepts for the 7C architecture. The first is the knowledge rationale. As the 7C is a model for understanding organizational knowledge creation, knowledge and how it is represented is essential. Knowledge rationale means backing up the explicit knowledge objects with solid argumentation. The second is the use of hypertext functionality, i.e. features such as linking, and metadata. The third is the concept of mobile aware Web information system which supports the Concurrent Connection required by the 7C model.

Because the 7C is a model for organizational knowledge creation and management, knowledge and how it is represented are crucial for it. This paper proposes that the rationale behind knowledge, i.e. knowledge rationale, should be treated equally important to the knowledge itself. This means that any produced concept of knowledge is stored with argumentation for it. This helps in many ways. For example, if another similar knowledge concept is being produced existing argumentation may be checked to understand why a certain knowledge concept is defined the way it is, or argumentation that has been found valid in one case may be found valid in the other case, too. It may also be possible to find knowledge traces in these argumentations, and this rationale might even include some of the tacit knowledge associated with the task at hand.

This might help managing the organizational memory also. For example, the piece of explicit knowledge could be an important decision, e.g. whether or not a company should expand to new markets, based on a collection of facts, e.g. an analysis by consultants. If the question at hand is argued for and against, the ultimate decision will be easier to make. Often this argumentation holds much of the knowledge, and it is imperative for the organization that it is stored with the knowledge as it may be more important to trace the arguments than to know the exact decision.

In the 7C model, knowledge rationale is embedded in 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 in the very heart of 7C architecture, and all of the processes deal with it in one way or the other. Knowledge rationale can be seen as an addition to Conversational Knowledge Management (CKM) [10][44]. In CKM knowledge is created and shared through questions and answers. This is typically done through email lists, discussion forums, or similar. Knowledge rationale adds the element of argumentation
to CKM. In Conceptualization the question-answer pair would not capture all relevant knowledge. While it is relatively easy to capture explicit knowledge in question-answer pairs, capturing tacit knowledge is more difficult.

In knowledge rationale one question can have many answers and each answer can have arguments against or for made by different people [34]. In this way, conversations carried out in the Conceptualization become dynamic and natural, and the arguments may embed tacit knowledge regarding the question-answer pair at hand.

CKM can also been as a way to transfer existing explicit knowledge to others, i.e. mainly the responder transferring his/her knowledge to the individual asking the question (and to others who read the questions and answers). In knowledge rationale, there is a better chance for new knowledge to emerge. New knowledge might emerge in the dialog between the arguments for and against as the users would have to come up with better arguments to counter other people's arguments. The same thing could also happen in CKM but knowledge rationale persuades users to do this through argumentation.

Besides linking and metadata discussed earlier the interaction capabilities provided by hypertext functionality are also important for the 7C model. They provide the means for "survaying and interacting with the external environment, integrating (...) intelligence (...), identify problems, needs and opportunities" [37]. Without the ability to interact with knowledge objects we loose some of the ability to "learn by doing" and re-experiencing [37]. 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 with 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 even further facilitate the Comprehension.

Hypertext functionality is also useful for Conceptualization and Collaboration, too. We can use linking and annotation to help the use of metaphors, for example. As another example structure-based query can support knowledge rationale. As knowledge is saved with its reasoning, knowledge-based search is not enough: there also has to be the capability to investigate the rationale. Annotations [6] 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 within teamwork [37].

The Concurrent Connection is realized through the concept of mobile aware Web information system [35]. A mobile aware Web information system (MAWIS) is a Web information system that has been designed with its potential usage through wireless interfaces in mind. 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.
To summarize, the key concepts of knowledge rationale, hypertext functionality and mobile aware Web information systems form the conceptual layer of the 7C architecture. It is shown in Figure 2. Knowledge rationale is perhaps the most important concept in the 7C system architecture. According to the 7C model, the outputs of Conceptualization are explicit concepts. In our architecture the explicit concepts consist of explicit knowledge and arguments behind them. The Connectivity and Concurrency suggest that the system should be designed as a mobile aware Web information system to increase the concurrent connection to information and to people. And lastly, the hypertext functionality serves as a basis for all 7C processes and it allows the use of linking and metadata, and user interaction with knowledge objects stored in the system thus helping Comprehension and Conceptualization.

