Designing Information Systems for Creative Problem Solving and Learning

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Abstract

Creativity is often seen as a crucial element in the innovation process. However, the individual and group creativity is difficult to recognise and support for the corporate innovation process. This research searches answers how information systems (IS) could facilitate the creativity, learning and problem-solving processes. Findings from systems theories literature suggest that social networks and brokering play an important role. The design process of a mobile information system is illustrated. Although an IS can be advantageous in the innovation process, certain leadership and human resource management questions are raised.

Keywords

innovation, creativity, brokering, problem solving, learning, design research, information system

Introduction

> Establishing a systematic process to capitalize on creativity is an essential capability for enterprises operating in an accelerated business environment. A seeming paradox of innovation is that the most-useful ideas originate from a structured process rather than random occurrences of creativity. (Rozwell, 2002)

Peter Drucker emphasises systematic innovation which consists in the purposeful and organized search for changes, and in the systematic analysis of the opportunities such changes might offer for economic and social innovation. (Drucker 1985) The challenge in the innovation process is how environmental factors (like search for changes and opportunities) could be supported. Below is illustrated a typical, generalised innovation process.

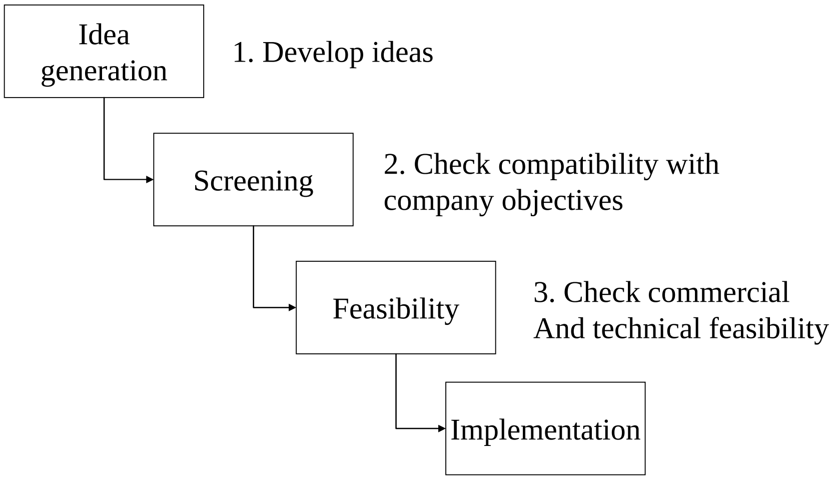

Figure 1. The innovation process (Majaro, 1988)

Many current initiative systems, innovation competitions and even innovation management information systems in use in organisations utilise this kind of process. The screening and feasibility phases in the picture above are sensitive, both from evaluation and process management perspective. Hargadon and Sutton (1997, 717) put it: “Valuable solutions seldom arrive at the same time as the problems they solve, they seldom arrive to the people working on those problems, and they seldom arrive in forms that are readily recognizable or easily adaptable.” Radically speaking, Amabile (1998) sees that evaluation kills creativity. We may also ask how functional the innovation process described by Majaro (1988) is when for example social innovations or research-based ideas are inspected. The paradox inherent in the innovation process is that innovators need wide-ranging ties across distant worlds to generate the innovative ideas in the first place, yet they also need strong, focused ties to build communities around emerging innovations. Firms must commit resources to both. (Hargadon, 2003, 89) For this reason innovation literature has more and more focused on meaning of social networks.

When McAdam and McClelland (2002) made a survey of published creativity and innovation process literature, their finding was that the idea generation literature tended to focus on the mechanics of idea generation to the detriment of the underlying knowledge creation philosophy. Three case organisations (an SME, a global company and a faculty) and their groups are chosen for this on-going dissertation work to understand these knowledge creation philosophies. When thinking about of level of analysis, the groups are here in focus: “Groups often create novel and unexpected combinations an organisation’s past knowledge in ways that individual or more formal organizational structures do not” (Hargadon, 1999, 137).

