A MOBILE COLLABORATIVE VISUAL SYSTEM TO SUPPORT KNOWLEDGE CREATION

GUSTAVO ZURITA

Information systems and Management Department, University de Chile, Diagonal Paraguay 257, RM, Santiago de Chile, Chile
e-mail: gzurita@fen.uchile.cl

NELSON BALOIAN and GABRIEL PEÑA

Department of Computer Science, Universidad de Chile, Blanco Encalada 2010, RM, Santiago, Chile
e-mail: nbaloian@dcc.uchile.cl, gpena@dcc.uchile.cl

Knowledge Management (KM) is a critical activity inside organizations. It has been said to be a differentiating factor and an important source of competitiveness. An important part of the knowledge asset an organization has is tacit knowledge, which is knowledge that is not formalized yet and is difficult to share. KM supporting systems help people inside an organization to convert this tacit knowledge into explicit knowledge and to share it. This paper presents the design, implementation, and preliminary tests of a KM system called MCKC, for Mobile Collaborative Knowledge Creation, supporting face-to-face knowledge creation and sharing in mobile scenarios, allowing people to create, make explicit and share their knowledge with their co-workers, using visual metaphors, gestures and sketches to implement the human-computer interface.

1. Introduction

Knowledge Management (KM) has gained growing interest among management theory and practice researchers (Becerra-Fernandez & Cousins, 2007; Jennex & Olfman, 2006; Maier, 2004; Soo, Deninney, & Midgley, 2005). KM theories identify two types of knowledge that might be managed: explicit and tacit. Explicit knowledge is systematized and standardized knowledge, which can be expressed by a formal language, using records, reports, or files. Tacit knowledge is the knowledge people acquire through verbal face-to-face conversations, exchange of personal experiences or by their own intelligence, but they are not able to communicate it. Tacit knowledge resides in someone’s mind and it is difficult to externalize due to some particular reasons, for example, because it is not structured enough, (Matuszewski & Balandin, 2007); it has to be transferred in a certain social context in order to be interpreted by the receiver, (Wiberg, 2001); or it is difficult to represent, (Yongjin, Xinyan, Jiancang, & Zhiguo, 2008). Nonaka and Takeuchi (I. Nonaka & Takeuchi, 1995) proposed the Socialization, Externalization, Combination, Internalization (SECI) model in order to convert tacit knowledge into explicit knowledge in the so called Knowledge Creation (KC) process. As opposed to explicit knowledge, it might be very difficult to take advantage of tacit knowledge in order to achieve KC, since it is difficult retrieve and share it. This process has been conceptualized as a never-ending spiral (Ikujiro Nonaka, Toyama, & Konno, 2000). There might be also some productivity barriers hindering its use due to the presence of free-riding practices, evaluation apprehension, production blocking, (Matuszewski & Balandin, 2007) or lack of trust among people who create knowledge in the organization, (Holsapple, 2003).

Nevertheless, Knowledge Creation (KC) is an important factor for competitiveness of an organization. Explicit and tacit knowledge may be of critical importance as input data and information to support decisions to improve business processes efficiency in an organization and have a better organized community (Becerra-Fernandez & Cousins, 2007; Jennex & Olfman, 2006; Ikujiro Nonaka, von Krogh, & Voelpel, 2006; Soo, et al., 2005). Much of the literature on KM systems addresses issues such as how to facilitate the creation, storage, and transfer of explicit knowledge (Alavi & Leidner, 2001). By their very nature such systems can mainly handle explicit, codified knowledge, and there is little guidance on how to render tacit knowledge into explicit, so that it can be handled by the system. Researchers have mainly directed their research towards understanding the codification of explicit knowledge for KM systems solutions, while the importance of tacit knowledge has gone unnoticed from an empirical perspective (I. Nonaka & Takeuchi, 1995). Most technologies used in KM and KC include from successful databases storing best practices to artificial intelligence systems supporting human decision making processes. These solutions have been so far designed for stationary workplaces and consequently require the corresponding infrastructure, i.e. personal computers and fixed line network access. This implies that mobile workers cannot be supported by the knowledge pool that is available in their organizations while performing their tasks outside the office, nor can they contribute to the knowledge pool at places and moments when they really need (Balfanz, Grimm, & Tazari, 2005; Becerra-Fernandez & Cousins, 2007; Fagrell, Forsberg, & Sanneblad, 2000; Matuszewski & Balandin, 2007). Mobile workers often have spontaneous face-to-face meeting anywhere, anytime which are nowadays considered critical activities in any organization. In these meetings they develop processes of social interaction, communication and mutual trust that yield to explicit and tacit knowledge creation. (Wiberg, 2001). The aim of this work is to explore the role of mobile technology (software applications running on PDAs and/or tablet-PCs) as technological support for this kind of mobile meetings, providing simple but helpful visual mechanisms to support knowledge creation, especially targeted for tacit knowledge (Matuszewski & Balandin, 2007). The inclusion of visual mechanisms is supported by the fact that smart visualization mechanisms have been recognized to be powerful tools supporting the transformation of tacit knowledge to explicit knowledge, thus promoting knowledge creation (Yongjin, et al., 2008).

We present a prototype of a collaborative face-to-face system supporting KC in mobile scenarios based on simple visual representations of knowledge. The prototype's design takes into consideration empirical and experimental researches including: 1) The SECI knowledge transformation model to developed a platform which supports acquisition of explicit knowledge, and helps to externalize implicit knowledge to explicit "new knowledge" (KC), (Ikujiro Nonaka & von Krogh, 2009; Ikujiro Nonaka, et al., 2006; Wierzbicki & Nakamori, 2007; Yongjin, et al., 2008). 2) Results of researchers about the loss of productivity in the generation of ideas (free-riding, production blocking, and evaluation apprehension, see section 2.2), and the relevance of working with a system supporting the face-to-face social interactions, (Brown, Dennis, & Gant, 2006; Chen & Huang, 2007). 3) Recommendations about the role of information visualization mechanisms in order to manage the KC process (see section 2.1) and the tacit and explicit knowledge management (section 4). 4) Recommendations about the role of mobile devices wirelessly interconnected when mobility is required (see section 3). And 5) Recommendations about using gestures and sketches as the main interaction paradigm with mobile devices having touch-screen in order to easily interact with the system and raise the productivity (sections 2.1 and 4).