5 Implementation considerations

All key concepts of the architecture imply some specific technological needs for the implementation. Some technologies meet these needs better that others. For example, one core competency of Web 2.0 is to “harness the power of collective intelligence” [33]. This will go hand in hand with the 7C model. On the other hand, some other technologies seem to emphasize aspects that are not so suitable for the 7C model.

We will first go through technologies that support hypertext functionality, in particular Web 2.0 technologies, as they will work also with the other concepts. Then we’ll look at the technologies that support the knowledge rationale, followed by technologies that support the mobile aware Web information systems. Finally, other possible technologies that might fit the overall 7C framework will be discussed.

5.1 Technologies supporting hypertext functionality

Web 2.0 [33] refers to a perceived or proposed second generation of Internet-based services, such as social networking sites, wikis, communication tools, and tagging, that emphasize online collaboration and sharing of knowledge between users. Web 2.0 is not a technical standard but rather a buzzword for innovative applications that are made possible by the ever growing number of Internet technologies and the novel use of combining existing technologies. Some characteristics for Web 2.0 have been defined [33]: 1) Web as platform, 2) Architecture of participation, 3) Rich user experience, and 4) Social networking.

The Web as a platform allows applications to be delivered and used through a Web browser. There is no need for software releases, licensing or porting to different operating systems [33]. For example, people can use www.google.com with just about any device that has a Web browser and they need no software updates or separate payments. In the Web 2.0 the importance and usefulness of a service is emphasized. This is mainly because the business value comes from delivering services over the Web platform [33]. A typical service could be a search engine or an on-line auction site. New Web services are also emerging in the form of mashups: a combination of existing Web services to form a new value-added service, e.g. combining Google Maps\(^1\) with apartment rental and home purchase services to create an interactive housing search tool) [33]. Web as a platform improves the Concurrent Connection: users can run the service any time, anywhere without the need of client software.

\(^1\) http://maps.google.com
Architecture of participation refers to the success of Web sites that promote user participation. For example, Flickr\(^2\) not only stores your photos, but it allows you to share them with others. Weblogs and Wikis also provide an example of participation. Weblogs, or “blogs” are frequently updated Web pages with a series of archived posts, typically in a reverse-chronological order [28]. They are primarily textual, but often they also contain photos or other multimedia content. They also may include hypertext links to other Internet sites (often to other blogs). While personal homepages and Web publishing are nothing new as such, it is the user participation that gives weblogs an edge: the audience can read the blog, but they can also comment them. Blog entries, their comments and comments-on-comments enable better participation. It is interesting to note that the thing that made blogging truly participatory was not just the ability to comment on other's texts but the introduction of two types of links, namely the permalink and traceback [8]. The permalinks gave each blog entry a permanent location at which it could be referenced and this allowed a blogger (the writer of a blog) to cite exact blog entries. A traceback allows a blogger to ping other weblogs by placing a reciprocal link in the entry they have just referenced [8]. Together permalink and traceback allowed weblogs to become participatory: a blogger would know when other blogger would cite and comment his texts and he could write a reply. Participation is very important for Communication, Conceptualization and Collaboration in 7C.

Another important Web 2.0 technology that supports participation and is important in knowledge management (see [44][39]) is a Wiki. Wikis are collaborative tools that enable groups to jointly create content [43], and they differ from plain discussion forums in collaborative aspects. In Wikis, users can edit any knowledge stored in it, not just their own writings as in discussion forums. Leuf and Cunningham [23] define Wiki as "a set of linked Web pages, created through the incremental development by a group of collaborating users". Wikis are found to be a good way to support question-answer pairs of CKM [44][10] and thus should also support knowledge rationale. The collaborative nature of Wikis allows Web documents to be authored collectively, which fits very well with the 7C model.