The aim of this paper is to briefly describe the building process of an integrated problem solving-learning artefact, starting from theories of learning and creativity, and extending scope on group processes, data gathering and use of information systems. Finally, the conclusion and summary chapters will illuminate which areas may require additional research.

Creativity and problem solving in the innovation process

Creativity is often seen as the generation and emergence of new ideas. It is thinking outside the box, coming up with novel ideas through divergent, tangential thinking. Conversely, innovation is turning ideas into products, services and processes. (Couger 1995) The following figure illustrates creativity as an integral element in the whole innovation process.

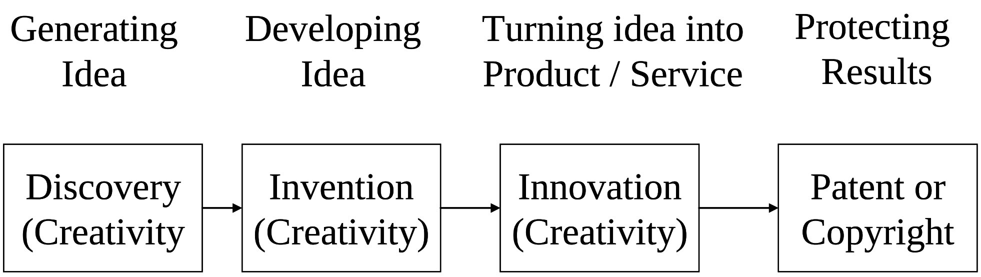

Figure 2. Creativity in the innovation process (Couger, 1995)

This view of Couger is different from Majaro's (1998), Couger's innovation process includes problem discovery. These phases can be broken down to even smaller CPS particles. Creative Problem Solving (CPS) is originally based on work of Osborne (1963) and is related to applied imagination. CPS means a step-based approach to define a problem and find solutions to it. Treffinger and Isaksen (1992) have for example defined following 6 phases: (1) mess-finding, (2) data-finding, (3) problem-finding, (4) idea-finding, (5) solution-finding and (6) acceptance-finding. When an artefact or an information system is built to support innovation process, author sees that all these phases should be supported. The question here is how these individual-based CPS phases can be modelled to support group creativity.

The following systems model of creativity by Csikszentmihalyi (1996) is a useful construct, since it emphasises the evaluation of creativity by the field and co-operation with different players. The model of Csikszentmihalyi changes one of the basic questions in the study of creativity from "What is creativity?" to "Where is creativity?".

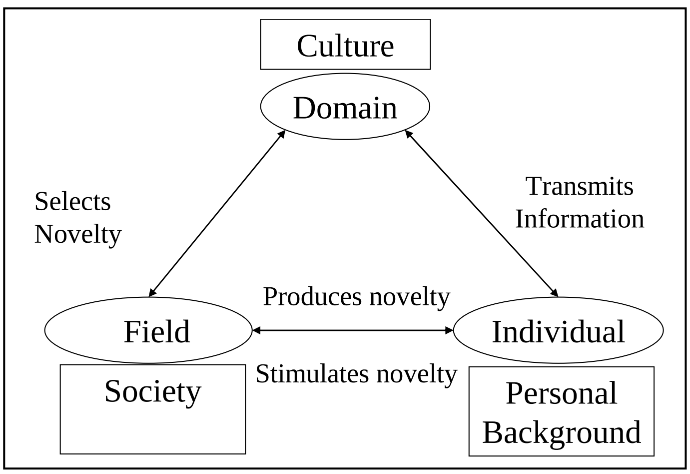

Figure 3. Systems model of creativity (Csikszentmihalyi, 1996)

To be able to create something new, the Individual needs to first to become an expert in the Domain. Only after that the Individual is able to change the rules of the Domain and produce novelty. This novelty needs to be evaluated and accepted by the experts in the Field.

How are the CPS processes integrated to Csikszentmihalyi's systems model of creativity? How is problem defining supported? The following figure illustrates a full problem-solving cycle *inside* the systems model.

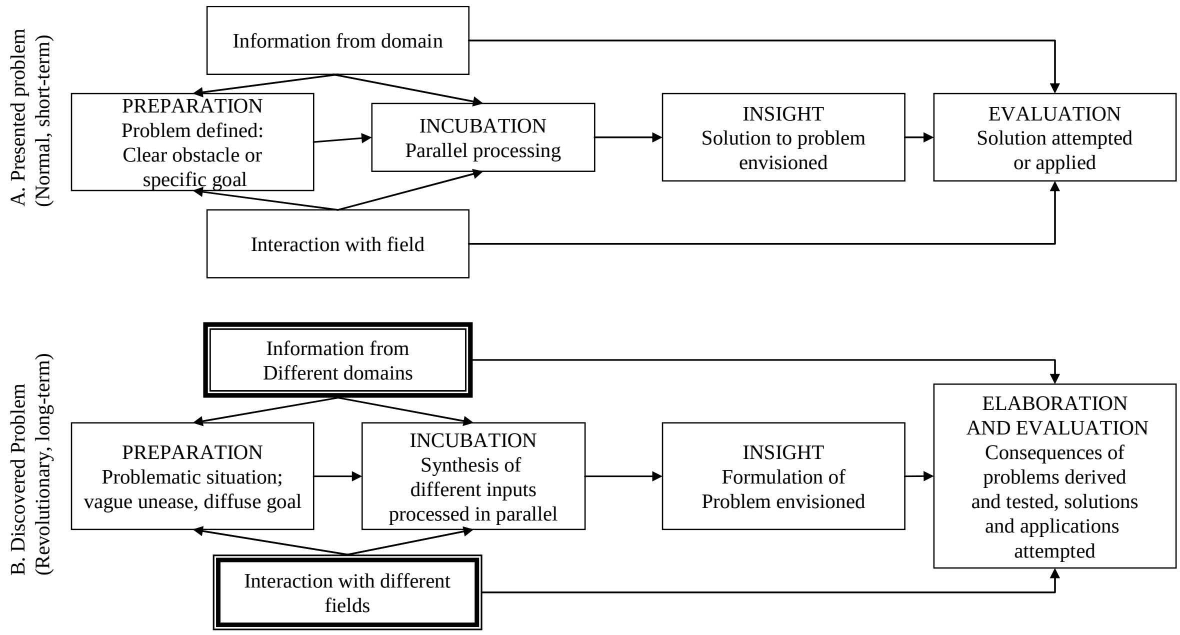

Figure 4. Proposed models of presented and discovered problem solving (Csikszentmihalyi and Sawyer, 1993)

In the picture above the presented problem solving is different from discovered problem solving. Discovered problem solving needs information from different domains and requires interaction with different fields. In that sense, the social network focus and brokering activities are built in the model. Regarding the CPS-phases, Csikszentmihalyi and Sawyer use four phases: (1) preparation, (2) incubation, (3) insight and (4) elaboration-evaluation.

Group problem solving and brokers in the social network

How do groups differ from individuals in problem solving? Hoffman (1988) sees organization problem-solving groups as having two principal objectives: (1) the maximum utilization of the resources brought by each individual member, including any added group potential; and (2) the generation of a high level of motivation for carrying out the group's decision in each and every member. Hoffman's hierarchical model of group problem solving has three aspects. Task-Maintenance, Normative-Localized and Explicit-Implicit are assumed to be activated simultaneously whenever a group solves a problem. The phases of problem solving are considered to be the implicit procedures of most problem-solving tasks.

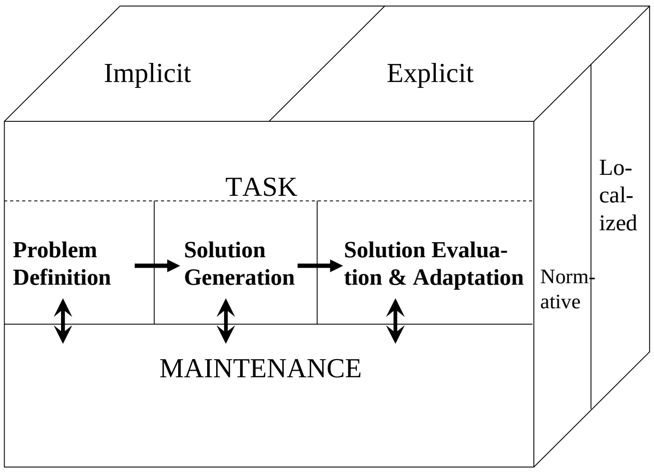

Figure 5. Hierarchical model of group problem solving (Hoffman, 1988)

According to Hoffman groups tend to move from phase to phase according to an implicit valence process by which problems are defined and solutions adopted. How do groups handle ideas? To answer this question, the technology brokering model (Hargadon and Sutton, 1997) is presented as the best describing model how to search for new ideas and how to store them for further use.

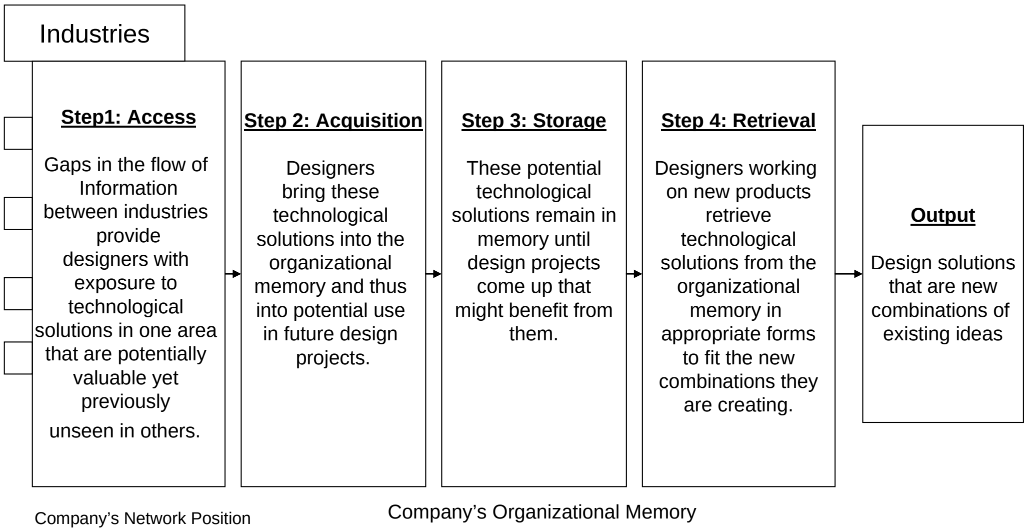

Figure 6. Technology-brokering model (Hargadon and Sutton, 1997)

The model above is originally based on observations how a certain company (Ideo) and it's designers develops innovative products. The concept 'industries' in the figure above means different communities and related social networks. The structural holes theory by Burt (1992) has also been used by Hargadon and Sutton (1997) as the basis of technology brokering process model. Social network theory suggests that innovators can innovate routinely because they occupy a "structural hole", a gap in the flow of information between subgroups in a larger network. For innovators, these gaps exist between industries where there was and was not knowledge about the new emerging technologies. Actors filling these gaps are brokers

who benefit by transferring resources from groups where they are plentiful to groups where they are dear (Hargadon & Sutton, 1997, 717).
The problem definition cycle is missing from the Hargadon and Sutton (1997) model and therefore the author sees Csikzsentmihalyi and Sawyer model (1993) complementary and valuable. What is still needed is the learning dimension.

Learning in the innovation process

> Normal or logical thinking and problem-solving leads to a predetermined answer which follows form the constraints of the situation. Uncreative thinking and uncreative problem solving have no need for self-discovery and learning. (Rickards, 1999, 26)

In the previous chapter there was mentioned that creativity stems from individual. This is also the case with learning. Marsick and Watkins suggest three personal characteristics which, if present, make work-based learning more likely, or may enhance it. These are:
(1) Proactivity - a readiness to take the initiative in situations. (2) Critical reflection - a tendency to reflect, not just on events, but on underlying assumptions. (3) Creativity - to enable a person to think beyond their normal point of view. (Marsick & Watkins,1990) When thinking about learning and learning transfer, the support for these characteristics can be built in the learning environment, here information system.

The term 'informal learning' seem to be more suitable here than the term 'work-based learning'. The reason is that learning that supports creativity takes place often outside work settings. The facilitating of informal learning is, however, difficult. Livingstone (2000, 54) sees major challenges in recognizing incidentally initiated learning and irregularly timed learning. Learning that happens ad-hoc and takes place in ubiquitous and mobile settings is called mobile learning (Syvänen *et al.*, 2003). According to Nyiri there seems to be two dominant approaches to mobile learning with consequences to the design of mobile learning application. The first points out that since the dominant mode access to the Internet will soon be through wireless devices, e-learning simply becomes m-learning, without any remarkable changes in content. The second approach stresses, that mobile learning will characteristically aim at specific kinds of knowledge, namely knowledge that is location-dependent and situation-dependent. (Nyiri, 2002) Author has earlier participated in developing an evaluation framework for mobile learning (Syvänen *et al.*, 2003) . This framework is for qualitative evaluation of mobile learning and can be used as a heuristic design tool for materials and environments. Author is planning to use it later for the evaluation of the constructed prototype.

When thinking about groups, within collaborative learning individuals often learn better by co-operating with others than they would on their own. (Cheetham & Chivers, 2001). Eraut et al. (1997) suggest that this results from a combination of observation, consultation, mutual exchange of information and a process of osmosis. When we inspect the earlier mentioned technology brokering process model (Hargadon & Sutton 1997) learning takes place in multiple levels. Hargadon (2002, 58) describes these four distinct activities: (1) learning about the existing resources of each new domain; (2) learning the related problems in that domain; (3) learning what others in their own firm know and (4) learning how to learn.

How does brokering support expertise development of individuals participating in it? Amabile sees that creativity consists of three components: (1) Domain relevant skills (expertise), (2) creative problem-solving skills and (3) task motivation. The componential model of creativity (Amabile, 1983) suggests that creativity will be highest in that area where the three components share their greatest overlap with the individual's strongest intrinsic interests and creative-thinking processes. In that sense both interest expressions and interest building should be valued in the innovation process, since these have a link to competence development. Ketola and Ahonen (2005) examined customer-developer interaction in the mobile phones development process and introduced the competence-in-co-operation – classification to already existing ones. The information system under construction will support competence development collaboratively.

Methodology

Since the author has interest in building an artefact, this research is design research oriented. The main research question is: (Q1) How to build an artefact to facilitate learning and creative problem-solving processes of groups in an organisation.

Additionally, the following additional research questions and some explanations are illustrated in the following table.

Table 1. The additional research questions and explanations.

Additional research questions	**Explanations, early findings**
Q2: What requirements can be found for this kind of artefact.	An action research (Susman & Evered 1978, Davison 2004) cycle and it's diagnosis phase collects data related to that. Ubiquitous computing, managerial, privacy and usability related requirements have emerged.
Q3: What model(s) could support building this kind of artefact.	Specific models, technology-brokering model (Hargadon&Sutton, 1997) and the systems model of creativity (Csikzsentmihalyi 1996) are chosen.
Q4: What kind of effect the artefact and it's use has on the case organisations. How do case companies currently handle ideas. How they handle ideas after the introduction of the artefact.	The original need of case organizations was illuminated through interviews. The mobile java –based prototype is currently being piloted in the SME. In Spring 2006 there will be additional pilots in a global company and in a university faculty.
Q5: How creative problem-solving, learning and innovation are interlinked.	Literature and theory review is conducted. The Creative Problem Solving (CPS) seems to be the bridging element.

From this starting point the author builds a mobile prototype, evaluates it and gradually improves it using a design science research framework (Hevner et al. 2004, Järvinen 2004) and action research (Susman & Evered 1978, Davison 2004) method. The design science research framework used in this research is fundamentally a problem-solving paradigm. It seeks to create an innovation that defines the ideas, practices, technical capabilities and products through which the analysis, design, implementation, management, and use of information systems can be effectively and efficiently accomplished (Hevner et al., 2004).

These need to be constructed with scientific rigor and relevance in mind to create a functional architecture and a tool to support earlier described creativity, learning and problem solving processes. The utility of the prototype is evaluated in three case organizations (an SME, a global company and a faculty).

In the next table there is listed how author's research has followed the proposed guidelines of design science:

Table 2. Design science research guidelines (Hevner *et al.* 2004) with comments

Guideline	**Research reflections, examples**
1: Design as an Artefact	1. Mobile Personal Development Plan, 2. Digital Portfolio with Interest support 3. Creative Problem Solving Tool with Learning Support.
2: Problem Relevance	Challenges in innovation processes in case organisations and related findings from literature; innovation process that does not support creativity and long-term learning goals
3: Design Evaluation	Completeness of models, Quality of ideas processed; Architecture analysis completeness, Ease of use.
4: Research contributions	Innovative information system, new (improved) models, design rules
5: Research rigor	Applying earlier creativity and innovation research results, selecting one model (Technology Brokering (Hargadon and Sutton 1997), enhancing it and building a prototype based on findings. Evaluating rigorously.
6: Design as a Search process	Recognising step-by-step deficiencies in prototype versions. Building multiple prototypes and rejecting certain constructions.
7: Communication of Research	Academic: Information Systems, Innovation, creativity, work-based learning, and HR research communities Business: Discussions with Case companies, presentations in PDM and KM conferences, consulting and teaching about creativity

The design science research framework and it's building and evaluation phases can be integrated in the action research data gathering cycle (Järvinen, 2004).

Information Systems supporting creativity and problem-solving

According to Rozwell *et al.* (2002) Innovation Management products are emerging in five categories: (1) Idea management, (2) Innovation life cycle management, (3) Product development (4) Environmental innovation management (5) "Outside-the-box" innovation management. In this article the focus is not on products, rather on research of innovation management and related information systems. When inspecting the list by Rozwell *et al.*, none of those items focus on supporting *both* problem-definition *and* environmental innovation management. What kind of system can support problem solving? There are some definitions in the literature.

> *A problem solving environment (PSE) is a computational system that provides a complete and convenient set of high level tools for solving problems from a specific domain. A PSE allows users to define and modify problems, choose solution strategies, interact with and manage appropriate hardware and software resources, visualize and analyze results, and record and coordinate extended problem solving tasks. (Vass et al., 2002)*

This description of Vass et al. does not emphasize collaborative or social networking focused aspects in problem definition and solving. Therefore, author's software prototype has focused on supporting first collaborative environment management and then problem definition.

How can information systems and artificial intelligence (AI) systems support creativity? Roger Schank (1988) points out that creativity consists of two subprocesses: (1) Search process, looking among previously experienced explanation patterns; (2) Alteration process, modifying an explanation derived from one situation to be used in another.

In the subprocess 1, Internet search engines and new personalised search agents can be utilised to find out what is publicly known about the topic and whether user's or group's approach is unique. This search can also take place within a community, for example in the intranet. The author has built search tools to match suggested ideas and environmental factors. Sometimes the ability to visualise things and see their connections is even more valuable than searching capabilities. Therefore, the author is currently inspecting mindmap tools that could help in visualising connections between different patterns and ideas.