The next section (Section 2) shows the state-of-the-art about knowledge creation in face-to-face working scenarios. Section 3 describes the design principles applied to the KC and KM system which we called MCKC (Mobile Collaborative Knowledge Creation). In section 4 we present a conceptual model on which the prototype is based, followed by the description of the prototype itself. In section 5 we present an activity carried on in order to make a preliminary test about the usability and utility of the system. In section 6 we present another practical experience with the system carried on in order to explore the role of the system in the KC and KM processes. Finally, we present in the conclusions (section 7) an analysis of the obtained results and we describe the following steps in the further development of this system.

2. Knowledge creation in a face-to-face scenarios

2.1. *Visual mechanisms, sketching and brain-sketching*

According to (Yongjin, et al., 2008), systems using visualization mechanisms to manage information facilitate the conversion of tacit knowledge into explicit knowledge. For them, visualization enables knowledge "mapping" facilitating its creation and sharing. In KC visualization is used to support the creation of tacit knowledge individually or collaboratively by means of sketches, concept maps, graphical representations, etc. It facilitates the clarification and enrichment of the tacit knowledge for an individual herself or when trying to share her knowledge with others, supporting the development of different points of view.

Previous works on the field (van der Lugt, 2005) highlight the following advantages of sketching in idea face-to-face generation meetings: a) in relation to thinking, sketching stimulates a re-interpretative cycle in the individual participant's idea generation process, b) in relation to the talking, sketching stimulates the participants to re-interpret each other's ideas; and c) in relation to the storing, sketching stimulates the use of earlier ideas in the idea generation process by enhancing their accessibility. The visualization technique called 'brainsketching' (van der Lugt, 2005) was used to describe idea generation techniques that use sketching. Brainsketching is a graphic variation of the more widely known brainwriting technique. Commonly during brainsketching, participants sketch ideas individually. After this, they briefly share their ideas and switch papers. In the next round they use the ideas already present on the worksheet as a source of inspiration. Van der Lugt concludes that: a) in idea generation groups, sketches can stimulate creativity, especially in the immediate individual idea generation process, by providing new directions for idea generation in an individual generate-interpret cycle; b) sketches can provide a more integrated group process by providing better access to the earlier ideas. (McGown, Green, & Rodgers, 1998), say that paper-based sketches is faster, easier to use, has better response quality, and better expressive quality than computer-based sketching, and concludes there is no reason to attempt to replicate freehand sketching by computer methods. However, computers provide desirable features not offered by traditional 'paper-based' methods: storage and retrieval of the work, faster search for material held in storage via meaningful processing techniques, durability and permanence.

2.2. *Brainwriting-based Knowledge creation in groups*

According to Bernard and Wolfgang (2006), Paulus and Yang (2000), most people believe that knowledge creation is best performed in a face-to-face groups because interaction with other people stimulates creativity. However, controlled research has consistently shown that people produce fewer and lower quality ideas working in a group as compared with when working alone or in nominal groups. Nowadays, much has become clear about the causes of the productivity loss of face-to-face brainstorming groups: a) **free riding** is the tendency to let to others group members do the work; b) **evaluation apprehension** is when groups start out with a low rate of production which are maintained in the rest of the session; c) **production blocking** refers to the fact that group members have to take turns when expressing their ideas as soon after they are generated because they have to wait for their turns.

In accordance to (Paulus & Huei-Chuan, 2000), electronic brainwriting and brainsketching can be used to reduce or even eliminate production blocking, evaluation apprehension, and also free riding. Moreover, the findings of (Herring, Jones, & Bailey, 2009; Paulus & Huei-Chuan, 2000) indicate that sharing written ideas in groups is a mean to enhance creativity. In (Paulus & Huei-Chuan, 2000) is proposed an initial session of independent writing of ideas. These ideas are subsequently shared by the group in a round-robin fashion and summarized, selected and chosen on a blackboard. Then the group discusses the ideas for clarification and evaluation. Finally, there is an individual and/or collaborative process to rank the ideas in order to take a final decision.

2.3. *Knowledge creation and collaboration*

KC focuses on the manifestation of "new knowledge", which is based on the inspiration and experience of individuals, groups and communities, obtained through the mutual transformation of tacit to explicit knowledge (Brown, et al., 2006; Chen & Huang, 2007; Soo, et al., 2005). KC is a social, collaborative, and dynamic process transforming tacit into explicit knowledge (Herring, et al., 2009; Ikujiro Nonaka & von Krogh, 2009; Vorakulpipat & Rezgui, 2006; Wierzbicki & Nakamori, 2007). It is produced by each person in the organization while doing their work individually or collaboratively in a face-to-face way. This knowledge is used as required at any moment and place.

Nonaka's SECI model (I. Nonaka & Takeuchi, 1995), includes four ways of knowledge transformation (see Fig 1): 1) **Socialization** (tacit-tacit) is the assimilation process of tacit knowledge and its conversion to a new tacit knowledge among individuals who experience face-to-face collaboration. Here, knowledge is transferred by demonstration, observation, apprenticing, behavior modeling, actual practice or, doing. 2) **Externalization** (tacit-explicit) is the change from tacit knowledge into explicit knowledge, which occurs when tacit knowledge is described or abstracted as concepts, formulas, rules and theorems, etc, directly with the spoken, written languages, observation, walk tracking, "osmosis", etc. This process occurs in groups and communities. Knowledge is transferred through (partially) explicit information by the use of metaphors, analogies, prototypes or sketches. 3) **Combination** (explicit-explicit) is the production of new explicit knowledge through analyzing, classifying and sharing of explicit knowledge. In this case, knowledge is transferred formally and informally, by verbal or written means. 4) **Internalization** (explicit-tacit) refers to individuals or organizations applying theory

to practice, turning explicit knowledge into one's own tacit knowledge through practice. Knowledge is transferred through common or shared understanding of abstract expressions or expert source of information.
Nonaka et. al. (2001) developed a model of KC that involves a continuous interaction between tacit and explicit knowledge in order to produce new knowledge within groups or communities. It has therefore been argued that tacit or implicit knowledge can be converted to explicit knowledge by “reflection in action” (Schön, 1983), by the use of metaphors and analogies (Ikujiro Nonaka, 1994) or by using mentoring and storytelling (Swap, Leonard, Shields, & Abrams, 2001). Although it is possible to “externalize” some parts of implicit knowledge, some aspects of tacit knowledge, particularly those related to creativity, intuition, emotions, and skills, are unlikely to be ever made completely explicit.