There are many Wiki software systems available as open source. These Wiki software systems differ from each other mainly in their special features. Some useful features could be voting, workflow management and file and image galleries [43]. Wikis would also take care of concurrency and versioning issues to avoid conflict or inconsistencies arising from multi-user capabilities [43].

For the 7C model, Wikis could be used as a platform for Collaboration and Comprehension, vehicle for Communication, argumentation and Conceptualization and as a knowledge repository for all the knowledge created in 7C processes. As such, Wikis seem to provide a natural way to implement 7C tools.

The term “Rich user experience” as well as “Rich Internet Applications” (see [2]) refers to fact that Web-based applications are starting to offer GUI-style application experiences to users [33]. An example of such user experience is Google Maps. Typically, in map-based Internet application a user has to click on a hyperlink to scroll the map. In Google Maps the user can click on the map and scroll it using the mouse, i.e. in a similar fashion as he would do on a desktop application. Google uses AJAX (Asynchronous JavaScript with XML) [17][27] and this collection of technologies has become one of the key components of the Web2.0 applications [33]. AJAX incorporates “standards-based presentation using XHTML and CSS, dynamic display and interaction using the Document Object Model, data interchange and manipulation using XML and XLST, asynchronous data retrieval using XMLHttpRequest, and JavaScript” [17]. While none of these

\(^2\) http://www.flickr.com
technologies are new in themselves, it is the novel use of them together that supports the
provision of a rich user experience in Web 2.0 applications. For the purposes in the 7C
model, rich user experience may facilitate the visual representation of concepts and
knowledge objects. This might have a positive effect on Comprehension as the user
experience would not hinder the work. The same applies to some degree to Collaboration,
too, as users would apply the produced concepts in their work.

With the Web 2.0, social networking has also found its way into Web applications.
Typically, social networking sites allow users to create and maintain a network of close
friends or business associates for social and/or professional reasons. An example of such a
Web site is LinkedIn\(^3\). It allows members to look for jobs, seeking out experts or to make
contacts with other professionals through a chain of trusted connections [32]. For the 7C
purpose, social networking could be used to seeking out expertise (as in LinkedIn).

Attaching metadata in the form of keywords (called tags) to content is a common way
of organizing content for future navigation, filtering or search [18]. With Web 2.0,
collaborative form of this process called tagging or folksonomy has gained popularity
[18][33]. In tagging, people not only tag information for themselves but for others, too.
This works best when there is no authority to control the tagging and people can use tags as
they see fit [18]: Somebody might tag a video about a man breaking his arm as “man” and
“funny” while another user can tag the same video with “accident”, or a photo of a puppy
could be tagged “puppy” and “cute” and the photo could be retrieved using either tag
correspondingly. This allows multiple and overlapping associative linking [7] imitating the
human brain rather than a formal categorization [33]. Tagging can help the user in
Comprehension because (s)he can browse, search and categorize explicit knowledge objects
(s)he (and others) tagged, and in Communication because he can see how others have
tagged knowledge and because (s)he can share his tags with others.

5.2 Technologies supporting knowledge rationale

Semantic Web is a project which tries to facilitate information exchange by bringing
structure to the meaningful content of Web pages [5]. This is done by putting documents
with computer-processable meaning (semantics). Semantic Web is not a separate Web but
an extension of the current [5].

In Semantic Web XML (eXtensible Markup Language) and RDF (Resource
Description Framework) are used to describe the structure (XML) and meaning (RDF) of
the information. Ontologies are collections of information that define relations among terms
[5] and they are created with OWL Web Ontology Language. Together, these techniques
form the basis of the Semantic Web. According to Berners-Lee et al. [5], "the real power of
the Semantic Web will be realized when people create many programs that collect Web
content from diverse sources, process the information and exchange the results with other
programs". These programs are called agents and their “effectiveness (…) will increase
exponentially as more machine-readable Web content and automated services become
available" [5].