The subprocess 2 mentioned by Schank (1988) requires rules and explanation patterns utilisation in the AI solutions. Often the individual and community can handle this alteration work better than computers. Certain question sets may help the user explain and structure the ideas from distant worlds to the community. The author has built these question sets as forms in the mobile prototype and metatagged them in XML-format. Within the ongoing research one challenge is how brokering activity (like in the Technology Brokering from Hargadon and Sutton, 1997) could be better supported in the problem definition and later in innovation building phases. Below is an architecture picture of the current prototype. The architecture of the prototype is described in detail elsewhere (Ahonen, 2005).

Figure 7. The information system architecture (Ahonen, 2005)

What user requirements have come up concerning the information system? Within the first case (SME) users expressed the need for ad-hoc idea input and related data gathering on the road. Therefore, mobile java (J2ME) clients were constructed with support for off-line functionality. Surprisingly, users in the SME case indicated that many ideas come up collaboratively in meetings and unofficial discussions. This was contradictory to author's original assumption about individual origin and the prototype was altered to support group problem definition tasks. One manager in the SME case pointed out that real business problems should guide the problem definition and solving. This feature will be added to the prototype.

Within the other case (global company) users requested that the prototype should be functional also for users who are not used to type with their mobile phones. Therefore, idea gathering in picture format will be enabled through camera-phones and only indexing words will be added. The global company emphasised multi-device support, therefore browser access through PCs and Macs will have different functionality than J2ME access through mobile phones.

Discussion

Author's research topic can be seen eccentric in the field of economics. Creativity research is often associated with psychology and educational sciences, while innovation research is associated with economics and organisational sciences. Ford (1996, 1112) sees that creativity researchers and innovation researchers have therefore failed to capitalise on potential synergies. Within this article this gap is hopefully diminished. There are also indicators that organisations are changing and their management requires new approaches.

> The old orthodoxy assumed that organizations could be studied and understood so that logically derived rules could be developed for their control. Scientific management required logical and rational thinking . More recently it has been argued that such an approach assumes that the organizational system has well-bounded and fixed characteristics that can be defined. A more convincing assumption is that organizations have ill-defined characteristics. Management involves thinking in ways that make it a reality-constructing activity. (Rickards, 1999, 26)

Mumford (2000) claims that creativity is affected by (1) work styles, (2) diversity of activities and (3) exchange of information with experts, among others. The ubiquitous information system and mobile computing may help to facilitate collaboration among experts, but leadership skills remain important. “The leadership of creative efforts seems to call for an integrative style — a style that permits the leader to orchestrate expertise, people, and relationships in such a way as to bring new ideas into being. This style combines: (1) idea generation and related supportive environment establishment, (2) idea structuring and (3) idea promotion.” (Mumford *et al.,* 2002)

As McAdam and McClelland (2002) point out, there is still very little research that combines knowledge creation and idea generation. A case study covering different etymologies of knowledge and how this knowledge is utilised in the innovation process would be worth future research. The knowledge management view in this paper was limited.

Conclusion

This article has described the building process of an artefact that facilitates innovation process. Different views of innovation process were first presented (Majaro 1998, Couger 1995). Author sees that research emphasis should be put to the problem definition phase and collaborative brokering activity. The systems model of Creativity (Csikszentmihalyi, 1996) was seen to supplement the Technology Brokering Process Model (Hargadon & Sutton, 1997). Brokering activity benefits from interest expressions and systematic social networking activities. Although the introduced software artefact was limited in it’s functionality, mobile tools seem to support ad-hoc idea processes and informal learning. More research is needed about the connections of innovation, creativity and learning. Leadership and management questions should be closely inspected when introducing new information systems and related tools to users.

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