2.4. *Communication channels and trust in Knowledge Creation*

According to (Derballa & Pousttchi, 2004), tacit knowledge creation is associated with social interaction and knowledge exchange at an individual level, where not only the verbal channel is important, but also visual and emotional channels play a significant role. It is important to also use these channels in contexts where explicit knowledge is being created and specified on the basis of tacit knowledge, (Matuszewski & Balandin, 2007). According to (Wiberg, 2001), informal social interactions among individuals are fundamental for a knowledge creation process and technology can play an important role establishing the needed communication channels facilitating the exchange of ideas during these interactions. In relation to this, (Baloian & Zurita, 2009; Zurita, Baloian, & Baytelman, 2008) explain that mobile technologies are not disruptive when used during social interactions among people. In (Holsapple, 2003) the author explains that trust has a direct effect on explicit and tacit knowledge creation. According to their findings the more interpersonal trust (described as the generalized expectancy that the verbal statements of others can be relied upon) and organizational trust (described as the employee’s faith in corporate goal attainment and organizational leaders, and to the belief that ultimately, organizational action will prove beneficial for employees), the more will be the amount of information sharing, thus enabling the knowledge creation.

2.5. *Mobile knowledge Management*

Becerra-Fernandez and Cousins (2007), indicate that knowledge is increasingly being created and applied on the move by knowledge workers who work jointly in a face-to-face way. In accordance to Wang et al. (2006) for the time being, the potential of KM is usually limited to stationary workplaces because most KM support systems are designed for being used in Desktop PCs connected to a central server. This excludes a multiplicity of mobile workers, many of them in charge of knowledge intensive activities. An organization’s capabilities to support KM may be extended through the introduction of mobile technology usage.
The authors in Balfanz et al. (2005) argue that mobile KM supporting situated work has not attracted as much attention as it should, considering its potential. There are mobile systems developed with the aim of extending the information access everywhere and anytime by using PDAs (Fagrell, et al., 2000). Balfanz et. al. (2005) argue that mobile KM systems should be aware of the situation of the user while working, stressing that system goals and KM methodology should be well focused. For Balfanz et al. (2005) the most important goals for using KM in mobile scenarios are: 1) facilitate the creation, registering and sharing of the mobile workers’ knowledge, 2) exploit the accessibility and availability of the information resources anytime and anywhere 3) to provide privacy while working on ad-hoc networks.
For Probst et al. (1999) the mobile KM systems should focus on: a) supporting the creation and preservation of the knowledge where it is generated, b) facilitating knowledge creation, sharing and distribution in collaborative scenarios supported by ad-hoc networks, and c) promote knowledge use, by giving access and situational assistance.

3. Design principles applied to a face-to-face Mobile KC support

In (Malhotra, Majchrzak, Carman, & Lott, 2001) authors conclude that rather than focusing on systems to codify knowledge, we should instead concentrate on systems that facilitate collaboration between knowledge holders, creators and those needing the knowledge. Indeed, recent research has already begun to recognize the need to

incorporate support for face-to-face KC and sharing when designing KM systems in order to facilitate the transfer of complex, context-specific knowledge (Brown, et al., 2006).
In accordance to (Balmisse, Meingan, & Passerini, 2007), there are key functional requirements for KM systems: 1) **facilitate information contextualization** – better results are more often associated with access to the conceptual representation, structure of information, 2) **facilitate social interactions and networking** – digital socialization systems need to encourage spontaneous as well as casual meetings at any where any time with multiple views or modes of interactions, and 3) **present a ease to use human-computer interface - providing visual representation and organization of information**.
Considering the arguments and ideas mentioned before, we decided to develop a prototype of a KM system supporting KC in mobile scenarios with people collaboratively working face-to-face, which we will refer to as MCKC, for Mobile Collaborative Knowledge Creation. Its design principles are derived from the results of various previous empirical and experimental KC research works. They also consider the characteristics of mobile devices and human-computer interface design principles.
MCKC runs on Tablet-PCs and PDAs wirelessly interconnected by an ad-hoc network, with the possibility of synchronizing the data of the mobile devices with a central repository when the required networking infrastructure is available. In this way, people have access to the existing explicit knowledge anytime and anywhere. The touch-screen mechanism of their displays is used as the main human-computer interaction mean to input information to the system. Sketching is used as a visual tool for information management (see sections 2.1 and 2.2) and for supporting brainwriting and brainsketching processes. It is also used to implement command inputs by gestures, in order to implement a simple and easy-to-use application interface. By using sketching, the system implements the electronic paper and pencil paradigm, which facilitate the communication of tacit knowledge.
The system uses various visualization mechanisms for information management. MCKC implements the free-hand-based input paradigm which means user are able to draw sketches, edit graphic information and free-hand text writing, as well as using visual metaphors for information management like conceptual maps, the usage of gestures to trigger options, object dragging, visual presentation of the concept maps' nodes, etc. The creation of conceptual maps allows users to relate various concepts they might require to specify while managing their tacit and explicit knowledge. They can also associate each of the nodes with various documents, like text files, images, etc.
The system's design is oriented to facilitate KC collaboratively based on the SECI model (see section 2.3). According to this, the system has three modes: 1) **brainwriting/brainsketching**, or knowledge externalization support mode, 2) **selection of relevant information**, or socialization and combination support mode, and 3) **visual presentation and knowledge semantics of the created knowledge** mode, which is associated to the socialization process. Each mode responds to different requirements. The MCKC conceptual model shown in Fig. 1. presents these three modes as different technological support mechanisms (see section 5 for details) to the four relevant KC processes proposed by the SECI model (I. Nonaka & Takeuchi, 1995). In order to reduce the productivity problems associated to generation of ideas, each user can in the brainwriting/brainsketching mode externalize her ideas despite there are other colleagues doing the same. MCKC allows each person to use her own device to explain her knowledge, without having to concentrate in other ideas of the group. They can explain their ideas to others in the next step.
The three modes of the application are aimed to provide the environment that facilitates tacit to tacit knowledge sharing and creation, without the need to convert tacit knowledge to explicit knowledge before sharing it. There are three major aspects that contribute to make the conversion of tacit knowledge to explicit knowledge difficult: 1) people are unaware of the tacit dimension of their knowledge, 2) there are no reasons for an individual to make it explicit in order to use it, and 3) the risk of losing power by sharing knowledge. Hence, face-to-face communication should be used to share and personalize tacit knowledge, rather than a way for attempting to extract and store it. The exchange of tacit knowledge is viewed as a social process between people that requires face-to-face interaction.
MCKC considers social interaction as a key factor for collaborative KC, although it can be also used to support individual KC. As shown in Fig. 1., in this way we expect to reduce the productivity problem described in section 2.2 (see more details in section 5.1). Writing ideas instead of speaking them inside a group minimizes the

problem of **production blocking** since individuals do not have to wait their turn to generate ideas. It may also reduce **evaluation apprehension** since the written format eliminates the need for public speaking and is typically more anonymous than oral brainstorming. Also the **free-riding** problem might be reduced because it will be easier to identify not contributing people. Employees should not be forced to use a knowledge creation or sharing system. The system must be created to support their work and their social behavior, (Matuszewski & Balandin, 2007). The system has to adapt to employees' social interactions in order to let them be a member of a successful KC community and gain recognition. The relevant information selection mode of MCKC allows a person to explain the semantic associated to the knowledge that has been made explicit in order to build a common language.

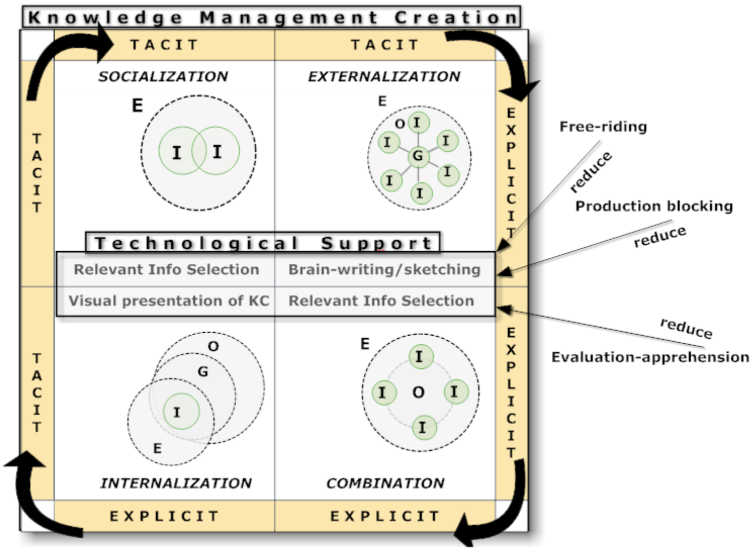

Fig. 1. Conceptual model of MCKC based on the SECI model. E=environment, O = organization, I = individual, G = group.

As for the face-to-face channels that users establish and the trust level they might develop during the use of this system, we can only say they are more dependent on the individuals themselves than on the support a system like this is able to provide. This means that the effectiveness of any KMS will always depend on the abilities, attitudes and intentions of its users and the level of trust they are able (or willing) to develop.

4. System description

As already establish, sketches help to externalize the tacit knowledge and hence express ideas and concepts from people's minds. They can also help people to order and clarify their own ideas before communicating them to others (McGown, et al., 1998; van der Lugt, 2005). This is why MCKC allows specifying the explicit and tacit knowledge by means of its interface. This interface allows the manipulation of information in a simple way using the device's stick to activate options using gestures. It uses visual mechanisms for presenting and manipulating information. It allows the edition of sketches and freehand writing and facilitates the interaction among members of a group working face-to-face collaboratively in KC. MCKC can be used anytime, anywhere which means it can be brought to any physical place of the organization, and can be even used while people are on the move (see section 3). In this section we describe briefly the functionalities of MCKC, its three working modes and the characteristics that make it a suitable tool for supporting KC. Each mode is oriented to support one stage of the SECI model. The system does not impose a certain order of sequence for using each mode which allows a spiral kind of development. It is always possible to go back to a previous mode in order to make corrections or even start from scratches again.

This description is based on a scenario where three persons of the marketing department of an organization are

trying to figure out how does the new poster advertising an all-terrain car should look like.
When the MCKC is started in each of the three persons' device the ad-hoc network is automatically established. The functionalities of the tool are the same for PDAs and Tablet-PCs and the application adapts the workspace to the screen's size. In small screens workspaces will appear with scrolling bars in order to match the size of the bigger screens. The first view of the interface is a white workspace with icons on the bottom to select one of the three modes the system supports (see the bottom of Fig. 2a.).

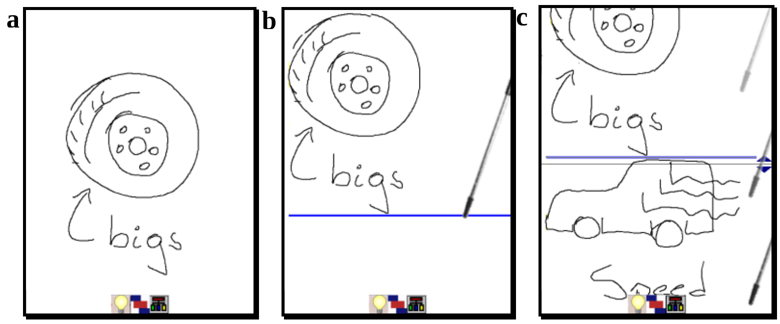

Fig. 2. Specification of an idea through sketching and freehand writing. In a) an idea consisting in a wheel and the text "bigs" is generated. In b) we see that a gesture of writing a horizontal line through the whole screen will mark the separation of two different ideas. In c) we see how the second idea is being produced with a sketch of a car and the "speed" text.

4.1. *SECI - Externalization: mode brain-writing/sketching*

The brainwriting/brainsketching mode supports the knowledge externalization allowing users to explain their tacit or explicit knowledge by jeans of freehand writing or sketching (see section 2.1). This mode works in a non-collaborative way by default, allowing users to freely prepare their ideas before sharing them, reducing the **free-riding, production blocking, and evaluation apprehension** problems (section 2.3). Users generate their ideas in parallel despite they are in a face-to-face situation (see Fig. 2).
If a previous idea has to be edited, the user selects the area where it is by a single click and "enters" the edition mode clicking the "arrow down" icon (see Fig. 3a.).

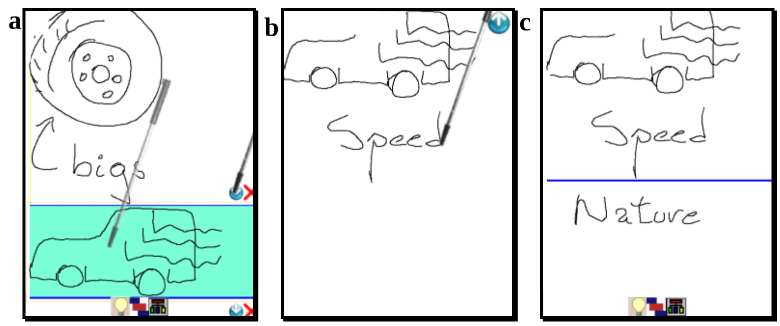

Fig. 3. Editing an idea. In a) an idea is being selected and then the "enter" icon is clicked. In b) the idea is being edited, which will be seen updated when the user leaves the editing mode.

In order to work collaboratively, participants have to activate the collaborative work option of the application. After this, they can share their ideas and start editing them collaboratively in the same way they did individually (sections 2.2 and 2.3). This supports the knowledge socialization process of the SECI model. Since ideas are shown one below the other a scrolling function is necessary to go through them, which is done by a gesture of sliding the stick up and down parallel to the right vertical border of the screen (Fig. 2c.).

4.2. *SECI-Socialization/Combination: relevant information selection mode*

Alter each user has externalized her ideas individually or collaboratively, it is necessary to refine them involving all group members, as already explained in section 4. In order to select the ideas it is necessary to define which are relevant and which can be discarded. In order to support this process, MCKC generates a list of all created ideas, which will be visually shown as rectangular boxes of similar proportions with colors associated to the participant who has created them. In this stage, the list of ideas is visible to all participants, as shown in figure 3. In order to rank them, participants have to vote for them positively or negatively. They can issue a positive vote for a certain idea by making a tick gesture on the left area of the rectangle representing it (see Fig. 4b). A negative vote is issued by making a tick on the right area of the rectangle (see Fig. 4c). Numbers from 1 to 5 represent the ranking of each idea according to the votes received, being 5 the most relevant. A 0 means the idea is not relevant at all. Because there might be many ideas, a scroll mechanism is also available in this mode (Fig. 4a.).

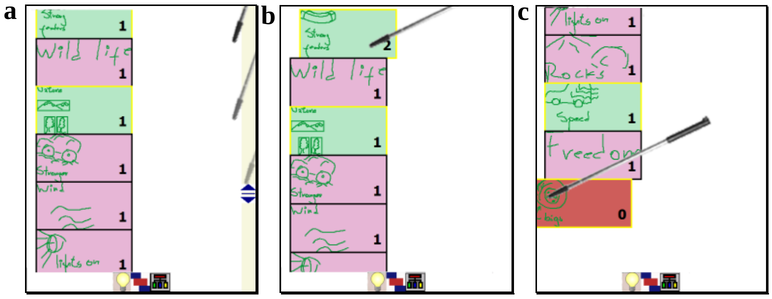

Fig. 4. List of ideas to be selected. a. Scrolling the ideas by moving the pen on the right of the screen; b. An idea is ranked from the level 1 to the level 2; c. An idea is ranked to the level 0 (irrelevant level).

At the beginning, before receiving any vote, the ranking number for an idea will be 1. The ranking number for an idea appears in the bottom-right corner of the rectangle. As ideas get ranked, they will be rearranged and grouped according to the ranking level. In this way, relevant ideas are easily differentiated from the irrelevant ones, supporting their selection.

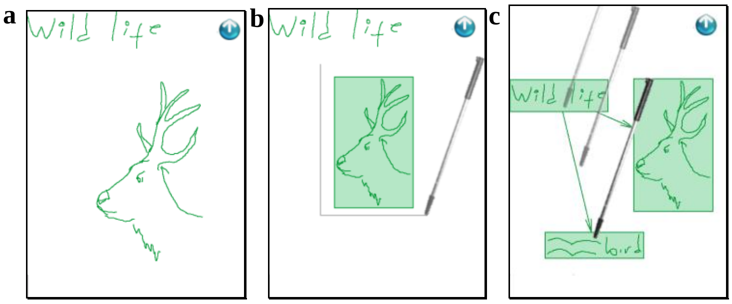

Fig. 5. Collaborative edition of an idea. In a) we see an idea's content in the editing mode consisting of a sketch and freehand written text. In b) we see how the sketch part of the idea can be converted into a node. In c) we see how we can relate nodes by creating arrows linking them.

An idea can be collaboratively edited while working in this mode by clicking in the middle area of the rectangle. Collaborative editing allows the socialization of the tacit and explicit knowledge (see section 4), allowing participants to combine their knowledge and perspectives about the ideas.

It is possible to add more information to an idea by means of including concept maps. Concept map's nodes can be created inside an idea by making an "L" gesture enclosing a single or a group of strokes previously drawn (see Fig. 5a.). This will be the node's label (Fig. 5b.). Users can get inside of these nodes to include more information as well as to create more nodes, creating a hierarchy of nodes. Nodes in the same level can be related to each other by drawing a line connecting two of them. This line will be converted to an arrow which will remain linking both nodes even if they are moved (Fig. 5c.). These conceptual maps allow users to organize and add a semantic meaning to the information. In order to have an overview of the concept maps already created and also in order to easily access them, MCKC offers a tree-view of them.

It is possible to merge ideas that might be similar. In order to merge similar ideas the user can drag the rectangle representing one of them (Fig. 6a.) and drop it over the idea which is similar (Fig. 6b.). An empty red rectangle at the end of the ideas' list will appear representing the idea which was moved. This is done in order to allow the "undo" of this action, by dragging the rectangle back and dropping it over the empty red rectangle (Fig. 6c.).

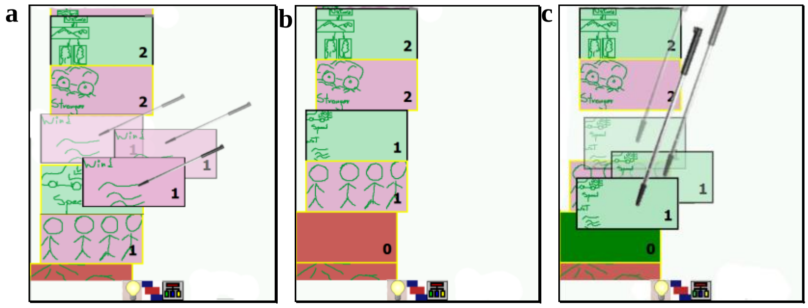

Fig. 6. Merging of ideas. In a) we see the action of merging two ideas. In b) we see that the rectangle containing the merged idea is situated at level 0. In c) we see the undo action.

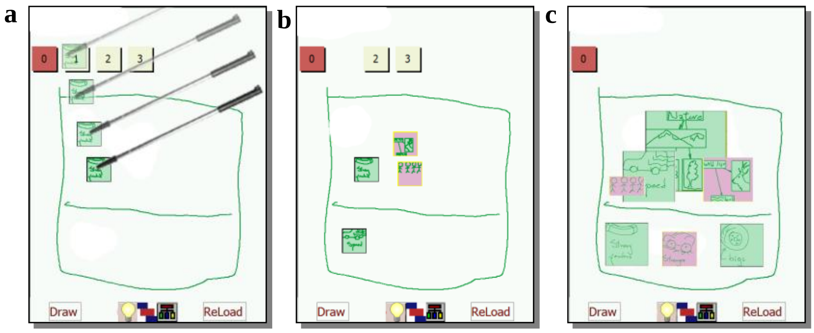

Fig. 7. Visual representation of the KC from the proposed ideas. a. An idea select, drag and drop on the visual representation; b. All ideas of level 1 were use on the KC representation, and this set disappears; c. Final result.

4.3. *SECI-Internalization: visual presentation and semantic of the KC mode*

This mode allows users to concretize the KC process using a final visual representation of the ideas. This process is done collaboratively with the agreement of all participants. For the example case, participants have to agree which ideas will be expressed visually and which in a written form on the poster.

At the beginning of this mode, an empty page will appear with a list of small squares at the top representing the ideas generated ordered according to their ranking. In this stage, participants have to make a visual arrangement of the ideas. This is an important stage during the KC because it is expected that the tacit and explicit knowledge to be expressed here with sketches and other visual representations (see section 2.1). It is expected that participants will first draw a sketch where ideas will be placed in a particular order according to the meaning of the sketch. In the example, users will determine the position where each idea will be placed in the poster. Ideas can be dragged from the list and dropped in the desired place (Fig. 7.). The placement of the ideas inside the sketch should represent a meaning collaboratively defined by all participants. The square representing an idea can be reshaped as desired (see Fig. 7.c). After placing the ideas on the schema, participants may finalize their proposal by skating which one would be fundamental to the project or they can go back to a previous mode in order to edit, the existing ideas or include new ones. Not used ideas might be deleted.

5. Usability and utility evaluation

The evaluation of collaborative technologies raises many methodological concerns and the evaluation strategies may differ in: moment (design, prototype, finished product), time span (hours, weeks, months, years), place (laboratory, work context), type of people involved (domain experts, final users, developers) and type of research questions (quantitative, qualitative) (Herskovic, Pino, Ochoa, & Antunes, 2007). Also, the scope of the evaluation may target different dimensions of analysis, from technical (e.g., interoperability) to organizational (e.g., effects on task performance) (Gauducheau, Soulier, & Lewkowicz, 2005; Vyhmeister, Mondelo, & Novella, 2006). Steves et al (2001) defend that inspection techniques should be employed in early development stages, when prototypes are still immature, and field methods should be employed afterwards. Based on this perspective, our evaluation method adopts inspection techniques.

For the usability and utility evaluation process we used two external consulters, two car sellers of a certain brand and two drivers (users). We proposed them the task of creating a commercial spot for a car. They had six working sessions during two weeks, during which they used MCKC in order to collaboratively work in a face-to-face modality to generate the ideas for the commercial spot. This work was monitored with inspection techniques to bring more context to the inspection task (Carroll, 2000; Haynes, Purao, & Skattebo, 2004). Then we conducted a workshop where all participants had to analyze the MCKC tool in the context of the predefined scenario. From the workshop we finally obtained a set of comments and observations regarding the usability and utility of MCKC tool. The workshop revealed that the free-riding, production blocking, and evaluation apprehension problems were partially mitigated by the use of technological support, which contrasted with the results of previous experiences where technology was not used. The explicit knowledge could be easily specified and communicated with the help of MCKC. It was also noted that that sketches helped to exteriorize and share tacit knowledge. The visualization of the artifacts on the system interface associated to data, information and functionalities triggered by gestures was well accepted and easy to use. However, more experimented user missed the menus, choice boxes and fast access keys. The "visual presentation and semantic of the created knowledge" mode, was by far perceived as the most helpful one because it's flexible and enriched way to represent knowledge as a final result of a goal. Second to this, the "brain-writing/sketching" mode, was also perceived as a very helpful way to easily specify ideas through sketches and the possibility to organize them as concept maps. In the whole MCKC was perceived as a relevant tool to support collaborative work because it enables people to contribute, explain, exteriorize and share their ideas. Regarding the usability of the MCKC, in general the participants suggested some additional improvements. A better support to navigating in the "relevant information selection mode". The participants regarded a major challenge to keep the awareness information and collaboration constantly up-to-date. The learning curve of MCKC was satisfactory completed during the second working session. Some difficulties were perceived on users who declared not having too much experience with technology.

6. Experiment and discussion

Another experience was carried on in order to check the hypothesis that MCKC effectively supports groups of users socially interacting among themselves in face-to-face scenarios in order to create knowledge by: 1) providing functionalities that facilitate information contextualization, social interaction, using an ease to use human-computer interface; 2) providing functionalities supporting brainwriting/brainsketching, selection of relevant information, and visual presentation and knowledge semantics of the knowledge being created; 3) reducing the productivity loss of groups due to free riding, evaluation apprehension, and production blocking. The samples included last-year undergraduate students from the School of Economics and Business, Commercial Engineering of the Universidad de Chile with an average age of 25. Two groups, totaling 18 students, participated in this experiment, 9 students were randomly assigned to the experimental group, and 9 to the control group. All of them had already passed the course about marketing foreseen in their studies program. Their task was to develop a marketing strategy proposal for a certain product that Based on information and specific features of a product that has to me released to the marked. The aim of this activity was to explore how each group of students conducted the necessary KC in order to achieve the proposed goal. The experimental

group used the MCKC tool to support their meetings and the control group used only paper and pen.
The research procedure was the following: First, they had a session where the task was explained. The experimental group had another session in which they learned how to operate MCKC. This session was about 2 hours long. After the introductory session(s) both groups were instructed to have mobile collaborative meetings at anytime and anywhere in the School dependencies in order to propose, discuss and develop the ideas for a marketing strategy. The only constrain was that they should have exactly 6 meeting during a period of time of two weeks. There should be three sessions per week; each session should be 1.5 to 2 hours long. After this activity the students had to submit an electronic document describing their ideas for a marketing strategy of the product. This document served as a basis to evaluate the work performed by both students groups. The analysis and evaluation of the document was conducted by three marketing expert faculty members. In addition, interviews were conducted consisting mostly of open answer questions. The questions were directed to identify the impact of the functionalities of the tool, the usage of the three working modes and the artifacts incorporated in order to reduce productivity loss, which were modified, verified and validates by domain experts.
All three faculty members confuted the evaluations and individually expressed that the quality and completeness of the proposal submitted by the experimental group were higher, however the proposal of the control group was fairly good enough for the faculty's market course standards. The experimental group work surpassed the quality of the control group work in identifying more precisely the goal market. Also their strategic plans were more innovative and described in more detail. They also proposed more ways to reach the potential clients, and they indicated more interrelation variables of various aspects that can capture the interest of the clients. Two faculty members also noted that the experimental group used more graphics and schemas to illustrate their proposal, which helped to better understand them.
Regarding the functionalities offered by MCKC, during the interviews the members of the experimental group highlighted following aspects: first the easiness to synchronize data and information entered to the system as well as the awareness about who is presenting and/or explaining something to the rest. Second, they said MCKC did not hinder the face-to-face contact, which was also important to achieve their goals. Third, the human-computer interface highly contributed to an easier sharing and synchronization of data representing their ideas. This last opinion of members from the experimental group highly contrasts with the opinion of one member of the control group who expressed that sharing the working documents took too a lot of time.
The use of the three modes of MCKC was considered very useful. Especially appreciated was the opportunity to exteriorize their ideas through sketches they can share immediately. The visualization of the relevant information and the possibility of organizing their ideas under a visual logic was the second most appreciated aspect of the tool.
Regarding the functionalities that MCKC provides in order to reduce productivity loss, some members of the experimental group opined that anonymity helped them to contribute more freely and felt that their ideas where considered while others expressed that they would have done exactly the same without anonymity. Some members of the control group expressed that they experienced problems associated to productivity loss when working together in the generation of a proposal, explanation of ideas as well as the analysis and selection of them.
The results of the experiment, as well as the interviews conducted with both group show that, with high probability, MCKC has a positive impact in KC. These preliminary results encourage us to do more formal experiments, with higher number of subjects involved, in order to more precisely determine the effects of causality between the SECI model and the functionalities and capabilities of the MCKC too.

7. Conclusions

People posses a big amount of tacit "hidden" knowledge which has to be converted into "new knowledge", in order to promote its delivery, sharing and innovation. In this way, this knowledge can be effectively used in the organizations where people work. MCKC is a tool that helps externalize this knowledge. Our work is based on the empirical and experimental findings of KC related Works, which have been incorporated into the system presented in this paper. The visualization technology of knowledge and the use of mobile devices as support for KM is a new field, which has already generated applications for different scenarios such as engineering, education and economy.

Our application supports the visualization of information in a free and extensible way. It also promotes the collaboration in mobile scenarios by making use of ad-hoc wireless networks, which helps to transform tacit into explicit knowledge, promoting the elicitation, transmission and sharing of information based on sketches. The KM success model developed by (Jennex & Olfman, 2006) emphasizes the need for KM systems to include both types of knowledge (tacit and explicit) and linkages or pointers to people with knowledge expertise. A better understanding of the various characteristics of the tacit knowledge dimension, as detailed in the present study, will assist researchers and practitioners in the development of more sophisticated knowledge management systems that can adequately address knowledge users' needs for both codified knowledge and interaction with human sources of knowledge.
In the near future we will focus on improving many functionalities of the prototype, studying alternative interaction modes, trying to minimize the overhead necessary to maintain data validity. Also, we will conduct more extensive tests of the prototype improved.

Acknowledgements

The work of this paper was funded by Fondecyt project 1085010

References

Alavi, M., & Leidner, D. E. (2001). Knowledge management and knowledge management systems: Conceptual foundations and research issues. [Article]. *MIS Quarterly, 25*, 107-136.

Balfanz, D., Grimm, M., & Tazari, M. (2005). *A Reference Architecture for Mobile Knowledge Management*. Paper presented at the Dagstuhl-Seminar 05181 2005, Mobile Computing and Ambient Intelligence.

Balmisse, G., Meingan, D., & Passerini, K. (2007). Technology Trends in Knowledge Management Tools. *International Journal of Knowledge Management, 3*(2), 118-131.

Baloian, N., & Zurita, G. (2009). MC-Supporter: Flexible Mobile Computing Supporting Learning through Social Interactions. *Journal of Universal Computer Science, 15*(9), 1833-1851.

Becerra-Fernandez, I., & Cousins, K. (2007). Nomadic context-aware knowledge management systems: applications, challenges and research problems. *International Journal of Mobile Learning and Organisation 1*(2), 103-121.

Brown, S. A., Dennis, A. R., & Gant, D. B. (2006). *Understanding the Factors Influencing the Value of Person-to-Person Knowledge Sharing.* Paper presented at the System Sciences, 2006. HICSS '06. Proceedings of the 39th Annual Hawaii International Conference on.

Carroll, J. (2000). *Making use: Scenario-based design of human-computer interactions*. Cambridge, Massachusetts: The MIT Press.

Chen, C.-J., & Huang, J.-W. (2007). How organizational climate and structure affect knowledge managementâ€"The social interaction perspective. [Article]. *International Journal of Information Management, 27*, 104-118.

Derballa, V., & Pousttchi, K. (2004). *Extending knowledge management to mobile workplaces*. Paper presented at the Proceedings of the 6th international conference on Electronic commerce.

Fagrell, H., Forsberg, K., & Sanneblad, J. (2000). *FieldWise: a mobile knowledge management architecture*. Paper presented at the Proceedings of the 2000 ACM conference on Computer supported cooperative work.

Gauducheau, N., Soulier, E., & Lewkowicz, M. (2005). *Design and evaluation of activity model-based groupware: methedological issues.* Paper presented at the Proceedings of the 14th IEEE International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprise, Washington, DC.

Haynes, S., Purao, S., & Skattebo, A. (2004). *Situating evaluation in scenarios of use.* Paper presented at the Proceedings of the 2004 ACM conference on Computer supported cooperative work, Chicago, Illinois.

Herring, S. R., Jones, B. R., & Bailey, B. P. (2009). Idea Generation Techniques among Creative Professionals. *Hawaii International Conference on System Sciences, 0*, 1-10.

Herskovic, V., Pino, J., Ochoa, S., & Antunes, P. (2007). Evaluation Methods for Groupware Systems. In J. Haake, S. Ochoa & A. Cechich (Eds.), *Groupware: Design, Implementation, and Use. 13th International Workshop, CRIWG 2007, Bariloche, Argentina, September 2007 Proceedings* (Vol. 4715, pp. 328-336). Heidelberg: Springer-Verlag.

Holsapple, C. W. (2003). *Handbook on Knowledge Management Knowledge Matters* (Vol. I). Berlin, Heidelberg and New York: Springer-Verlag.

Jennex, M. E., & Olfman, L. (2006). A model of knowledge management success. *International Journal of Knowledge Management, 2*(3), 51-68.

Maier, R. (2004). *Knowledge Management Systems* (2 ed.). Springer.

Malhotra, A., Majchrzak, A., Carman, R., & Lott, V. (2001). Radical Innovation without Collocation: A Case Study at Boeing. [Article]. *MIS Quarterly, 25*, 229-249.

Matuszewski, M., & Balandin, S. (2007). *Peer-to-Peer Knowledge Sharing in the Mobile Environment.* Paper presented at the Creating, Connecting and Collaborating through Computing, 2007. C5 '07. The Fifth International Conference on.

McGown, A., Green, G., & Rodgers, P. A. (1998). Visible ideas: information patterns of conceptual sketch activity. *Design Studies, 19*(4), 431-454.

Nonaka, I. (1994). A Dynamic Theory of Organizational Knowledge Creation. [Article]. *Organization Science, 5*, 14-37.

Nonaka, I., & Takeuchi, H. (1995). *The Knowledge Creating Company*. New York: Oxford University Press.

Nonaka, I., Toyama, R., & Konno, N. (2000). SECI, Ba and Leadership: a Unified Model of Dynamic Knowledge Creation. [Article]. *Long Range Planning, 33*, 5-34.

Nonaka, I., & von Krogh, G. (Writer) (2009). Tacit Knowledge and Knowledge Conversion: Controversy and Advancement in Organizational Knowledge Creation Theory [Article], *Organization Science*.

Nonaka, I., von Krogh, G., & Voelpel, S. (Writer) (2006). Organizational Knowledge Creation Theory: Evolutionary Paths and Future Advances [Article], *Organization Studies (01708406)*.

Paulus, P. B., & Huei-Chuan, Y. (2000). Idea Generation in Groups: A Basis for Creativity in Organizations. [Article]. *Organizational Behavior & Human Decision Processes, 82*, 76-87.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York: Basic Books.

Soo, C., Deninney, R., & Midgley, D. (2005). Knowledge Creation in Organizations: A Multiple Study Overview *Knowledge Management: Organizational and Technological Dimensions*. New York: Springer-Verlag.

Steves, M., Morse, E., Gutwin, C., & Greenberg, S. (2001). *A Comparison of Usage Evaluation and Inspection Methods for Assessing Groupware Usability.* Paper presented at the Proceedings of the 2001 International ACM SIGGROUP Conference on Supporting Group Work, Boulder, CO, USA.

Swap, W., Leonard, D., Shields, M., & Abrams, L. (2001). Using Mentoring and Storytelling to Transfer Knowledge in the Workplace. [Article]. *Journal of Management Information Systems, 18*, 95-114.

van der Lugt, R. (2005). How sketching can affect the idea generation process in design group meetings. [Article]. *Design Studies, 26*, 101-122.

Vorakulpipat, C., & Rezgui, Y. (2006). *From Knowledge Sharing to Value Creation: Three Generations of Knowledge Management,*. Paper presented at the Engineering Management Conference, 2006 IEEE International.

Vyhmeister, R., Mondelo, P., & Novella, M. (2006). Towards a Model for Assessing Workers' Risks Resulting from the Implementation of Information and Communication Systems and Technologies. *Human Factors in Ergonomics & Manufacturing, 16*(1), 39-59.

Wiberg, M. (2001, 3rd-6th January 2001.). *Knowledge Management in Mobile CSCW: Evaluation Results of a Mobile Physical/Virtual Meeting Support System.* Paper presented at the In Proceedings of the 34th Hawaii International Conference on System Sciences (HICSS'34), Maui, Hawaii, USA.

Wierzbicki, A. P., & Nakamori, Y. (2007). Knowledge Sciences: Some New Developments. *Zeitschrift fur Betriebswirtschaft, 77*(3), 271-296.

Yongjin, Z., Xinyan, H., Jiancang, X., & Zhiguo, W. (2008). *Study on the Knowledge Visualization and Creation Supported Kmap Platform*. Paper presented at the Proceedings of the First International Workshop on Knowledge Discovery and Data Mining.

Zurita, G., Baloian, N., & Baytelman, F. (2008). A collaborative face-to-face design support system based on sketching and gesturing. *Advanced Engineering Informatics, 22*(3), 340-349.