Semantic Web as such seems to give more power to the computers, e.g. putting
documents into computer-processable form for software agents, whereas Web 2.0 relies on
users working collectively, e.g. through tagging and social networks. Since knowledge
creation is a collective and social process Web 2.0 technologies seem to be more important
for the knowledge management purposes than those of the Semantic Web. That is also why
we do not represent knowledge artifacts through Semantic Web ontologies but rather
through argumentation in conjunction with Web 2.0 technologies. Knowledge (be it in any

\(^3\) http://www.linkedin.com
computerized form – text, pictures, audio, video) is stored with reasoning concerning the knowledge. Typically, argumentation (or design rationale) means the understanding of why an artifact has been designed the way it has [15]. To argue for knowledge, we will use the Question-Answer-aRgument (QAR) method [34] and apply its concepts to knowledge rationale. QAR has been chosen because of its inherent support for hypertext functionality (linking, annotating, hyperdocument structure, etc.) and simplicity. In matter of a fact, it has originally designed in order to simplify the explicit rhetorical structure of rationale capture [34]. One suitable Web 2.0 technology for knowledge rationale is provided by Wikis. Knowledge objects can be argued within Wiki pages using QAR. In this way Wiki users would contribute collectively in the forming of the rationale. One of the most important steps in implementing the 7C Knowledge Environment is the integration of Wiki and QAR: the users must be able to interact with the argumentation stored in QAR and the knowledge stored in the Wiki pages.

5.3 Technologies supporting MAWIS

A mobile aware Web information system is a Web Information System that has been designed with potential usage with wireless interfaces in mind [35]. For successful construction of mobile aware Web information systems, content and presentation (functionality) should be separated from each other [36]. This enables information exchange with other information systems and also makes customization towards wireless devices easier, which further increases support for Connectivity and Concurrency. One way to separate the content and presentation is using XML to define the content and document structure and a stylesheet language to define the presentation [24]. Often Cascading Style Sheet (CSS) or Extensible Stylesheet Language (XSL) is used for presentation. As XML, CSS and XSL are integral parts of AJAX implementing 7C as mobile aware should be rather straightforward.

5.4 Other technologies for implementing 7C

Other solutions besides AJAX have emerged to support rich user experiences. One such solution is Adobe Flex. Typical Flex applications consist of interface elements build with MXML (Macromedia Flex Markup Language) and interactivity designed with ActionScript [9]. With Flex it is possible to create Flash-based applications with features such as chat, real-time dashboards, messaging and data push services [9] that run in a Flash player embedded in the browser. These Flash applications have excelled in recent years in streaming video on-demand [12]. An example of Flash for video streaming is YouTube⁴. Besides just streaming video Flash also lets users create layered visual effects by combining video with text, vector graphics, and other elements [12]. This could help users to comment certain interesting parts of the video instead of just commenting the whole video. This would imply that a Flash player would be suitable for playing the videos stored in the 7C environment.

A challenge for using solutions such as Flex is that they require a plug-in⁵ to work with. This does not enable the best possible connectivity since all users will not install the plug-ins needed. Also the use of plug-ins in mobile settings is often impossible. Another way to provide richer use experiences is by extending the browser through user interface markup languages [45]. One such markup language is XUL (XML User Interface Language

⁴ http://www.youtube.com
⁵ A plug-in is a program that interacts with a Web browser to provide a certain function on-demand.
A specific support tool for Comprehension should allow rich interaction with the existing knowledge: the users should be able to browse, search and categorize knowledge and the knowledge rationale stored in the 7C environment. Using personal and shared tags supports Comprehension by providing the kind of associative linking which enables the user to recognize similarities and possibly to identify specific needs and opportunities as well as potential problems. A richer user experience provided through AJAX or Flash may facilitate this interaction even more as the user is able to ‘play with’ the knowledge in a richer way than with the normal interaction capabilities provided by the static Web pages. In fact, the richer the interaction the better the chances probably are for comprehending something new.

By tagging a user may share associative links with other users. This may facilitate Comprehension and Communication. For example, navigating through pieces of knowledge that have been tagged in a similar manner forms a path [6]. This may provide context for deeper Comprehension, e.g. through recognizing similarities. In a matter of fact, tags, as well as other ways to support link typing, are in the very heart of both Comprehension and Communication subprocesses, and for this reason the 7C Knowledge Environment should support flexible linking through different types of links.

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 weblog. Weblog entries should be able to link with anything within the system (see Figure 3). Writing and reading blog entries may facilitate Communication, in particular when users comment other users’ blog entries. Users should be able to modify one’s own blog entries, but they should only be allowed to read and comment other users’ blogs.

Figure 3. Users can link their blog entries to other users’ blog entries and to other objects within the system.
A tool that would support Conceptualization should enable users to collectively articulate tacit knowledge in order to form explicit concepts. This paper approaches these concepts through the knowledge rationale. Each concept consists of an explicit knowledge object and the rationale behind it (see “Concept 1” in Figure 3). A Conceptualization tool should allow people to edit the explicit knowledge as well as argue for or against the question-answer pairs in the QAR and attach these debates into the knowledge objects at hand. Users should also be able to link concepts and knowledge objects together to show associations between them [6], e.g. concept1 could be linked to concept2 or to knowledge object1, and knowledge object1 could be linked to knowledge object2 or to concept1, etc.

It should be also possible to form different concepts from one knowledge object. The same knowledge object may be used in different situations and each situation may require different arguments. Thus, we can create many concepts from one knowledge object (see Figure 4).

![Concept Flow Diagram]

**Figure 4.** One knowledge object can belong to many concepts.

Storing and retrieving knowledge is important because without it organizations would not have a memory, and knowledge would be forgotten as soon as it was not used anymore. In the proposed architecture all explicit knowledge artifacts created in any subprocesses must be stored. This includes communications in the Communication process, knowledge rationale and the concepts produced in Conceptualization, and so on.

A knowledge repository tool has two main features. It must allow the knowledge to be stored and retrieved, and it should enable removing unnecessary or gratuitous knowledge, when seen fit. The easiest implementation of the knowledge repository tool would probably be to make it a Wiki [43].

A tool support for Collaboration must allow the use of explicit concepts created in Conceptualization as well as the reuse of previous work carried out. The collaboration should be based on a shared virtual environment which would form a basis for the whole toolset. This may be done through a Wiki, where users may work collaboratively with the Concepts produced. The Wiki should also support visualizing the conceptualizations. In addition, a Wiki should handle the organization and distribution of work.

7 Discussion

The application layer of the 7C architecture is represented in Figure 5. In its simplest form, 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 to define 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 produced knowledge objects using QAR. Wiki also works as a vehicle for Collaboration.
Integrating Blogs or at least blog-like features into Wikis should be rather straightforward. In a lightweight solution, normal Wiki pages could be used as personal blogs, but to take full advantage of the 7C model, at least permalinks and traceback of the blog functionality must be included in the implementation.

The implementation of the 7C Wiki should use the technologies of Web 2.0. Especially tagging is essential, since it allows the kind of associative linking that could help both Comprehension and Conceptualization. QAR is suitably lightweight in supporting rationale related to knowledge objects. Too complicated a method of including rationale to knowledge objects might discourage users, and they might end-up not using the tool. AJAX and the technologies included in it offer the kind of rich user experience that might facilitate Comprehension and Collaboration. XML offers the technology to capture the content of all the knowledge produced in 7C Information System. Different stylesheet languages (CSS and XSL, in particular) provide a way to represent this knowledge in any required form, e.g. mobile device or desktop computer.

On the conceptual level of the proposed architecture we have the key concepts that influence both of the layers above it. In a way the key concepts in the conceptual layer are a summary of the whole 7C environment: A mobile aware Web information system providing the needed Concurrent Connection on top of which hypertext functionality provides the means for users producing the knowledge rationale.

Table 2 presents the key 7C subprocesses and how they are supported by the 7C Knowledge Environment.

Concurrent Connection is provided by designing the system as a mobile aware Web information system (basically a Wiki). For the Comprehension subprocess the user’s interaction with the existing knowledge should be as rich as possible. The rich user experience delivered possibly by AJAX may be a key to success as richer experience may foster Comprehension. (S)he should also be able to use associative linking (tagging) to identify similarities. For the Communication, traceback and permalink features provide better participation and thus help users to communicate as they know better when and how someone comments their texts. Conceptualization is probably the least researched part of knowledge management. We propose that knowledge rationale can be used to better support forming of explicit concepts required by the model. Wiki technology seems to be a natural way to support Collaboration. However, implementing all of the 7C features on top of a Wiki may be challenging.
Table 2. Support of the proposed architecture for the subprocesses of the 7C model.

<table>
<thead>
<tr>
<th>7 Cs</th>
<th>How they are supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connection</td>
<td>The system is designed as a mobile aware Web information system</td>
</tr>
<tr>
<td>Concurrency</td>
<td>Wiki handles concurrency control. Mobile access improves the chances for concurrent users.</td>
</tr>
<tr>
<td>Comprehension</td>
<td>The users can interact with the knowledge and arguments stored in the environment, e.g. editing, linking (including tagging), commenting, combining existing knowledge</td>
</tr>
<tr>
<td>Communication</td>
<td>Users can blog to communicate about their experiences and to read other users’ experiences.</td>
</tr>
<tr>
<td>Conceptualization</td>
<td>The users can use QAR to argue for and against a question to define the explicit concepts in a form of knowledge rationale</td>
</tr>
<tr>
<td>Collaboration</td>
<td>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.</td>
</tr>
<tr>
<td>Collective Intelligence</td>
<td>All the created knowledge is stored in the environment and it can be retrieved whenever needed, e.g. in the Collaboration process</td>
</tr>
</tbody>
</table>

The continuous use of the proposed knowledge environment (in which all of the created knowledge is stored) should improve the efficiency and capabilities of its users, and thus in time also the Collective Intelligence of the organization. The most critical part of the environment is the Knowledge Rationale and how it can capture the concepts created in Conceptualization.

8 Conclusion

This paper presented the 7C information systems architecture. The architecture consists of three layers, supporting extendibility and modularity as the role of extendibility and modularity are essential in IS architectures [31]. The conceptual layer composes of the key concepts posited by the 7C model. The technology layer presents possible technologies that could be used to implement the key concepts. And finally, the application layer presents the working applications of the 7C environment.

In its simples for the 7C Knowledge Environment is a Wiki that supports knowledge rationale using QAR. The environment must also allow the users to communicate (using permalinks and traceback) and to interact with the knowledge stored in it. This interaction should go deeper than just browsing the knowledge: the user should be able ‘play with’ the knowledge. This richer interaction can provide a way for comprehending something new. The Wiki technology in itself supports the Collaboration very well.

As a future work, a toolset following this architecture should be implemented and experimented with. The most crucial parts of the 7C model as well as the proposed architecture are Comprehension and Conceptualization. Special emphasis should be put on implementing and testing those, in particular the capture of knowledge rationale through the QAR method as the conceptualizations are used or interact with in many 7C subprocesses. Another important aspect that needs further study is the use of linking and different link types for Comprehension and Communication, e.g. using tags to recognize similarities or guided tours in sharing experiences.

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References:


