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Applying Collective Intelligence to Idea Evaluation at the Front End of Innovation

Examiners: Professor Vesa Harmaakorpi
Professor Hannu Rantanen

ABSTRACT

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Applying Collective Intelligence to Idea Evaluation at the Front End of Innovation

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The study focuses on the front end of innovation process. Due to changes in innovation policies and paradigms customers, users and shopfloor employees are becoming increasingly important sources of knowledge. New methods are needed for processing information and ideas coming from multiple sources more effectively. The aim of this study is to develop an idea evaluation tool suitable for the front end of innovation process and capable of utilizing collective intelligence.

The study is carried out as a case study research using constructive research approach. The chosen approach suits well for the purposes of the study. The constructive approach focuses on designing new constructs and testing them in real life applications. In this study a tool for evaluating ideas emerging from the course of everyday work is developed and tested in a case organization.

Development of the tool is based on current scientific literature on knowledge creation, innovation management and collective intelligence and it is tested in LUT Lahti School of Innovation. Results are encouraging. The idea evaluation tool manages to improve performance at the front end of innovation process and it is accepted in use in the case organization. This study provides insights on what kind of a tool is required for facilitating collective intelligence at the front end of innovation process.

TIIVISTELMÄ

Lappeenrannan teknillinen yliopisto
Teknistaloudellinen tiedekunta
Tuotantotalouden osasto

Juho Salminen

Kollektiivisen älykkyyden soveltaminen ideoiden arviointiin innovaatioprosessin alkupäässä

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Tutkimus keskittyy innovaatioprosessin alkupäähän. Asiakkaat, käyttäjät ja lattiatason työntekijät ovat tulossa aiempaa merkittävämmiksi tietämyksen lähteiksi innovaatiopolitiikan ja paradigmojen muutoksista johtuen. Sen vuoksi tarvitaan uusia ja tehokkaampia tapoja useista lähteistä tulevan tiedon ja ideoiden prosessointiin. Tämän tutkimuksen tavoitteena on kehittää innovaatioprosessin alkupäähän soveltuva ja kollektiivisen älykkyyden hyödyntämiseen kykenevä ideoiden arviointityökalu.

Tutkimus toteutetaan tapaustutkimuksena konstruktiivista tutkimusotetta käyttäen. Valittu lähestymistapa soveltuu hyvin tutkimuksen tarkoituksiin. Konstruktiivinen tutkimusote keskittyy uusien konstruktioiden suunnitteluun ja niiden testaamiseen käytännön sovelluksissa. Tässä tutkimuksessa kehitetään työkalu jokapäiväisestä työstä kumpuavien ideoiden arviointiin ja testataan sitä tapausorganisaatiossa.

Työkalun kehitystyö perustuu tietämystä, innovaatiojohtamista ja kollektiivista älykkyyttä käsittelevään ajankohtaiseen tieteelliseen kirjallisuuteen ja sitä testataan LUT Lahti School of Innovationissa. Tulokset ovat rohkaisevia. Työkalu kykenee parantamaan suorituskykyä innovaatioprosessin alkupäässä ja se hyväksytään käyttöön tapausorganisaatiossa. Tämä tutkimus lisää tietoa siitä, millaisia työkaluja tarvitaan kollektiivisen älykkyyden edistämiseen innovaatioprosessin alkupäässä.

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I got the initial idea for this thesis in 2007 during my exchange in Eindhoven, Netherlands. I was killing time in the library of Technische Universiteit Eindhoven and happened to flick trough an issue of National Geographic Magazine featuring an article about Swarm Theory (Miller 2007). The article described various ways how collective intelligence is utilized in nature and business applications and it triggered a long process leading eventually to this thesis.

Many people have helped me during this process. I would like to thank my supervisor Vesa Harmaakorpi for his open-minded support and valuable advices which contributed prominently to the success of this thesis. I also acknowledge Tuomo Kässi, who encouraged me in early phases of the process and provided me with contacts. Jouni Koivuniemi helped me to develop the initial idea to a research proposal. My colleagues at LUT Lahti School of Innovation deserve my gratitude for making the thesis possible by participating eagerly to prototype testing. Working with you has been great. Finally, I would like to thank my family for support and help in various aspects of life.

TABLE OF CONTENTS

ABSTRACT
TIIVISTELMÄ
ACKNOWLEDGEMENTS
TABLE OF CONTENTS
LISTS OF FIGURES, TABLES, APPENDICES AND ABBREVIATIONS
GLOSSARY

1 INTRODUCTION 1
1.1 Research problem and objectives of the study 5
1.2 Structure of the study 6
2 METHODOLOGY 8
2.1 Case study research 10
2.2 Criteria for judging quality 11
2.3 Research strategy of the present study 12
3 KNOWLEDGE 13
3.1 Knowledge creation process 14
4 INNOVATION MANAGEMENT 19
4.1 Innovation process 21
4.2 Generations of innovation process 24
4.3 Innovation networks 26
4.4 Collaborative Innovation Networks 28
5 COLLECTIVE INTELLIGENCE 31
5.1 Issues in decision making 32
5.2 Facilitating collective intelligence 34
5.2.1 Diversity 34
5.2.2 Independence 35
5.2.3 Decentralized decision making 36
5.2.4 Modularity 38
5.2.5 Self-organization 40
5.2.6 Motivation 43
5.3 System design: Genome of collective intelligence 44
5.3.1 Who performs the task? 44
5.3.2 Why the task is performed? 45
5.3.3 What is achieved and how? 45
5.3.4 From genes to genome of collective intelligence 47
6 BUILDING THE CONSTRUCT 50
6.1 Requirements for idea evaluation tool 52
6.2 Assessment of existing systems 53
6.2.1 Group decision support systems for front end of innovation 53
6.2.2 IBM Innovation Jam 55
6.2.3 Crowdsourcing websites 56
6.2.4 Nest-site selection process of honey bees 57

6.3 Model for idea evaluation tool 62
6.4 Features of idea evaluation tool 63
7 CASE STUDY: APPLYING IDEA EVALUATION TOOL AT LUT LAHTI SCHOOL OF INNOVATION 67
7.1 LUT Lahti School of Innovation 67
7.2 Innovation Catcher 69
7.3 Adjusting the Catcher 70
7.4 Applying the Catcher 71
7.5 Results 72
7.5.1 Comparison of results and requirements 74
7.5.2 Acceptance of Innovation Catcher in case organization 76
8 DISCUSSION 81
9 VALIDITY AND RELIABILITY OF THE STUDY 85
10 CONCLUSIONS 87
11 DIRECTIONS FOR FURTHER RESEARCH 88
REFERENCES 91

APPENDICES

LIST OF FIGURES

Figure 1. Closed innovation paradigm 3
Figure 2. Open innovation paradigm 4
Figure 3. Research approaches 8
Figure 4. Elements of constructive research 9
Figure 5. Forms of knowledge 14
Figure 6. ‘Rye bread model’ of knowledge creation 17
Figure 7. Map of innovation space 20
Figure 8. Innovation process 21
Figure 9. The third generation innovation process 25
Figure 10. Decision making structures 36
Figure 11. Positive and negative feedback loops 42
Figure 12. Development of staff resources at LUT Lahti School of Innovation 68
Figure 13. Framework of Innovation Catcher 70
Figure 14. Comparison of scores on linear and non-linear scales 74
Figure 15. Summary of the results from questionnaire and interviews 80

LIST OF TABLES

Table 1. Properties of a COIN at different levels 29
Table 2. Different combinations of What and How genes for crowds 46
Table 3. Genome of development process of Linux operating system 49
Table 4. Simplified relationships between knowledge creation process and innovation process in the context of idea development 50
Table 5. Features of GDSS for the front end of innovation process described with genome of collective intelligence 54
Table 6. Features of IBM Innovation Jam described with genome of collective intelligence 56
Table 7. Features of crowdsourcing websites described with genome of collective intelligence 57
Table 8. Features of nest-site selection process of honey bees described with genome of collective intelligence 60
Table 9. Relations between the functionality of brain and swarm cognition of honey bees 61
Table 10. Features of the idea evaluation tool described with genome of collective intelligence 63

LIST OF APPENDICES

Appendix 1. Conditions when genes of collective intelligence are useful

Appendix 2. Requirements for idea evaluation tool

Appendix 3. Examples of systems utilizing collective intelligence

Appendix 4. Instructions for the users of the Innovation Catcher prototype

Appendix 5. Summary of results from Innovation Catcher prototype testing

Appendix 6. Results from questionnaire and interviews

ABBREVIATIONS

4P's	4P's of innovation: Product, Process, Position and Paradigm
COIN	Collaborative Innovation Network
DUI	Doing, Using and Interacting
GDSS	Group Decision Support System
IBM	International Business Machines Corporation
LUT	Lappeenranta University of Technology
MIT	Massachusetts Institute of Technology
P&G	Procter & Gamble
SECI	Socialization, Externalization, Combination and Internalization
STI	Science, Technology and Innovation
TQM	Total Quality Management
R&D	Research & Development

GLOSSARY

5th generation innovation process: An innovation process with parallel information processing, in which electronic information processing and face-to-face human contact operate in a complementary manner. (Rothwell 1994)

Ba: A specific forum or arena where collective learning takes place. (Nonaka & al. 2000)

Collaborative Innovation Network (COIN): A self-organized team of highly motivated people working towards a common goal and communicating with each other directly trough the Internet. (Gloor 2006, p. 11)

Collective intelligence: Groups of individuals doing things collectively that seem intelligent. (Malone & al. 2009)

Closed innovation paradigm: Traditional approach to innovation, where ideas have only one path to market. (Chesbrough 2003a, p. 30)

Crowdsourcing: The act of outsourcing a task usually performed by an employee to a large, undefined group. (Howe 2006)

Doing, Using, Interacting (DUI): A mode of innovation in which the focus is on tacit knowledge, organizational learning and user needs. (Berg Jensen & al. 2007)

Explicit knowledge: Knowledge that can be codified and therefore is relatively easy to communicate, process, store and transfer over the distances. (Nonaka & al. 2000)

Genome of collective intelligence: A framework aiming to provide more understanding on how the systems based on collective intelligence work. (Malone & al. 2009)

Group Decision Support System (GDSS): Electronic systems designed for supporting meetings and group work. (Dennis & al. 1988)

Idea evaluation: Assessment of quality, feasibility, usability etc. of ideas.

Idea generation: Activities and processes resulting in creation of ideas that may form the basis for innovations.

Innovation: A process of turning opportunity into new ideas and of putting these into widely used practice. (Tidd & al. 2005, p. 66)

Innovation Catcher: A toolset implemented by employees of an organization with a goal to change the innovation activities more open and practice oriented and to improve the performance especially at the front-end of the process. (Paalanen & Parjanen 2008)

Knowledge: Contextual and situated information. (Nonaka & al. 2000)

Modularity: A feature that allows a system consisting of independent units to work together as an integrated whole. (Baldwin & Clark 1997)

Open innovation paradigm: An innovation paradigm under which ideas can emerge both inside and outside an organization and have parallel paths to market. (Chesbrough 2003a, p. 43)

Rye bread model: A revised SECI model of knowledge creation with self-transcending knowledge included. (Harmaakorpi & Melkas 2005)

Science, Technology, Innovation (STI): A mode of innovation, which focuses on codified knowledge and science based learning. (Berg Jensen & al. 2007)

SECI process: A spiral of collective learning between tacit and explicit knowledge on all organizational levels. It consists of four phases: Socialization, externalization, combination and internalization. (Nonaka & al. 2000)

Self-organization: A process in which pattern at the global level of a system emerges solely from numerous interactions among the lower-level components of the system. (Camazine, & al. 2001, p. 8)

Self-transcending knowledge: Tacit knowledge prior to its embodiment. (Scharmer 2001)

Swarm intelligence: Collective behavior emerging from a decentralized self-organizing group of insects. Even if one individual is not capable of much, collectively a swarm of insects can solve difficult problems of nest-site selection and nest building, foraging, task division and route optimization. (Bonabeau & Meyer 2001)

Tacit knowledge: Knowledge that is personal and difficult to formalize, making it hard to transfer. (Nonaka & al. 2000)

1 INTRODUCTION

The welfare state of Finland is currently under huge pressures for change. Globalization, demands for sustainable development, new technologies and demographic changes create serious challenges for society and economy. Finland needs a top class innovation environment to cope with these challenges and to improve competitiveness and productivity. In addition to maintaining the existing strengths the innovation systems must be actively improved and diversified. Increasingly fierce competition, environmental concerns, reduced resources and ageing population force us to maximally utilize the investments in innovation. (Valtioneuvoston innovaatiopoliittinen… 2008)

Finnish innovation system is currently one of the best in the world. Success has relied on high quality of education, functional institutions and persistent investments in research and development. Mastery of science and technology based innovation activities has been a clear strength for Finland (Harmaakorpi & al. 2008, p. 1). Even though the science and technology policies have paved the way for many successful industries, a science based innovation strategy is not enough. Traditional logic of inventing is not valid anymore; competitiveness is increasingly based on the ability to understand the needs of customers and users before competitors and to offer products and services satisfying these needs. As a result various forms of open and public innovation have become more common. (Valtioneuvoston innovaatiopoliittinen… 2008)

The change taking place in the Finnish innovation environment can be described as a shift of emphasis from Science, Technology and Innovation (STI) mode towards Doing, Using and Interacting (DUI) mode. STI mode relies strongly on the use of codified knowledge and science based learning. In DUI mode on the other hand the focus is on tacit knowledge, organizational learning and user needs. Therefore close interactions between users and developers are a prerequisite for DUI. Experiences from Denmark show that the highest improvements in innovation performance are gained when both modes of innovation are combined in a complementary manner. By focusing only on STI mode companies may miss many opportunities for gains that could be reaped by supporting informal learning by doing, using and interacting. (Berg Jensen & al. 2007) Neglecting DUI mode can be costly indeed as researches suggest that only 4 percent of innovations are derived from the STI mode (Office for… 2004, p. 24).

Even though the focus of Finnish innovation policies has clearly been on the STI mode (Harmaakorpi & al. 2008, p. 1), a change is now coming as the new innovation policy of Finland emphasizes DUI mode by encouraging product and service development with much stronger focus on customer needs. The aim is to improve cooperation between users and developers. In this approach success is based on sharing of knowledge and on skills to combine different viewpoints and approaches. Diverse models and platforms for innovation are used to combine the needs, knowledge, skills and creativity of customers, users and developers. (Valtioneuvoston innovaatiopoliittinen… 2008)

While the emphasis on different modes of innovation is shifting the process of innovating is also changing. Traditional approach to innovation known as closed innovation paradigm was successful for the most part of the twentieth century and used to fit well the knowledge environment of the time. Closed innovation paradigm can be described as a funnel with strict organizational boundaries. Ideas enter companies from left, are screened and filtered and the most promising ones are then transferred into development and finally to market. Vertically integrated central R&D organizations are typical for this paradigm. There are lots of ideas inside the companies, but not many available outside of them as can be seen in Figure 1. The ideas have only one path to the market. (Chesbrough 2003a, p. 30-31)

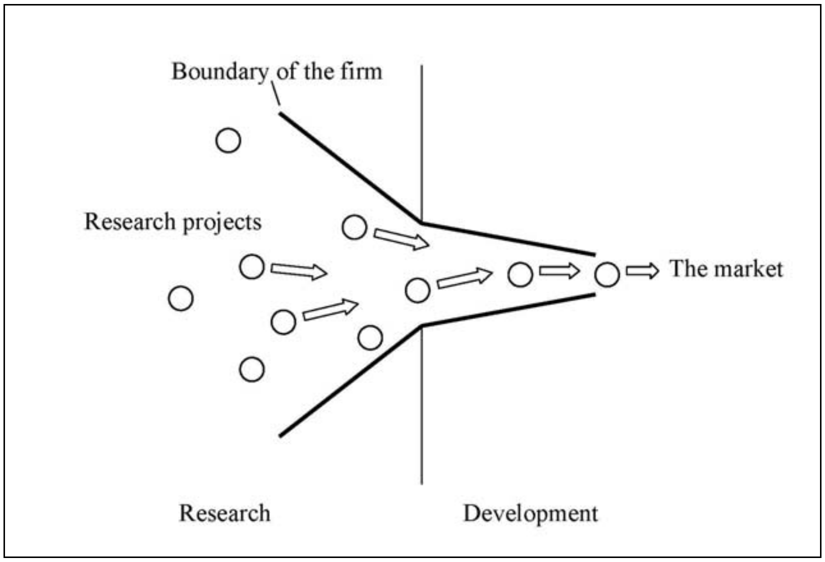

Figure 1. Closed innovation paradigm
(Chesbrough 2003b)

The knowledge environment has now changed though. Chesbrough (2003a p. 34-40) lists four eroding factors leading to this development:

1. Increasing availability and mobility of skilled workers
2. Venture capital market
3. External options for ideas sitting on the shelf
4. Increasing capability of external suppliers

Together these factors have loosened the linkage between research and development. Distribution of knowledge has changed from central R&D facilities towards a diverse distribution of knowledge across the landscape. The closed innovation paradigm is becoming ineffective in this changed environment. (Chesbrough 2003a, p. 40-41)

The changes in the distribution of knowledge have lead to an emergence of open innovation paradigm. Logic about the sources and use of ideas has changed. Under the open innovation paradigm valuable ideas can come both from inside and outside of the company boundaries and can similarly go to market from inside or outside of the company. Parallel paths for innovations are now equally important as the traditional internal route. (Chesbrough 2003a, p. 43.) The open innovation paradigm is depicted in figure 2.

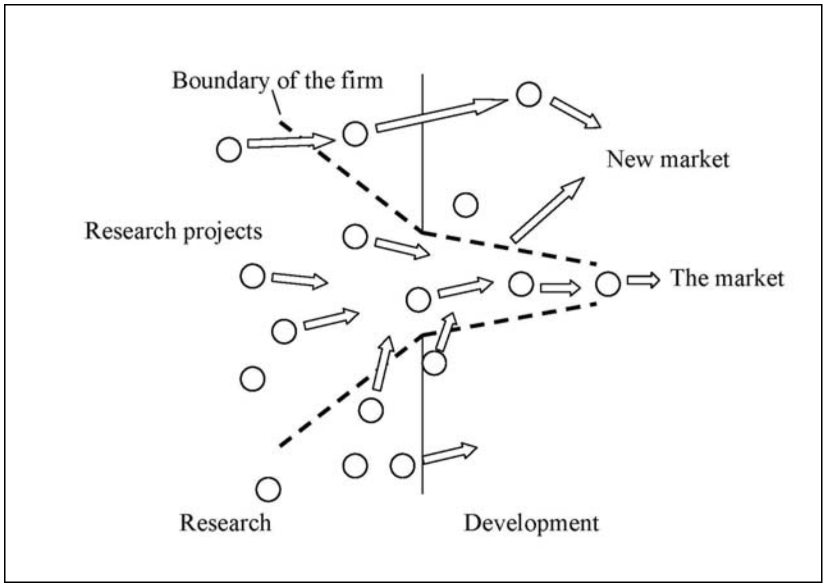

Figure 2. Open innovation paradigm
(Chesbrough 2003b)

Results of this paradigm change are by no means minor. After finding out its internal R&D was not anymore capable of sustaining high levels of growth Procter & Gamble changed its approach to innovation from Research and Develop to more open Connect and Develop. By utilizing its clear sense of customer needs P&G is able to identify promising ideas from all around the world and create better and cheaper products faster. As a result the company's R&D productivity has increased almost 60 percent from 2000 to 2006. (Huston & Sakkab 2006)

In addition to changes on the level of paradigms also the technological environment is under significant changes. Recent development of communication technologies such as the Internet has increased interest towards a multidisciplinary field of collective intelligence. Even though the term itself is old, the improved communication technologies now allow huge numbers of people to cooperate in completely new ways. Vast possibilities of collective intelligence are demonstrated by recent emergence and indisputable successes of such systems as Google and Wikipedia. (MIT Center… 2009) As the aim of collective intelligence is to integrate the knowledge of large groups, it seems like a promising approach to dealing with current issues of front end of innovation.

1.1 Research problem and objectives of the study

Changes in innovation policies and paradigms have major effects on the front end of innovation process. Customers, users and shopfloor employees are becoming increasingly important sources of knowledge. Therefore new methods are needed to process information and ideas coming from multiple sources more effectively.

This study focuses on the front end of innovation process. Scope of the study is limited to idea collecting and evaluating phases. Despite the major importance of implementation of ideas that topic is not discussed in this study. The issues of implementation are broad enough to deserve a separate study and cannot therefore be given a meaningful contribution in limited extend of this thesis. Goal of this study is to develop an idea evaluation tool capable of utilizing collective intelligence. Employees on the shopfloor form the main target group for the tool. Relevant literature on the fields of knowledge, innovation management and collective intelligence is first reviewed and gained theoretical insight is then used to build a construct, which is then tested in a case organization. The study is scheduled to be completed in six months.

The research problem of the study can be defined as follows:
What kind of a tool is required for facilitating collective intelligence at the front end of innovation process?

Objective of the study:
The objective of this study is to construct an effective idea evaluation tool for the front end of innovation process capable of utilizing collective intelligence.

To solve the research problem and to reach the objective of the study at least the following research questions should be considered:

What are the relevant processes involved in innovative activities?

What are the major issues at the front end of innovation process and how should they be managed?

How ideas emerging from multiple sources can be collected and evaluated effectively and efficiently?

1.2 Structure of the study

The background and motives for the study were discussed in Introduction and the used research methodology will be presented in the next chapter. Theoretical background of the study is presented in chapters 3 trough 5. Literature on knowledge creation is reviewed in Chapter 3, relevant topics on innovation management are discussed in Chapter 4 and Chapter 5 covers current views on collective intelligence. In Chapter 6 implications of the theoretical part are summarized and requirements for an idea evaluation tool are defined. Some existing evaluation systems are then assessed and the construct developed in this study is described. In Chapter 7 the construct is tested in a case organization and result of the experiment are presented. Findings are discussed and compared to theoretical background in Chapter 8. Validity of the study is demonstrated in Chapter 9. Conclusions are drawn in Chapter 10 and directions for further research on the topic are offered in Chapter 11.

2 METHODOLOGY

Research methodology can be classified according to their main emphases on theoretical-empirical and descriptive-nomothetical axes (Kasanen & al. 1993). Such classification of research approaches is depicted in Figure 3.

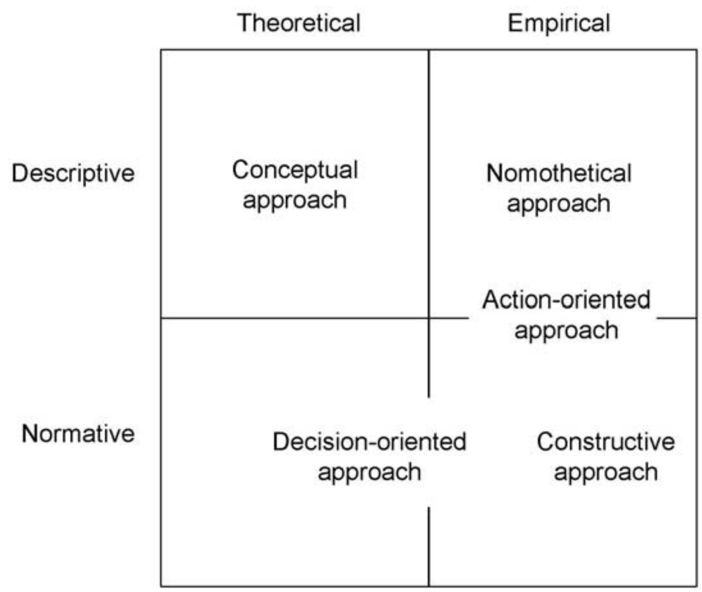

Figure 3. Research approaches
(Kasanen & al. 1993)

Conceptual approach is used to develop concept frameworks for describing and categorizing new phenomena and organizing information. Nomothetical approach aims to show causality or at least correlation between the studied phenomena. This is a positivistic approach which typically applies statistical methods. The results can be used in designing activities and in forecasting. Decision-oriented approach gives often recommendations for action based on mathematical models or computer simulations. Action-oriented approach aims to understand the problem hermeneutically. It is useful in situations where the problem is difficult to structure and usually deals with organizations, people, leadership and decision-making processes in addition to “hard” facts. (Olkkonen 1993, p. 65-76) Constructive approach is a normative approach, which uses managerial problem solving through utilizing theoretical knowledge in construction of new models, plans and organizations and testing them in real world (Kasanen & al. 1993). This relationship is explained in Figure 4. Next the constructive research approach is described in more detail.

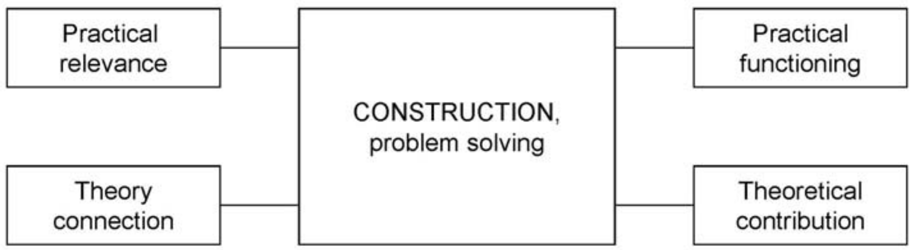

Figure 4. Elements of constructive research
(Kasanen & al. 1993)

The constructive research process can be understood better by dividing it in six phases, the order of which may vary depending on the situation (Kasanen & al. 1993):

1. Find a practically relevant problem which also has research potential
2. Obtain a general and comprehensive understanding of the topic
3. Innovate i.e. construct a solution idea
4. Demonstrate that the solution works
5. Show the theoretical connections and the research contribution of the solution concept
6. Examine the scope of applicability of the solution

Innovative phase is a core element of this approach. Without a new solution there is no use in going on with the study. The developed construction should be relevant, simple and easy to use. Validation of a constructive research can be achieved through market tests. In a weak market test the constructed solution has been implemented in one site. In order to pass the semi-strong market test the solution must become widely adopted. Finally the strong market test requires that the business units applying the construction are doing statistically significantly better than the ones without it. Already the weak test is quite strict, and not many constructions are able to pass it. (Kasanen & al. 1993)

2.1 Case study research

Yin (1994, p. 13) defines case study research as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident." Typically case studies use multiple sources of evidence because of high number of variables compared to number of data points. For the results of a case study to be reliable, data from different sources needs to converge. Study propositions based on theory guide data gathering and analysis. (Yin 1994, p. 13)

Designing a case study research can be divided in five components, the order of which may vary. The first component is the study questions which define the appropriate research strategies. Case study strategy is best suited in answering questions how and why. The second component is study propositions, or in cases where the propositions cannot be made, the purpose of the study. The propositions or purpose direct the attention to things that should be examined in the scope of the research. The third component is unit of analysis, which defines the case in hand and its boundaries regarding the studied group and time limits. The unit of analysis should be similar to previous studies in order to make the comparison easier. The final two components, the logic of linking the data to the proposition and the criteria for interpreting findings are not precisely defined for case studies. Nevertheless the design of a study should indicate what will be done with the data after it is collected. (Yin 1994, p. 20-27)

2.2 Criteria for judging quality

Quality of a case study research can be judged by using four tests: construct validity, internal validity, external validity and reliability. Additionally the study should be relevant, meaning the importance of the topic and contribution to the existing knowledge (Kasanen & al. 1993). Various tactics can be utilized to ensure sufficient quality in different stages of the research. (Yin 1994, p. 32-33)

Construct validity covers the establishment of correct operational measures for data collection and composition. To meet the requirements of construct validity specific types of changes that are to be studied must be selected and the relationship of these changes and selected measures demonstrated. This is often problematic in case studies because of the high risk of researcher's biases influencing the results. Issues can be avoided by using multiple sources of evidence and by having key informants review the report. (Yin 1994, p. 33-34)

Internal validity is a concern only in data analysis in causal or explanatory case studies and deals with establishing causal relationships. Researcher should be careful when making inferences as the correlation does not implicate causation. Pattern-matching, explanation building and time-series analysis are useful tools for avoiding internal validity issues. (Yin 1994, p. 33, 35)

External validity covers the establishment of the domain in which the results of a case study apply (Yin 1994, p. 33). Methods for generalizing beyond the immediate research include statistical, contextual and constructive generalization rhetoric. Statistical rhetoric uses commonly accepted statistical methods to justify the generalization of results. Contextual rhetoric relies on thorough understanding of the case and its relevant surroundings, whose validity can then be widened trough efficient triangulation of the data. In constructive rhetoric the acceptance of the developed solution works as a measure for generalizability. If the solution is proven to work in on place, it is likely that it would work also in other similar conditions. (Lukka & Kasanen 1995)

Reliability of a study is established by demonstrating that by repeating the operations of the study the same results would be reached. This way errors and biases of the study can be minimized. The key issue in demonstrating reliability is sufficient documentation of all the research phases. Using a well-defined case study protocol helps too. (Yin 1994, p. 33, 36-37)

2.3 Research strategy of the present study

This study is carried out as a case study research using constructive research approach. The chosen method suits well for the purposes of the study. The constructive approach focuses on designing new constructs and testing them in real-life applications and in this study a tool for evaluating ideas emerging from the course of everyday work is developed and tested in a case organization. The tool is evaluated using multiple sources of evidence: performance of the tool is observed, opinions of users are collected with a questionnaire and management of the case organization is interviewed. Collected evidence is then used to draw conclusions.

3 KNOWLEDGE

Knowledge can be defined as ‘justified true belief’. The knowledge is dynamic by nature; it is created in social interactions among individuals and organizations. It is also context specific and relational, as it depends on space and time and the value of knowledge depends on the individual. Without context the knowledge is just information. (Nonaka & al. 2000)

Knowledge can be divided in explicit knowledge, tacit knowledge and self-transcending knowledge. Explicit knowledge is knowledge that can be codified and therefore is relatively easy to communicate, process, store and transfer over the distances. It is often public or at least widely known. Tacit knowledge means knowledge that is personal and difficult to formalize, making it more difficult to transfer and a more valuable asset. Tacit knowledge can be shared trough common experiences, observations and imitation. (Nonaka & al. 2000) Tacit knowledge can be further divided in embodied tacit knowledge (normal tacit knowledge) and self-transcending knowledge, which is defined as “tacit knowledge prior to its embodiment.” It means the ability to sense the emerging opportunities. (Scharmer 2001) Different forms of knowledge are depicted with an iceberg model in Figure 5.

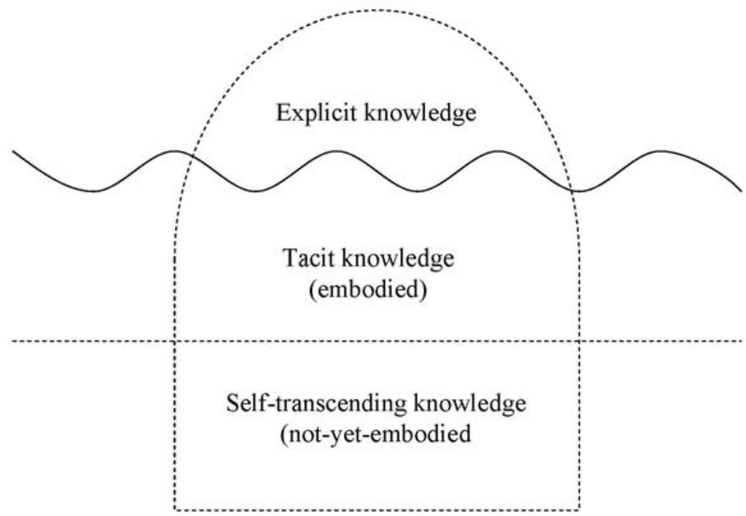

Figure 5. Forms of knowledge
(Scharmer 2001)

Explicit knowledge is situated above the waterline as it is relatively easy to disseminate and share. The two types of tacit knowledge are below the waterline. They are very difficult to transfer between the separate parts of an organization. (Scharmer 2001)

3.1 Knowledge creation process

Knowledge is created trough a continuous process of dynamic interactions among individuals and between individuals and environment. It consists of three elements: SECI model, *bas* as arenas for knowledge creation and knowledge assets. The process is directed with a knowledge vision. The SECI model is a spiral of collective learning between tacit and explicit knowledge on all organizational levels. It consists of four phases: Socialization, externalization, combination and internalization. The *bas* are specific forums or arenas where the collective learning takes place, forming the context for knowledge creation. Each knowledge conversion requires a different *ba*. Foundation for knowledge creation is formed by knowledge assets. These assets consist of inputs, outputs and moderating factors of the knowledge creation process. The knowledge assets must be built and used internally, as it is impossible to sell or buy them. In order to synchronize and direct the knowledge creation process a common knowledge vision is needed. The knowledge vision is used to define the values against which the created knowledge is evaluated. A common vision is especially important when knowledge creation takes place in a network of actors from differing backgrounds. (Nonaka & al. 2000)

Even though the SECI model was originally designed for hierarchical organizations, it is arguably usable also in network context with some modifications. The revised SECI model is called 'rye bread model'. The major changes are involvement of self-transcending knowledge in the process and addition of knowledge assets as a source of knowledge and knowledge vision for steering the process from the middle. The SECI spiral and knowledge conversion are used for knowledge creation in defined *bas*. The process is both collective and individual and it reforms the knowledge assets. (Harmaakorpi & Melkas 2005) The revised model consists of six phases, each of which corresponds to a specific *ba*:

1. Visualization in imagination *ba* (from self-transcending knowledge to tacit knowledge)
2. Socialization in originating *ba* (from tacit knowledge to tacit knowledge)
3. Externalization in interacting *ba* (from tacit knowledge to explicit knowledge)
4. Combination in cyber *ba* (from explicit knowledge to explicit knowledge)
5. Internalization in exercising *ba* (from explicit knowledge to tacit knowledge)
6. Potentialization in futurizing *ba* (from tacit knowledge to self-transcending knowledge)

In visualization phase self-transcending knowledge is embodied from the abstract to visions, feelings and mental models (Harmaakorpi & Melkas 2005). Sharing of this newly formed tacit knowledge between individuals takes place in socialization phase trough physical proximity and face-to-face contacts. A typical example of internal knowledge sharing is apprenticeship, where apprentices learn trough hands-on experiences. External tacit knowledge can be acquired trough interactions with partners and customers. Externalization means a conversion of tacit knowledge into explicit form which can be shared to others. In combination phase explicit knowledge from multiple sources are combined to form more complex and systematic sets of explicit knowledge. Information technology and communication networks can be used effectively to facilitate this mode of knowledge conversion. The newly created knowledge is then embodied in practice in internalization phase by a conversion from explicit knowledge to tacit knowledge. This is closely related to learning by doing. The knowledge from documents is applied to practice, which increases the tacit knowledge base. (Nonaka & al. 2000) Finally in potentialization phase tacit knowledge is disembodied to self-transcending knowledge, which forms the basis for understanding future potentials and seeing things that do not yet exist. This knowledge can then work as a starting point to a new spiral of knowledge creation. (Harmaakorpi & Melkas 2005) The 'rye bread model' is depicted in Figure 6.

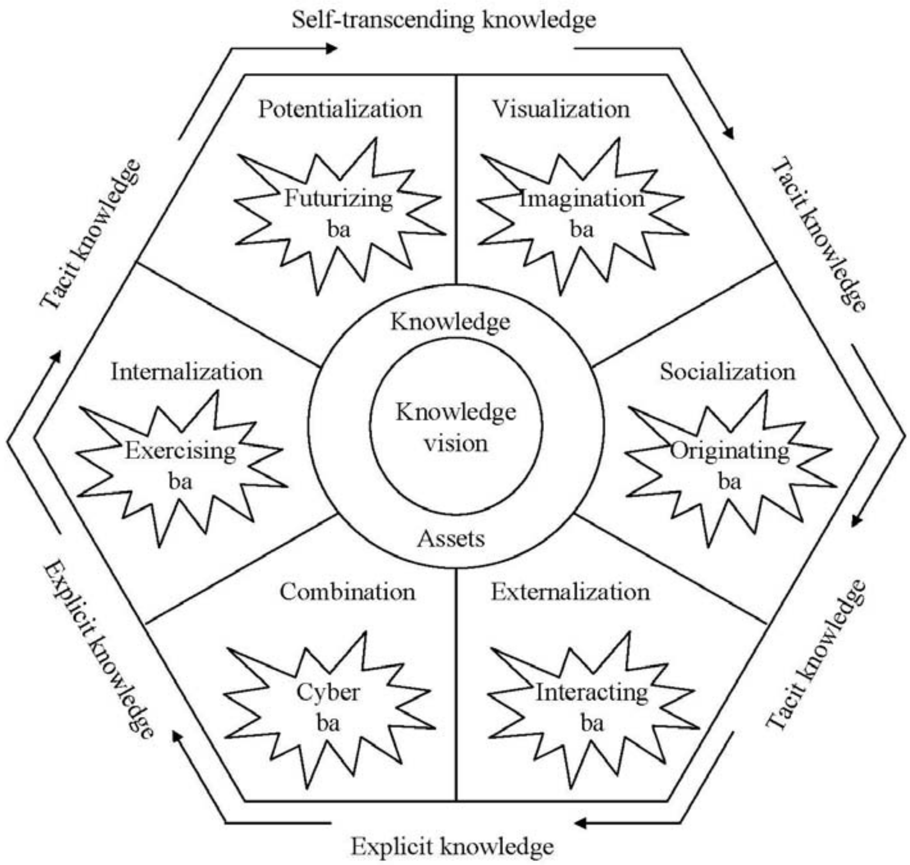

Figure 6. 'Rye bread model' of knowledge creation
(Harmaakorpi & Melkas 2005)

Several key issues should be taken into account when facilitating the SECI process of knowledge creation. Existence of the future-oriented (self-transcending) knowledge should be acknowledged. Documentation of ideas is essential during socialization and internalization phases of the process, as many valuable ideas tend to be forgotten fast. The importance of idea evaluation process is related to this issue (Forssen 2001). Finally the structure of the innovation network should be kept unbiased and unconventional, and participation of talented actors should be rewarded, thus giving them the motivation to participate. (Harmaakorpi & Melkas 2005)

Ability to create new knowledge is essential for companies to maintain a competitive advantage in the long run. Still, other processes are needed to transform the knowledge to value. Value is only created when the knowledge is utilized to improving, changing or developing specific tasks or activities. This is to say that improvements do not follow automatically from creating huge quantities of knowledge. Usually the transition from knowledge to value is carried out trough an innovation process. (Newell & al. 2002 p. 141-142)

4 INNOVATION MANAGEMENT

Innovations are a way of securing competitive advantage trough renewal of products, processes and services (Tidd & al. 2005, p. 37). Innovation can be defined as "a process of turning opportunity into new ideas and of putting these into widely used practice" (Tidd & al. 2005, p. 66) or as "an invention implemented and taken to market" (Chesbrough 2003a, p. ix). Innovation is definitely more than just coming up with good ideas or a single event; it is more of a process of making ideas work in practice and then commercializing them. Importantly this process can be managed. (Tidd & al. 2005, p. 87)

Innovation is about change, which can take place on several forms or types. The types of innovation can be broadly categorized to 4P's of innovation: product (or service) innovation, process innovation, position innovation and paradigm innovation. Product innovation means changes in the things the organization offers, for example a new car model or an insurance package. In process innovation the change takes place in the ways in which products or services are created. A new manufacturing method or an office procedure can be viewed as process innovations. Position innovation is about changes in the context in which the products or services are offered. The product remains unchanged, but it is offered for a new, completely different user or market. Finally the paradigm innovation means changes in the underlying mental models about what the organization does. The shift to low-cost airlines and the emergence of online shopping are examples of paradigm innovation. (Tidd & al. 2005, p. 10-11)

Innovations can also be categorized based on the degree of novelty involved. On this scale the innovations range from minor, incremental improvements trough innovations new to the enterprise all the way to radical changes capable of transforming the way a product or service is used or even the way the whole society works. Decreasing fuel consumption of a car can be considered as an incremental innovation whereas introduction of hydrogen powered car would be a radical innovation. The novelty is a relative matter and depends on the context of innovation. A commonplace thing for one organization can be a radical improvement for another; it is the perceived novelty that matters. When the types of innovation are combined to degree of novelty, a map of innovation space can be formed, as depicted in Figure 7. (Tidd & al. 2005, p. 11-13)

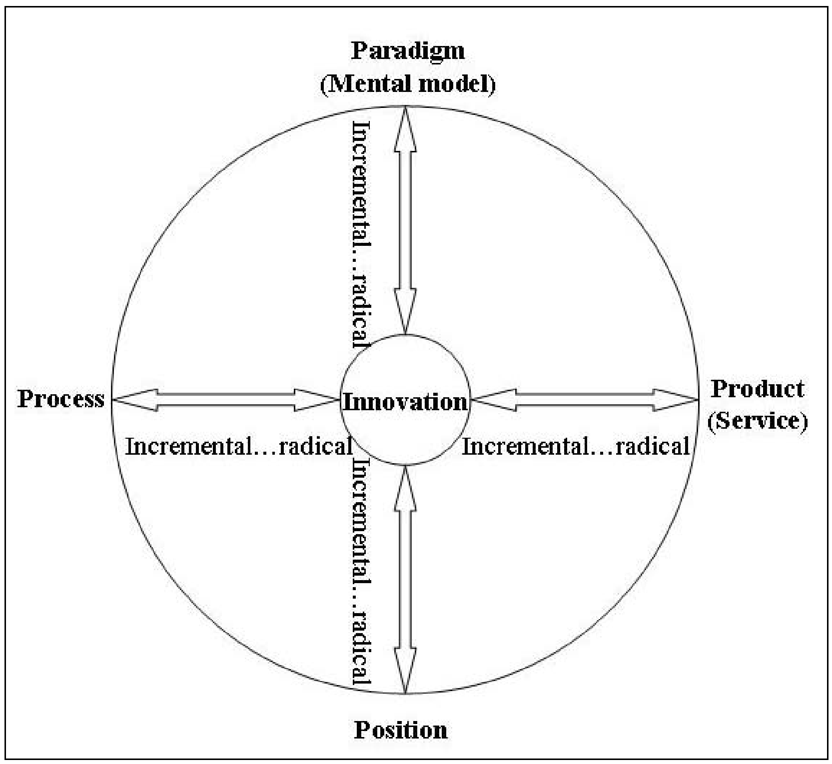

Figure 7. Map of innovation space
(Tidd & al. 2005, p. 13)

Each of 4P's of innovation can take place anywhere on the axis running from incremental to radical innovations. Innovation space defines the boundaries within which an organization can operate while the actual areas explored and exploited are determined by innovation strategy of the organization. The categorization of innovations is important as different types of innovation require different management approaches. (Tidd & al. 2005, p. 11-13)

4.1 Innovation process

Because innovation involves lots of uncertainty (technical, market, social, political etc.) it is a high risk activity. Most of the developed ideas never make it to the market. Still, not to innovate is rarely an option to companies as it would mean certain failure in rapidly changing and fiercely competed environments. Efficient management is needed for innovations to be successful. (Tidd & al. 2005, p. 39) Even though the innovation process is often complex with much iteration, some general phases can be discovered. One way to describe the innovation process is depicted in Figure 8.

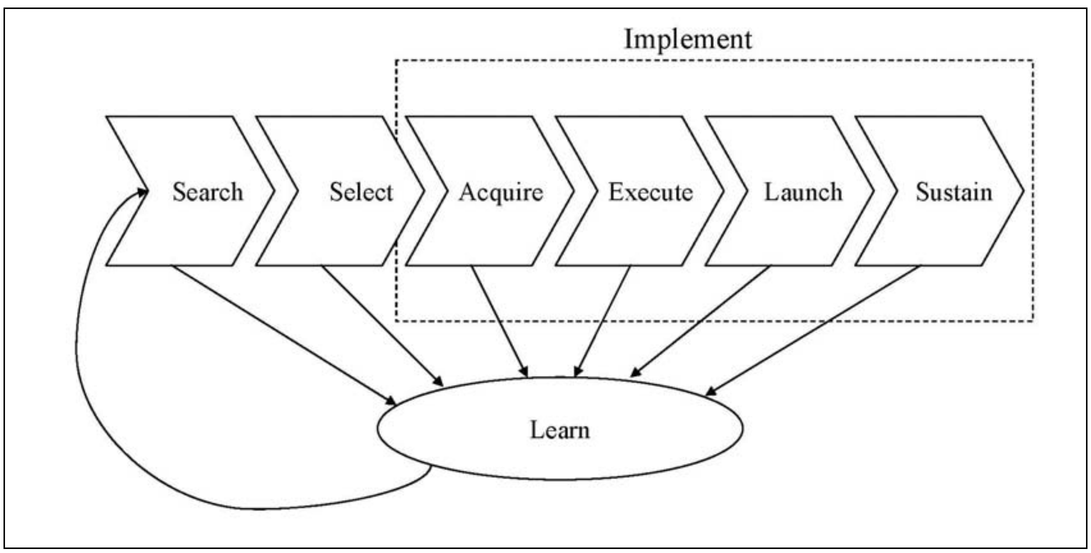

Figure 8. Innovation process
(Adapted from Tidd & al. 2005, p. 89)

The first phase of the innovation process is searching. It involves scanning the environment for new ideas and possibilities for innovation. These signals can be new technological opportunities, actions of competitors or changes in market requirements or legislation. Especially innovations generated by users tend to be widely distributed and cannot be predicted in advance (Hippel 2005, p. 144). Because of the wide range and huge amount of information, well-developed mechanisms for identifying, processing and selecting are necessary for successful completion of this phase. (Tidd & al. 2005, p. 89-90)

After the search phase a selection must be made. The purpose here is to form an innovation concept which can be put forward trough the development organization. In this phase three factors should be considered: available technological and market opportunities, the current technological base of the company and the fit of the innovation to other businesses of the enterprise. (Tidd & al. 2005, p. 90)

The first phases of innovation process are often described as the fuzzy front end of innovation. The fuzzy front end is defined as the activities taking place before the formal, well structured development process begins. Activities in the front end of innovation process are often unpredictable and unstructured and therefore hard to manage. Nevertheless these activities have a major role in determining which projects to execute and affect strongly on the definitions of quality, costs and time frame of the project. (Herstatt & al. 2004)

The strategic decision about which possibilities to pursue is followed by implementing phase. During the implementation the high uncertainty of the early stages is gradually replaced with accurate knowledge about technological feasibility, market demand, competition and regulations. Research on all these factors naturally increases costs. Implementation phase can be further divided in three core elements, which are acquiring knowledge resources, executing the project and launching and sustaining innovation. (Tidd & al. 2005, p. 91)

Knowledge acquiring phase involves combining new and existing knowledge from both inside and outside of the organization. This phase is about problem solving, creativity and exploration of ideas. The sufficient amount of creativity depends on the case; a minor improvement in existing design needs much less creativity than development of a totally new concept. Both internal R&D and technology transfer from outside can be used. Therefore the key skills in knowledge acquiring phase are effective organizational routines in R&D and abilities to find, select and transfer technology. (Tidd & al. 2005, p. 91-92)

Executing the project is the heart of the innovation process. Inputs of this phase are a clear strategic concept and initial ideas about the innovation and outputs consist of developed innovation and market ready for the final launch. Essentially executing the project is about project management in uncertain conditions, which means that flexibility is required from the process. This stage can also be described as a funnel which moves gradually from broad exploration phase trough narrow and focused problem solving towards the final innovation. Executing the project includes the most time, costs and commitment of the innovation process, and is characterized by series of expected and unexpected problem-solving loops. It is important to ensure suitability of the final design to market conditions, manufacturability and user preferences. Therefore close cooperation of different functions is essential. Nowadays this traditionally linear process is becoming more and more parallel as a result of the demand for ever faster product development. (Tidd & al. 2005, p. 93-95)

Launching an innovation to market is done partly simultaneously with the development process. Main goal here is the preparation of the market for the launch. The process involves typically collecting information, solving problems and focusing effort towards the final launch. Particularly important is to collect information about customer preferences and feeding them into the development process. Deep understanding of user needs is essential, especially when high degrees of uncertainty are involved. This can be achieved by involving end-users in the development process as early as possible. (Tidd & al. 2005, p. 95-96) In addition the lead users have been shown to be an important source of commercially attractive innovations (von Hippel 2005, p. 30).

Throughout the process and after the launch the organization should be learning both from successes and failures. This valuable information gives possibilities for improvement and re-innovation and helps to avoid repeating old mistakes in the future. (Tidd & al. 2005, p. 96) Trough the learning cycle the processes of knowledge creation and innovation are closely connected. Knowledge in general and tacit knowledge in particular plays an important role in all phases of the innovation process. For the innovation process to be successful the organizational structures and culture should allow effective knowledge transfer both inside the company and from external sources of knowledge. (Seidler-de Alwis & Hartmann 2008)

4.2 Generations of innovation process

Even though the basic structure of the innovation process remains static, the details and information flows of the process have changed vastly during the twentieth century. Rothwell (1994) describes five generations in the development of innovation processes. The first and the second generations were simple and linear processes based on technology push and market pull accordingly. They were dominant from the 1950s until the early 1970s. The third generation innovation process combined these two extreme approaches into a one more general process. It is a sequential process with feedback loops to earlier phases, which is depicted in Figure 9. (Rothwell 1994)

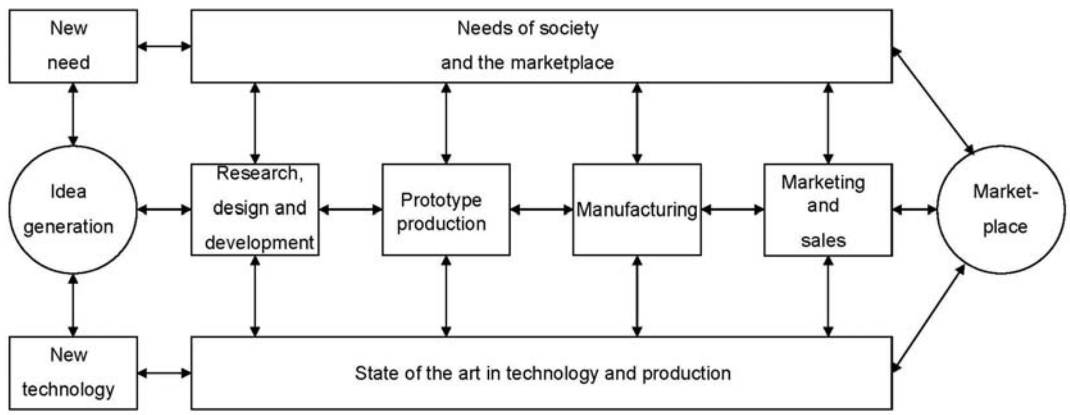

Figure 9. The third generation innovation process
(Rothwell 1994)

The fourth generation of innovation processes began in Japan in the 1980s. Main improvements over the third generation process are integration and parallel development. The development work is carried out in different departments more or less simultaneously, and suppliers are closely involved in the process. There is also a lot of information exchange between the departments. Overlapping of the phases increases the speed of product development and information exchange favors design for manufacturability. (Rothwell 1994)

Many of the trends established already in 1980s continue still while the innovation process is developing towards its fifth generation. Technology strategy is still important and strategic networking is increasing. Shortening product life cycles and pressures for faster product development increase the importance of speed-to-market. Product strategies emphasize the quality and performance features as well as design for manufacturability while focus is shifting increasingly on the customer. The flexibility and adaptability of the organization, manufacturing and the product itself are highly valued. These goals are pursued trough strategic integration with suppliers, horizontal technological collaboration, electronic data processing strategies and total quality control.

Among these trends the speed of innovation is seen as an important factor in competitiveness of a company. There is a trade-off between the development speed and costs though, as the development costs tend to rise when the development time shortens. Therefore companies search for ways to improve the efficiency of the development process and make the trade-off between development costs and speed less severe. The fifth generation innovation process is essentially a further developed version of the integrated and parallel fourth generation process, with technological changes on the system level. Companies try to achieve advantages by developing integrated and parallel activities, strong and early vertical linkages, devolved corporate structures and by using information technology based design and information systems. Innovation process is becoming more of a networking activity with strong horizontal linkages. (Rothwell 1994)

Primarily the development described above is enabled by greater overall organization and systems integration and flatter, more flexible organizational structures for rapid and effective decision making. These features are complemented by the use of fully developed internal data bases combined with effective external data link. It can be concluded that the fifth generation innovation process is "a process of parallel information processing, in which electronic information processing and face-to-face human contact operate in a complementary manner". (Rothwell 1994)

4.3 Innovation networks

With the transition towards the fifth generation innovation process networks are becoming increasingly common environment for innovation activities. Networks appear to offer many benefits of the traditional internal development without the usual drawbacks of collaboration. The definitions vary from author to author, but generally networks are seen as a hybrid form between an organization and market or as a transitory organization between the companies and the market. Different perspectives can view networks at national, regional, sector, organizational or individual levels. (Tidd & al. 2005, p. 307-308)

A network can be defined as a collection of nodes and links between them, together forming a configuration which is more than the mere sum of the bilateral relationships (Tidd & al. 2005, p. 307). Nodes of an innovation network can be individuals, business units, companies, universities, governments or customers. The most interesting attribute of a network are the dynamic interactions between nodes which lead to a nonlinear, unstable and unpredictable set of relationships. A network can influence its actors trough the flow and sharing of information and by the position of the actor in the network. The position in the network is an important strategic decision, which influences strongly the actor's power and control over the network. (Tidd & al. 2005, p. 310-311)

Configuration of a network can be tight or loose depending on quantity, quality and type of interactions. Innovation networks become appropriate alternative for internal development when benefits of cooperation in a network outweigh the costs of network maintenance and communication. High transaction costs of technology transfer and high uncertainty of the environment also increase the relative benefits of networking. (Tidd & al. 2005, p. 310-311)

Management of innovation networks can be challenging. Tidd & al. (2005, p. 414) list several issues regarding these challenges:

1. How to manage something we do not own?
2. How to see the system-level effects instead of the narrow self-interest?
3. How to build trust and share risks without complicated contracts?
4. How to avoid free-riding and information leakage?

For these reasons traditional hierarchical approach is not very suitable solution for managing networks. Bottom-up approaches such as Collaborative Innovation Networks have emerged outside the official organizations to rise to these challenges.

4.4 Collaborative Innovation Networks

Gloor (2006, p. 11) defines a Collaborative Innovation Network (COIN) as a self-organized team of highly motivated people working towards a common goal and communicating with each other directly trough the Internet. Main characteristics of COINs are innovation, collaboration and communication. Ideas and innovations are generated trough large scale collaborative creativity. Rules of collaboration are derived from a shared ethical code, which results in an environment of high trust. This enables open creating and sharing of information and gives everyone an unrestricted access to knowledge. Communication between members happens in direct-contact networks. Loose and uncontrolled COINs may appear to be chaotic when looked from the outside, but their structure enables fast creation and exchange of ideas and can also be extremely productive, because every participant knows intuitively what needs to be done. (Gloor 2006, p. 11-12) COINs can be used to facilitate close cooperation between customers and product developers and some companies are even expanding collaborative innovation from idea generation for product development to a business model. Examples of such pursuits include online digital photo service Flickr, bookstore Amazon.com, and Swizz retailer Migros. All these companies rely strongly on their customer in creation of services. (Gloor & Cooper, 2007)

Benefits of COINs are numerous for both organizations and individuals. First of all COINs are highly agile and productive at very low cost (Gloor 2006, p. 104). Organizations using COINs are more innovative and collaborative and can react more flexibly to changes. Development costs and time to market are reduced. COINs can help organizations to acquire external knowledge, release synergies, uncover new business opportunities and identify experts and hidden contributors. Additionally the transparency and high trust increase the security of the organization. For individuals participating in COINs offers possibilities to build wider networks with direct access to knowledge and personal relationships to experts on their field. Consequently they learn new skills and get often promoted. (Gloor 2006, p. 12-15)

Collaborative innovation networks are enabled by shared vision, technology and certain culture. Internet and related technologies provide asynchronous and instantaneous global reach needed for unrestricted communication (Gloor 2006, p. 92). For a COIN to be successful it needs to support a culture of meritocracy, consistency and internal transparency. In a meritocracy people are rewarded solely based on their merits. Consistency means that organization operates in a predictable way and follows an unwritten ethical code. Unrestricted sharing of knowledge for all members of organization allows participants to make well-informed decisions and leads to internal transparency. (Gloor 2006, p. 84) The effects of these cultural properties on innovation, collaboration and communication on different levels of organization are summarized in Table 1. A COIN can succeed only if the organizational culture is right (Gloor 2006, p. 106).

Table 1. Properties of a COIN at different levels
(Adapted from Gloor 2006, p. 89)

	Innovation	**Collaboration**	**Communication**
Organization	Meritocracy	Consistency	Transparency
Team	Swarm creativity	Code of ethics	Trust network
Individual	Creative intelligence	Ethical conscience	Knowledge sharing

Currently the existing COINs have mostly emerged “naturally” in the course of everyday work and they are often found outside the official organizational boundaries. Despite the current lack of evidence it could be possible to create Collaborative Innovation Networks on purpose by taking actions supporting the emergence of COINs. (Gloor 2006, p. 183)

Traditional centralized control should be substituted with decentralized decision making. This is a bold step for most organizations and requires high levels of confidence, but without it swarm creativity and self-organization cannot be fully unleashed. Instead of central control the emphasis in COINs is on offering strategic guidance, supporting cultural environment and necessary collaboration tools for flexible teams, in which the members and their roles continuously change depending on situation. For such teams to function it is essential to maintain high levels of trust between the members of the organization. Trust can be established most effectively by face-to-face meetings, even though the Internet and collaboration tools enable slower trust building remotely. Open sharing of knowledge, transparent work environment and common code of ethics support the development of high levels of trust. (Gloor 2006, p. 184-185)

Organizational structure should be low with high connectivity and interactivity between members. Easy scalability, flexibility and robustness of the network are also important. Connectivity and interactivity can be improved by setting up a collaborative web workspace, which consists of simple web-based tools such as email, blogs, wikis and chats. These tools enable the global knowledge sharing and work as a common memory for the network and store the trail of what has been happening in the network. It should be noted that these tools alone cannot create a COIN; the people participating in the network and their willingness to share information are much more important factors. Despite the growing emphasis on networks the traditional organization has still its place in the innovation process. Collaborative innovation networks are best suited for the exploring and early development phases. The final key to success is to know when the time to change from a COIN to traditional development organization is. (Gloor 2006, p. 186-188)

5 COLLECTIVE INTELLIGENCE

Success of Collaborative Innovation Networks can be partly explained as resulting from facilitating collective intelligence. It is a term used to describe the phenomena that enables groups to perform effectively in large collaborative systems such as Wikipedia, Google or COINs. Collective intelligence can be defined broadly as "Groups of individuals doing things collectively that seem intelligent" (Malone & al. 2009).

The term is closely related to swarm intelligence inspired by social insects, which means collective behavior emerging from a decentralized self-organizing group of insects (Bonabeau & Meyer 2001). Even if one individual is not capable of much, collectively a swarm of insects can solve difficult problems of nest-site selection and nest building, foraging, task division and route optimization (Bonabeau & Meyer 2001; Camazine & al. 2001; Conradt & Roper 2005; Visscher 2007). Many artificial systems have been designed on the basis of swarm intelligence, including Internet traffic routing algorithms and logistics and production line management systems (Bonabeau & Meyer 2001). Similarities can be found also between innovation networks and insect swarms. COINs are typically self-organized communities with transparent communication and information sharing. Like in insect swarms, the decision making is decentralized. Both the swarms and COINs are united by common interests or goals. For insects the survival of the queen means the survival of their genes while members of a COIN strive to make the innovation work. Even if behavior of individuals may seem erratic the community as a whole works highly efficiently. (Gloor 2006, p. 22)

Collective intelligence is an age-old phenomenon, but what make it highly relevant now are the recent changes in technology. Constantly decreasing costs of communication enable new forms of decentralization in organizations (Malone 1997).

The slogan of MIT Center for Collective Intelligence captures the essence of current trends on the field well: “How can people and computers be connected so that – collectively – they act more intelligently than any individual, group, or computer has ever done before?” (MIT Center… 2009)

In business context collective intelligence usually takes a form of decentralized and collective decision making, which can be used to gain outreach, additive aggregation or self-organization. Outreach means getting more people to generate or evaluate ideas. Open source software development relies largely on this approach; “with enough eyeballs all bugs are shallow”. Additive aggregation means collecting information from multiple sources and then using some form of averaging on the data. The simplest example is using a crowd to estimate the number of jellybeans in a jar and then calculating the average of all responses. Self-organization covers the mechanisms of interaction which allow the whole to be more than the mere sum of its parts. (Bonabeau 2009) Effective utilization of collective intelligence in business context requires the companies to give up some of the decision power, share the fruits of collective work fairly and focus on supporting the collective “swarm” instead of making money on the short term. (Gloor & Cooper 2007)

5.1 Issues in decision making

Even though various networks and development communities are often very effective at their tasks it should not be assumed that the performance of a group is automatically intelligent. Information processing and decision making of human beings are susceptible to many biases, which can take place both on individual and group levels. On the individual level people tend to seek mainly for information which confirms their original assumptions, maintain the assumptions even when conflicting evidence appears, find patterns in places where none exists and be overly affected by the way how the information is presented. These biases are called selfserving bias, belief perseverance, pattern obsession and framing and they are just a few examples of the many ways how human nature can misdirect decision making (Bonabeau 2009). Even the performance of experts varies greatly making individual decisions inaccurate and inconsistent (Surowiecki 2004, p. 33).

Group level biases are influenced by multiple factors including group size, degree and nature of biases in individuals and the process of group decision making. While the group decision making situation can preserve the effects of individual level biases, attenuate or exaggerate them, and while any simple and systematic relationship cannot be found, the strengthening of negative effects seems to be the general pattern. (Hinsz & al. 2007) Cascade effects are suggested to be a major factor behind many issues in group deliberation and decision making (Sunstein 2006, p. 88; Iandoli & al. 2008). In a group deliberation situation information is typically propagated consecutively. Because of social dynamics the information contributed early in the process can have a disproportionally large impact on the outcome of the decision. Members of the group rely on information from other members in their contributions instead of their private knowledge. This effect can seriously impair the group decision making process. (Sunstein 2006, p. 88-92)

Examples of resulting group level biases include error amplification, information disclosure and polarization. Error amplification means the tendency of group discussions to propagate the errors of individuals; a group consisting of biased members is likely to be even more biased than the average member of the group (Sunstein 2006, p. 80). Error amplification results from informational pressures (How could all these people be wrong?) and social pressures like fear of conflict, fear of shame and low status preventing the open expression of opinions. The conformism resulting from these forces causes groups to be unable to explore possible solutions extensively enough and to converge too fast to a most preferred solution. Information disclosure means that group concentrates on the information shared by everyone instead of exploring diverse private knowledge the members might have. Therefore groups are often unable to benefit from the information that is held by only a few members of the group (Sunstein 2006, p. 82). Polarization refers to the tendency of groups to radicalize their opinions especially about moral, political and cultural issues. People desire to be part of a group and therefore members adopt and reinforce the shared ideological view of the group, finally ending up to even more extreme positions than any of the individual members alone would. (Iandoli & al. 2008)

5.2 Facilitating collective intelligence

Like demonstrated by the issues in decision making the performance of groups can often be far from intelligent. Decision making systems are required to possess certain features in order to facilitate collective intelligence. Diversity increases the amount of available information while independence and decentralization improve the quality of decisions. Modularity makes decentralization of tasks easier and self-organization reduces the need for external control. Finally the motivation of users is essential to ensure sufficient participation. Next these aspects are discussed in more detail.

5.2.1 Diversity

Diversity of opinions is a critical factor in collective intelligence. Adding new perspectives to a subject matter is valuable as it brings in new ideas and viewpoints which would otherwise probably remain absent in a group. (Surowiecki 2004, p. 29; Bonabeau 2009) Homogenous groups tend to be good at what they do, but they often lack the capability to explore for new solutions (Surowiecki 2004, p. 31). Simulation models have shown that diverse groups of problem solvers can outperform homogenous groups of highly skilled problem solvers (Hong & Page 2004).

Diversity can also help to reduce the negative effects of individual and group level biases trough addition of perspectives and by making it easier for people to voice their opinions (Surowiecki 2004, p. 39; Bonabeau 2009). Nevertheless the right balance of diversity and expertise is required when tapping into collective intelligence of crowds. While some problem solving situations benefit from adding more perspectives, this beneficial effect is prevented if the problem solvers do not have any knowledge about the topic whatsoever. (Bonabeau 2009)

5.2.2 Independence

Certain level of independence is another major factor enhancing collective intelligence. Independence produces a random error in individual estimates, which can be filtered out through aggregation. Individual assessments contain always some errors, but unless the mistakes the people make do not become correlated and are not systematically pointing in the same direction, the errors do not harm the collective decision making. Independent individuals are also more likely to have new information which increases the diversity of the group. Keeping the assessments independent is difficult in most group decision making situations because of the social interactions involved. People are social beings and eager to learn from each other. (Surowiecki 2004, p. 41)

To avoid the group decision making biases the collective intelligence system should support the independence of estimations produced by the group members. For a group to be collectively intelligent the availability of diverse information and the ability to make individual aggregations are required. (Surowiecki 2004, p. 41)

5.2.3 Decentralized decision making

Costs of communication have a fundamental effect on decision making structures in business context. The effect of constantly reducing costs of communication can be seen in history. Before the 19th century, when the costs of communication were high, the most of decision making was done by independent decision makers. Each village and shop made decisions more or less independently. Later the falling costs of communication made centralized decision making more efficient. Information from different locations could be collected and decisions based on a broad perspective. This was typical for the most of the 20th century with large centralized corporations. But now, as the costs of communication are still falling, at some point in at least some situations decentralized decision making will become more economical than centralized decision making. Decentralized decision makers can combine global information with local knowledge and creativity. (Malone 1997) Different decision making structures are presented in Figure 10.

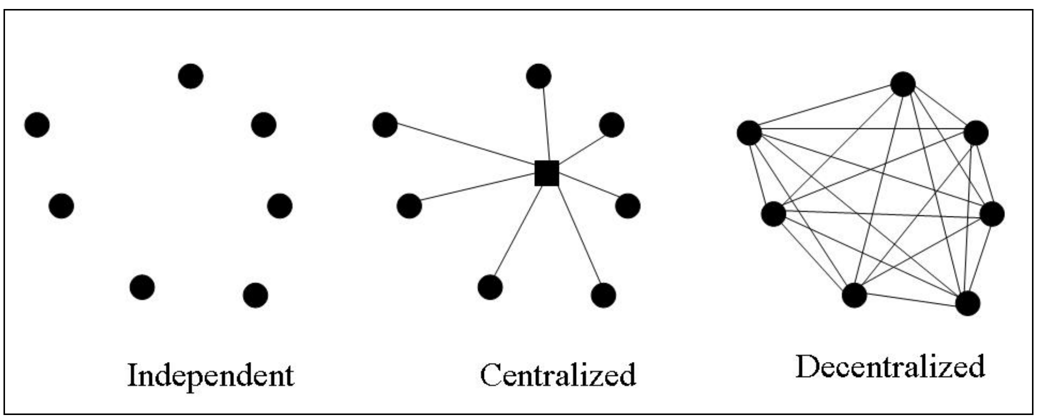

Figure 10. Decision making structures
(Malone 2004, p. 189)

Decentralization of decision making has potential to yield many benefits trough increased efficiency, motivation and creativity of individuals and higher flexibility of organizations. Decentralized decision making both fosters and is fed by specialization. Specialization makes people more effective and productive as well as increases the scope and diversity of the knowledge. At the same time decentralization can be used to utilize tacit knowledge, which is otherwise difficult to transfer. Good decisions require accurate information, and information technology makes the structures requiring high levels of communication feasible. As the transferability of knowledge varies, it would make sense to transfer the easily communicated explicit knowledge to the decision makers possessing sticky and tacit knowledge (Malone 1997). The assumption is that the closer a person is to a problem the more relevant the possessed knowledge and the higher the likelihood he or she can find a solution to that particular problem. (Surowiecki 2004, p. 70-72) Decentralization also allows many minds to work on the same problem simultaneously (Malone 2004, p. 114). Energy and creativity of people often depend on who makes the decisions about their work. Physically hard or routine work requires more supervision from above while creative work flourishes when the external control is reduced. This way the decentralized decision making can increase motivation and creativity. (Malone 1997)

On the negative side the decentralization of decision making means that part of the power must be given away. Resulting lack of control may lead to undesirable or unpredictable decisions. Another issue is liability; it may not be clear who can finally be held responsible for decisions made by a crowd. Involving more people in an activity also increases the likelihood of misbehaving by some individuals. Some form of policing may be necessary, but that introduces a risk of negative effects trough restricted expression of ideas (Bonabeau 2009). Many self-organized communities solve this problem by democratically promoting active and trusted members to be moderators for others (Gloor 2006, p. 25; Malone 2004, p. 61). For these reasons the inclusion of more people in decision making is always a risk, but benefits of tapping the expertise of the outside world may well make it worthwhile. Finally the intellectual property causes concern in two ways. Leakage of proprietary information outside the company should be prevented, which can be difficult if the communication is open. On the other hand there is the question of the ownership; who owns the rights to cooperatively developed innovations? (Bonabeau 2009)

While the economy is increasingly based on knowledge work and technological improvements continuously lower the costs of communication the decentralized decision making can be expected to increase in the future despite the issues mentioned above. Decentralization should be considered when potential benefits of decentralization are important, potential costs can be compensated and the benefits outweigh the costs (Malone 2004, p. 114). These requirements are typically met in conditions where the amount of information is too large for any single individual to aggregate, many perspectives are necessary to solve a problem and transferring the information to central decision maker would limit everyone’s ability to make good decisions (Denning & Hayes-Roth 2006). Generally decentralized decision making is suited well for situations where the high motivation and creativity of many people is critical for the success (Malone 2004, p. 121).

5.2.4 Modularity

The strength of decentralization is that it encourages independence while still allowing people to coordinate their activities and solve problems collectively. On the other hand there is no guarantee that valuable information from one part of the system will find its way to other parts of the system. Therefore the system needs methods to let people to specialize and acquire local knowledge, thus increasing the total amount of information in the system, while simultaneously being able to aggregate the local information into a collective entity. A right balance is needed between making individual knowledge global and collectively useful while still allowing it to remain specific and local. (Surowiecki 2004, p. 70-72) Modularity can be used to ensure the global compatibility of local actions.

Modularity has been used extensively in product development, but it can also provide benefits in organizing work (Malone 2004, p. 135). A modular system consists of independently designed units that work together as an integrated whole. This can be achieved by dividing the information precisely, unambiguously and completely in visible and hidden design parameters. The visible parameters are defined early in the process and they describe what modules the system includes and what their functions are (architecture), how the modules interact with each other (interfaces) and how the performance of the modules is measured and compared (standards). The visible parameters are communicated to all participants of the process and individual participants cannot change them. Hidden design parameters on the other hand can be changed freely and they are not usually communicated globally. While increased freedom in module design boosts innovation, the problem of modularity lies in difficulties of system design. The problems in visible parameters can often be found only after the design of modules is finished. (Baldwin & Clark 1997)

Modularization facilitates collective intelligence by making decentralization of tasks easier. Here the focus is on the interfaces between the activities instead of physical products. Paradoxically the strict standards in certain parts of the system can enable massive amounts of flexibility in other parts of the same system. A process architecture formed by a set of rigid standards can provide guidelines for dispersed individuals enabling them to merge their works effectively to a complete entity. (Malone 2004, p. 133) Wikipedia is a good example of projects, where a huge mission – producing an encyclopedia containing all the information in the world – can be effectively divided in small tasks that anyone can take care of.

5.2.5 Self-organization

Self-organization can be defined as “a process in which pattern at the global level of a system emerges solely from numerous interactions among the lower-level components of the system. Moreover, the rules specifying interactions among the system’s components are executed using only local information, without reference to the global pattern” (Camazine, & al. 2001, p. 8). In this context pattern means a particular, organized arrangement of objects in space or time, and it is an emergent property of the system as opposed to a property determined by an influence external to the system (Camazine & al. 2001, p. 8). Examples of such external control include pattern formation via instructions from a supervisor or trough various directives such as blueprints, recipes, pacemakers or templates (Camazine & al. 2001, p. 12). The pattern resulting from a self-organizing system can be complex in comparison to interactions between system components. (Camazine & al. 2001, p. 11).

Self-organization is considered to be one of the facilitating factors of collectively intelligent phenomena because it increases flexibility and robustness of a system. A flexible system is able to adapt to changes in environment and robustness means that even if a part of the system fails it is still able to perform its tasks. Social insects use self-organizing systems extensively to solve complex problems such as foraging route optimization, nest-site selection and division of work. (Bonabeau & Meyer 2001; Gloor 2006, p. 20, Camazine & al. 2001)

Self-organization results from a set of mechanisms relying on easy to use components at hand. The main components include simple rules of thumb, multiple interactions, positive and negative feedback loops and constraints of environment. (Camazine & al. 2001, p. 488)

In animal world the interactions of individuals are often based on simple rules of thumb, which need only very limited access to global information. Furthermore the required cognitive abilities are often relatively low compared to emerging global patterns. The used rules are simple stimulus-response acts executed in a probabilistic manner, which means that the stronger the stimulus the higher is the probability of a response. It should be noted however, that simple rules are also used in many situations which do not involve self-organization. The important point here is the way how the rules are used. (Camazine & al. 2001, p. 488) Globally used rules of thumb can be understood as one form of simple modularity.

Generally self-organization emerges in systems consisting of multiple actors interacting iteratively according to the same rules of thumb. In principle just one individual could produce a self-organizing pattern, but typically it arises when a group of individuals makes use of both the results of their own and other group member's activities. Interactions usually include a random component, which contributes strongly to systems ability to discover, explore and adapt to changes in environment (Gloor 2006, p. 21). The interactions can be dynamic by nature, so that the ongoing interactions affect the features of the system and provide new stimuli for further interactions. (Camazine & al. 2001, p. 488)

Most self-organizing systems use positive feedback loops to promote changes in the system. In a positive feedback loop a system responds to a change with a deviation towards the same direction as the original input. The result is a snowballing amplification of the original input. This amplification can also reinforce random fluctuations of a system. In biological systems positive feedback is most of the time coded behavior. (Camazine & al. 2001, p. 15-19)

Uncontrolled positive feedback loop can cause disastrous exponential growth or implosion in any process it is involved in. Negative feedback loops are therefore necessary to counterbalance and stabilize the system. As opposed to positive feedback loops, in a negative feedback loop the system responds to a change with a deviation in the opposite direction of the original input. This helps to shape the global pattern by limiting amplifications. Negative feedback loop may result from an explicit rule, but most of the time it is due to saturation, depletion or competition of the resources of the system or due to environmental constraints. The positive and negative feedback loops are depicted in Figure 11. (Camazine & al. 2001, p. 16, 19, 489)

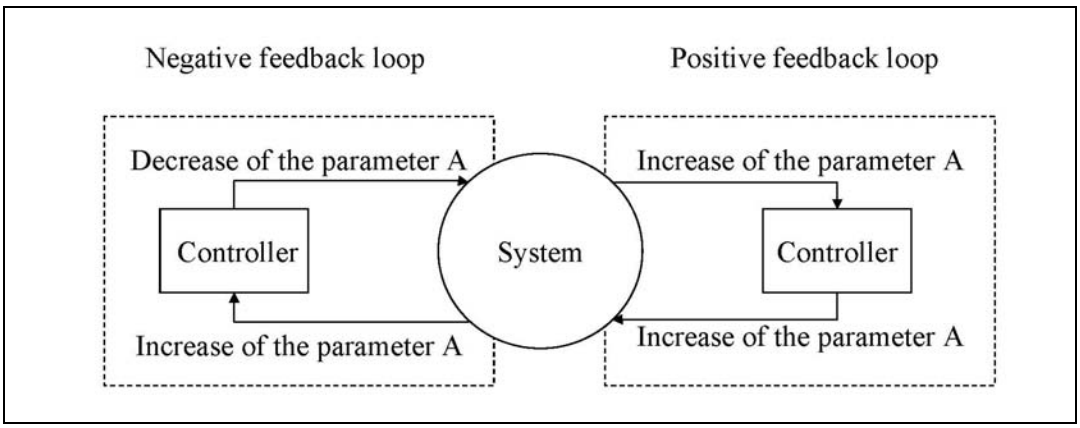

Figure 11. Positive and negative feedback loops
(Adapted from Camazine & al. 2001, p. 17)

Environmental constrains play frequently an important role in formation of emergent phenomena. Many systems are strongly affected by initial and boundary conditions and random environmental fluctuations. Therefore a part of the complexity of the emerging pattern or process is often a result from the complexity of the environment. (Camazine & al. 2001, p. 490)

Mechanisms of self-organization can be further clarified with an example from nature. Flocks of birds or fish schools can move in unison as if they were controlled by a single mind. Nevertheless the impressive performance is a result of self-organization. In a flock all the animals follow only a few simple rules (Camazine & al. 2001, p. 180-181; Wikipedia 2009):

1. Avoid collisions with neighbors (short range repulsion)
2. Move towards the average direction of the closest neighbors (alignment)
3. Move towards the average position of the neighbors (long range attraction)

These simple rules are enough to make the flock stay together, move synchronously and evade predators by suddenly breaking up during the attack and then gathering quickly back together (Camazine & al. 2001, p. 180-181).

5.2.6 Motivation

Motivation or incentives to participate is a major, maybe even the most crucial factor contributing to success of collective intelligence systems (Bonabeau 2009; Gloor & Cooper 2007; Malone & al. 2009; Tapscott & Williams 2006, p. 288). The motivating factors can take many forms. Significantly the financial incentives such as money, prizes, promotions or possibilities for future gains typical for traditional organizations are less important in many new forms of collaboration. In open source development communities recognition by peers, desire to achieve a common goal, learning new skills and sheer fun of the activity itself are often major motivators for most participants. Opportunities to socialize with other people and to make new friends can also play an important role. (Gloor 2006, p. 29; Malone 2009) Applications aimed at serving a common goal rely strongly on value-driven incentives. Here the desire to share knowledge and experiences, sense of civic duty and contributing to a valuable cause are often the driving forces. (Bonabeau 2009) Even if the forms of motivating factors vary widely, one general principle is common to all successful communities. Sharing of responsibilities and rewards should be fair for all participants. (Gloor & Cooper 2007)

5.3 System design: Genome of collective intelligence

Despite their apparent simplicity collective intelligence systems can be demanding to design (Bonabeau 2009). Complicated interactions between the system components make predicting global performance difficult. In order to relieve this issue Malone, Laubacher and Dellarocas (2009) have developed a framework aiming to provide more understanding on how collective intelligence systems work. The framework is based on identifying a small set of fundamental building blocks, the genes of collective intelligence. Analogy comes from biology and in this context a gene is defined as “a particular answer to one of the key questions (Who, Why, What or How) associated with a single task in a collective intelligence system” (Malone & al. 2009). The questions are related to each other and help to classify the genes:

1. Who performs the task and why?
2. What is accomplished and how?

A collective intelligence system can be built by combining individual genes from different classes into a genome of the system. (Malone & al. 2009)

5.3.1 Who performs the task?

There are two basic answers to the question of who carries out the activity. In traditional organizations the answer is usually determined by hierarchy, where someone in a position of authority gives the assignment to a particular person or a group. An alternative to hierarchy is crowd, where anyone in a large group of people can decide to perform the task without anyone telling that particular person to do so. Low communication costs provided by the Internet enable the crowds to participate in various activities in many more ways than before. (Malone & al. 2009)

5.3.2 Why the task is performed?

The question of why do people take part in an activity is closely related to previous question of who undertakes the activity. Motivation and incentives to participate are definitely one of the most important aspects in collective intelligence systems. Even if the question about the motivation is very broad, it can be divided in three basic high level categories of money, love and glory. Money means a promise of economic gain in exchange for participation and can be in a form of salary, cash or product prizes or indirect possibilities of future income. Love as a motivator means the enjoyment of the activity itself, possibilities to socialize with other people or opportunity to contribute to a valuable cause. This type of motivation is important for example among the Wikipedia community. Glory means recognition by peers. It is one of the main motivators in open source software development communities. Remarkably many recently developed collective intelligence systems rely on love or glory as incentives instead of economic gains. (Malone & al. 2009)

5.3.3 What is achieved and how?

Traditional organizations usually deal with the questions of what is done and how by defining a mission statement and by describing the organizational structure and processes. In collective intelligence systems the answer to the question of what is achieved can usually be divided in two basic genes: create and decide. Create gene means that the crowd creates something new, be it a piece of software, a new design for t-shirt or an article in an encyclopedia. Decide gene covers the actions where something is evaluated or an alternative is selected. These tasks can be carried out either independently or dependently. The questions are again closely related. Different combinations of these genes for crowds are presented in Table 2. (Malone & al. 2009)

Table 2. Different combinations of What and How genes for crowds
(Malone & al. 2009)

	Independent	**Dependent**
Create	Collection (or Contest)	Collaboration
Decide	Individual decisions	Group decision

Collection means that contributed items are all created independently without significant communication between the group members. Contest is a subtype of collection, where a few best items of the collection are chosen to receive a reward. In collaboration the members of a crowd work together and exchange information while creating the contributions. (Malone & al. 2009)

Decisions are divided in individual and group decisions. When a crowd makes individual decisions, each member makes their own decisions, which may be influenced by others but are not necessarily the same. Individual decision gene is further divided to markets and social networks. Markets involve some kind of formal exchange. Participants make individual decisions about what to sell or buy and at what price. All these decisions collectively determine the supply and demand, which in turn have their effect on the prices. Markets in general are an age-old phenomenon, but new technologies make many new ways to use them feasible. In social networks members of a crowd form a network of relationships which might lead to trust, similarity of tastes or other common characteristic which in turn make the individuals feel affinity for each other. This allows individuals to give different weights to various inputs based on the relationships. Blogosphere and personalized recommendations of Amazon.com are examples of such networks. (Malone & al. 2009)

In group decision some form of aggregation is used to generate a decision that applies for the crowd as a whole. Alternative ways to achieve a group decision include voting, consensus decision, averaging and prediction markets. Voting is an old method, but here again low costs of communication make it feasible in many new situations. In a consensus decision essentially all members of the crowd agree on the final outcome. Averaging can be used when the decision involves picking a number. This method can work surprisingly well in certain situations, such as using a crowd to evaluate the number of jellybeans in a jar. Prediction markets are used to generate estimations about the probabilities of future events. A crowd is let to buy and sell "shares" of predictions. When predictions come true the owners of corresponding shares are rewarded. The prices of the prediction shares represent probabilities of different events. (Malone & al. 2009) Studies have shown that prediction markets can produce accurate forecasts about future events (Berg & al. 2008, Cowgill 2005, Wolfers & Zitzewitz 2004).

5.3.4 From genes to genome of collective intelligence

Individual genes can be combined in various ways to create genomes of collective intelligence systems. Mapping of the genome makes it easier to see the underlying structure and to think of new ways of arranging the genes to form new solutions. Combining genes to form new genomes requires careful assessment, as the usability of different genes depends strongly on the situation. For example the crowd gene is suitable when useful resources are distributed widely or their location is not known in advance. In addition it must be possible to divide the activities in smaller pieces satisfactorily. Often a crowd is used for creation and intermediate decisions while the final decision is left for a specialized group. (Malone & al. 2009)

The choice of motivational factors in a collective intelligence system can be clarified by two rules of thumb. Appealing to love or glory can help to reduce costs, while using money and glory can make the crowd work faster. Motivation is a difficult issue but still an extremely important one. Getting the motivational factors wrong guarantees the failure of the whole system. (Malone & al. 2009)

Collection gene can be applied when the conditions for crowd gene are met and activities can be done mostly independently. Competition, the subtype of Collection gene is suitable when only a few best solutions are needed. It should be noted that for competition to work the incentives must be strong enough to ensure participation without guaranteed rewards. Collaboration gene is usable when a satisfactory way to divide the task into independent pieces does not exist and it is possible to manage the dependencies between the individual contributions. (Malone & al. 2009)

Group and individual decision genes both require that the conditions for the crowds are met. Group decision should be used when the whole group has to be bound by the decision. For example everyone in a product development team should agree on product specifications. When an agreement is not necessary the decisions can be individual. (Malone & al. 2009) A more detailed presentation of required conditions for each gene can be found in appendix 1 and an example of a complete genome in Table 3.

Table 3. Genome of development process of Linux operating system (Malone & al. 2009)

Example	What		Who	Why	How
Linux	**Create**	New software modules	Crowd	Money Love Glory	Collaboration
	Decide	Which modules warrant inclusion in next release	Torwalds and lieutenants	Love Glory	Hierarchy

6 BUILDING THE CONSTRUCT

Producing innovations comes down to creating knowledge and transforming it to value trough two overlapping processes. Knowledge is created in knowledge creation process as described in rye bread model and innovation process is then used to transform the newly created knowledge to value. Interactions between the processes are complex and dynamic with multiple feedback loops. Simplified relationships between the processes in the context of idea development are presented in Table 4.

Table 4. Simplified relationships between knowledge creation process and innovation process in the context of idea development

Phase of knowledge creation process	Phase of innovation process	Idea development activity
Visualization		Idea generation
Socialization		Idea generation
Externalization	Search	Idea collection
Combination	Search	Idea evaluation
Internalization	Select/Implement/Learn	Idea selection & implementation
Potentialization	Learn	Formation of basis for new ideas

The reason for this simplified approach is to provide an accessible model for the purposes of the study. It is assumed that ideas are mostly generated in visualization and socialization phases by embodying from the abstract to mental models and by forming new combinations of shared tacit knowledge. Defining a clear starting point of innovation process is difficult because of the fuzziness of the front end. For the sake of simplicity here the innovation process is considered to begin when ideas are made explicit in externalization phase of knowledge creation process; documenting ideas generated in previous phases transforms knowledge from tacit to explicit form making the communication easier. Evaluation takes place in combination phase; knowledge about the quality and feasibility of ideas is combined to ideas in explicit form. In internalization phase the ideas are implemented. First a selection is made about which ideas are developed further and then they are put into practice. Large part of learning involved in innovation process also takes place in internalization phase, when developed ideas are tested in the real world. Learning continues in potentialization phase, where the experiences gained in internalization phase are transformed to self-transcending knowledge, forming the basis for new ideas.

Focus of this study is on the search phase, the interface between knowledge creation process and beginning of innovation process. A smooth transition over this interface requires effective documentation and evaluation of ideas generated during the knowledge creation process. In STI mode of innovation the transition over the interface from research to development is relatively straightforward and simple. Increasing emphasis on DUI mode, open innovation paradigm and shift towards the fifth generation innovation process complicate the matters significantly. Large amount of information from multiple sources and weaker signal-to-noise ratio increase the strain on idea processing mechanisms. Both knowledge creation and innovation processes are becoming networked activities making the traditional hierarchical management difficult. Collaborative Innovation Network (COIN), being an integrated networking model and as such an example of the fifth generation innovation processes, appears to be a more promising approach to managing networks. COINs aim at flexibility, robustness and self-organization. Processes involved in innovation networks should be compatible with these demands. Capable of satisfying the requirements of COINs, collective intelligence offers a promising basis for idea evaluation tool development.

Collective intelligence has been successfully utilized in business context to gain outreach, additive aggregation and self-organization. In order to facilitate collective intelligence and to avoid common pitfalls of decision making the system should ensure diversity, independence and decentralization in decision making and motivate participation. Other desirable features are modularity and self-organizing properties. An evaluation method relying on these features could prove to be useful in crossing the interface between knowledge creation and innovation processes in the changed innovation environment.

6.1 Requirements for idea evaluation tool

In DUI mode of innovation users are one of the main sources of knowledge. Shopfloor employees form a large user group with lots of potential for innovations, but this potential is often neglected in companies and other organizations. Innovation activities of the shopfloor are known to be subject of various common issues. Often idea generation is not seen as a part of the work. Traditional suggestion boxes do not support bringing up observed problems and expect the ideas to be complete with cost and profit predictions. Informal and naturally emerging idea development requires new channels, which allow more efficient documentation, discussion and exchange of ideas. Critical evaluation phase should be improved. Good ideas should be recognized rapidly and feedback given to employees to keep them motivated. When people get enthusiastic about idea generation, the high number of ideas can easily overload most evaluation systems usually relying on only a few employees. As a result the evaluations are slow and inefficient. Some method for coarse elimination of ideas would be needed to improve the efficiency of the evaluation process. (Paalanen & Konsti-Laakso 2008). Feedback from co-workers has been found to increase cooperation, communication, effectiveness of decision making and self-organization, so in principle anyone in the organization could evaluate the ideas (Dominic & al. 1997).

A need for more effective and efficient tools for collecting and evaluating ideas emerging from the everyday work clearly exists. Requirements for such a tool can be derived from current literature on innovation management. Growing emphasis on user-based innovation both in national innovation policy and practice stresses the importance of users as a source of knowledge. To ensure a smooth transition from knowledge creation process to innovation process documentation, evaluation and processing of ideas in general must be effective. The tool should have the capacity to process large amounts of ideas accurately and be able to provide fast feedback. In addition to collecting completed ideas identifying problems and undeveloped ideas is also valuable and the tool should be able to process them as well. Taking into account the current trends in innovation management the compatibility of the tool with fifth generation innovation process and Collaborative Innovation Networks is important. The tool should help avoiding the common pitfalls of human decision making. Instead collective intelligence should be facilitated trough diversity, independence and decentralization. Finally the motivation to participate should be ensured. A more complete list of requirements with references to literature is presented in appendix 2.

6.2 Assessment of existing systems

Many systems and processes have been developed for capturing the collective intelligence of groups. Some well-known examples of such systems are listed in appendix 3. Next a few selected approaches for idea generation and evaluation are presented.

6.2.1 Group decision support systems for front end of innovation

Group decision support systems are electronic systems designed for supporting meetings and group work (Dennis & al. 1988). Various such systems have been developed to help in activities at the front end of innovation. They are usually aimed at relatively small groups of people closely related to product development. Group decision support systems suit well for facilitating various collaborative tasks at the front end of innovation process involving the development team and customers. Main benefits of these systems are enhanced sharing of knowledge and the possibility to work systematically in a homogenous group of less than 10 people. Group decision support systems have been shown to be capable of facilitating opportunity identification, idea generation and assessment, customer need assessment and concept evaluation. (Elfvengren 2006, p. 91) Especially various voting features have been described as very useful, allowing the users of the system to see which ideas are viewed as the most important (Elfvengren 2006, p. 71) Group decision support systems are mainly aimed at improving the effectiveness of work in small teams. They are not very usable in facilitating idea generation of large groups of employees who do not work simultaneously. Features of a group decision support system designed for the front end of innovation process are described with genome of collective intelligence in Table 5.

Table 5. Features of GDSS for the front end of innovation process described with genome of collective intelligence

Example	**What**		**Who**	**Why**	**How**
GSS for front end of innovation process	**Create**	Ideas	Hierarchy	Money Glory	Collection
	Decide	Which ideas are most promising	Hierarchy	Money Glory	Voting Averaging

6.2.2 IBM Innovation Jam

IBM Innovation Jam is a massive scale (up to 150 000 participants) collaborative innovation session held over the Internet. It consists of two collaboration phases. In the first phase ideas are generated freely and the second phase is used to refine the best ideas emerging from the first collaboration session. Ideas are evaluated separately after each phase, first by a group of volunteers and then by senior executives and professionals. Various automatic tagging and categorizing tools support the evaluation process. (Bjelland & Wood 2008)

Advantages of the IBM Innovation Jam are that it takes every comment seriously and is capable of aggregating many mediocre ideas together. It has been successful in generating significant new businesses for IBM, but the evaluation of ideas is still the weak point of the process. During the collaborative sessions the ideas were piled up and evaluation was taken care of afterwards. The evaluation process was slow and required a lot of resources; volunteers had to read trough 46 000 ideas and after that the top management spent a week reviewing the results. (Bjelland & Wood 2008) The process could benefit from some form of positive feedback loop directing the attention of participants towards promising ideas. Features of IBM Innovation Jam are described with genome of collective intelligence in Table 6.

Table 6. Features of IBM Innovation Jam described with genome of collective intelligence

Example	What		Who	Why	How
IBM Innovation Jam	**Create**	Ideas for new businesses	Crowd	Love Glory	Collection
	Decide	Which ideas seem promising	Hierarchy	Money Glory	Voting
	Decide	Which ideas to pursuit	Hierarchy	Money Glory	Consensus

6.2.3 Crowdsourcing websites

Several crowdsourcing websites use continuous voting to aggregate information and highlight important topics as they emerge. Examples of such sites include Digg.com, Salesforce IdeaExchange and My Starbucks Idea, all working in a similar manner. Users post items they find interesting on the site and visitors then vote on which new items are the most important. The items getting the most votes are displayed at the top of the page and visitors are encouraged to comment on them. The main advantage of these systems is that when a good idea is submitted the discussion can evolve fast on how the idea could be put into practice. These systems can also be scaled up easily. (Bjelland & Wood 2008)

The main problem with this type of systems is that the items getting the most votes are not always the best ideas in business or scientific sense. If a well written unimportant item happens to be submitted simultaneously with a poorly written great one, the unimportant item may capture all the attention of visitors leading to ignorance of the valuable idea. This effect can be seen easily at digg.com where the top items are often sensational trivia. (Bjelland & Wood 2008) A strong positive feedback loop without a controlling negative feedback loop is a probable source of these issues. Snowballing of votes on the first even mildly interesting item causes these systems to produce plenty of false positives. Additionally the items of different ages are very difficult to compare when the number of votes correlates strongly with the age; is a 3 hours old item with 500 votes more important than a month old item with 37 000 votes? Features of crowdsourcing websites described above are summarized with genome of collective intelligence in Table 7.

Table 7. Features of crowdsourcing websites described with genome of collective intelligence

Example	What		Who	Why	How
Crowdsourcing websites	**Create**	Ideas	Crowd	Love	Collection
	Decide	Which ideas are most interesting	Crowd	Love	Voting

6.2.4 Nest-site selection process of honey bees

Nest site selection is a crucially important decision for social insect colonies. While in most cases this decision is made individually by the founding female, in some species of ants, bees, polistine wasps and stingless bees the colony moves to a new nest as a whole. In these cases the decision about the nest site is made collectively. Studies on the field of biology have found striking similarities between the nest site selection processes of these species although they have all evolved the mechanisms of social behavior independently. Separate species are converging towards the same solution from differing initial conditions. (Visscher 2007)

Generally all the species follow similar decision making process. The scouts explore the environment and when an individual scout finds a potential nest-site, it estimates the quality of the site, effectively integrating multiple properties of the site in evaluation. After the evaluation the scout returns to swarm to recruit other scouts to the site. The quality of the site affects the recruiting behavior so that better sites stimulate more intense recruiting. Resulting competition concentrates the attention of the swarm on the higher quality nest-sites trough positive and negative feedback mechanisms. When the number of scouts at one nest-site reaches the species-specific quorum threshold, the decision has been made and scouts stimulate the rest of the colony to immigrate to the chosen site. (Visscher 2007) This decision making process is scalable and fits well for different sizes of insect colonies (Franks & al. 2006).

On honey bees the nest-site selection process has been studied thoroughly and it is also one of the most complex examples of self-organizing group decision making among social insects. Like other species, bees use weighted additive strategy (Seeley & Buhrman 1999; Visscher 2007). All the relevant attributes of each alternative are evaluated and given different weights depending on their relative importance. Then the weighted evaluations are combined and the best overall option is chosen. Other possible decision making strategies would be satisficing strategy and elimination-by-aspects strategy. In satisficing strategy alternatives are evaluated sequentially and the first good enough option is chosen. In elimination-by-aspects strategy attributes of the alternatives are evaluated in the order of importance and alternatives are dropped from consideration when they do not meet the acceptable minimum. Out of these options the weighted additive strategy is the most accurate and cognitively most demanding decision making strategy. (Seeley & Buhrman 1999)

The phases of the nest-site selection process of honey bees are the following (Seeley & Buhrman 1999):

1. A swarm forms a cluster on a tree branch.
2. Several hundred scouts start searching for a suitable nest sites in the environment more or less randomly.
3. When a scout bee finds a possible nest-site, it evaluates the site and returns to swarm to announce it's finding to other scouts by means of a waggle dance. The total number of dance rounds the bee performs depends on the quality of the site on a near exponential scale (15, 45, 90, 150, 225, and 315 dance rounds) (Seeley & al. 2006). The higher the number of dance rounds the higher the likelihood that another scout will follow the dance.
4. Scouts following a dance fly to the described site by themselves and repeat the evaluation process.
5. Soon there will be scouts flying back and forth between various possible nest-sites and the swarm. Traffic to high quality nest-sites increases faster than the traffic to lower quality nest-sites.
6. When the number of scout bees evaluating simultaneously a particular nest site reaches a threshold value of 15, the scouts interpret that the decision has been made, return to the swarm and stimulate it to take off and fly to the new nest-site.

Simulations have shown that natural selection has tuned the different parameters of this process near the optimum compromise between the speed and accuracy of the decision (Passino & Seeley 2005). The attention of the swarm turns quickly to better quality sites while the poor quality sites are dropped from consideration relatively fast (Passino & al. 2007). That is, the resources of the swarm are directed to evaluation of the higher quality sites. At the same time the likelihood of a bad decision remains low (Passino & Seeley 2005).

The decision making process has many interesting features from collective intelligences point of view. During the process the individual scouts use only local information and no direct comparison of nest-sites is necessary. All the available information is taken into account in the process, but none of the bees has to hold all the information. Exponential scale used during the evaluation process amplifies perceived differences in nest-site qualities (Seeley & al. 2006). Even while each individual follows only simple rules of thumb and uses only local knowledge, the self-organizing system manages to integrate the information in a meaningful way. (Conradt & Roper 2005; Visscher 2007) Features of the nest-site selection process are described with the genome of collective intelligence in Table 8. In this case the honey bees are considered to use a form of non-linear scale averaging as their decision making method.

Table 8. Features of nest-site selection process of honey bees described with genome of collective intelligence

Example	What		Who	Why	How
Nest-site selection process of bees	**Create**	Suggestions for possible nest-sites	Crowd	Love	Collection
	Decide	Which suggestion is the best	Crowd	Love	Averaging

Interestingly numerous similarities can be found between the functions and information processing of social insect swarms and the brains of vertebrates both at the neuron/insect and the brain/swarm levels. (Passino & al. 2007) These similarities are summarized in Table 9.

Table 9. Relations between the functionality of brain and swarm cognition of honey bees
(Passino & al. 2007)

Brain	**Swarm**
Early sensory processing	Field of view
Neurons	Bees
Activation thresholds	Dance thresholds
Action potentials	Dances
Neuron populations	Groups of dancing bees
Neural network structure and communications	Communication between bees on random topology
Neural image	Spatially distributed internal model
Short-term memory	Group memory
Lateral inhibition	Cross inhibition
Late memory based processing	Allocation of exploring and recruitment and quorum sensing
Parallel and converging paths	Simultaneous assessment of multiple sites and late processing for agreement on the best-of-N

In addition to similarities in single functions, the performance of a swarm as a whole is closely related to performance of brains. On average the swarm is able to use group memory to provide it with a representation of the relative nest-site qualities under consideration. This is very similar to attention-perception-choice tasks studied in cognitive neurosciences. Comparison of these two fields reveals surprising similarities between attentional systems of brains and social insect swarms. Like brains, the swarm is able to eliminate distracters from consideration and focus attention on the best alternatives. Then the swarm considers its field of view, develops a representation of the problem domain and uses this knowledge to make the choice about the nest-site. (Passino & al. 2007)

6.3 Model for idea evaluation tool

Various existing applications use voting or averaging to aggregate opinions of groups. Usually either all the users are expected to vote on everything or users are allowed to choose which items they wish to evaluate. Both of these approaches have their drawbacks. Using all the users to evaluate everything leads to serious waste of resources in large groups capable of generating vast amounts of ideas. On the other hand letting users choose which items to evaluate by themselves introduces a risk of systematic biases to the system. Users might evaluate only ideas they find interesting, which would limit the diversity of aggregated information. Further, many good ideas could be lost if nobody happens to evaluate them.

In this study the nest-site selection process of honey bees is used as a model for an idea evaluation tool. Issues in nest-site selection and idea evaluation are very similar. In both cases the number of alternative options is high and a good decision requires accurate assessment and integration of multiple attributes of each option. In nest-site selection important attributes are at least sizes of the nest cavity and the entrance, while idea evaluation should take into account economic, technical and organizational viewpoints. It is likely that the abilities and knowledge needed to evaluate different attributes are dispersed among various individuals.

The nest-site selection process of honey bees is an effective solution to attention-perception-choice type of problems. This statement is supported by simulation models and the convergent evolution of nest-site selection processes of various social insect species. Significant similarities between the functions of a bee swarm and a brain further indicate the general characteristics of effective network information processing. The nest-site selection process also utilizes all the facilitating factors of collective intelligence: diversity of opinions, independence of evaluations and decentralization of decision making in a self-organizing modular process.

6.4 Features of idea evaluation tool

Constructed evaluation tool uses a strictly standardized procedure with random allocation of evaluation tasks to ensure the equal treatment of all the ideas, to optimize the use of resources and to minimize the negative effects of systematic biases. General features of the idea evaluation tool are described in Table 10 with genome of collective intelligence. The genome of the evaluation tool is almost identical to the genome of the nest-site selection process of honey bees.

Table 10. Features of the idea evaluation tool described with genome of collective intelligence

Example	**What**		**Who**	**Why**	**How**
Idea evaluation tool	**Create**	Ideas	Crowd	Love	Collection
	Decide	Which ideas are the most promising	Crowd	Love	Averaging

Crowd is used both for generating and evaluating ideas in order to utilize tacit and self-transcending knowledge. In these tasks the required resources are distributed and it is impossible to know in advance where good ideas are going to emerge. Furthermore many already existing idea evaluation applications demonstrate that both idea generation and evaluation tasks can be divided satisfactorily. Using crowd here is therefore justified. Motivation to participate in activities is a complex question. In this case intrinsic motivation is assumed to be enough to ensure sufficient participation and external rewards are not offered. Collection is selected as the format of activities because ideas can be generated independently. In evaluation phase group decision is used to assess the quality of ideas. Following the example of honey bees averaging on non-linear scale was chosen as the aggregation method. This method is suitable for the evaluation task because the quality of ideas can be presented numerically and systematic biases can be minimized trough independence of evaluations and diversity of opinions.

The phases of the idea collection and evaluation process are the following:

1. A user generates an idea and feeds it into the system.
2. The system selects evaluators for the idea randomly.
3. Selected users evaluate the idea on a linear scale from 1 to 5 (1, 2, 3, 4 and 5).
4. The system transforms the evaluations to a non-linear scale (0, 0.5, 1.5, 3 and 5). The ratio of the scale is the same as in the process used by honey bees for nest-site selection.
5. The scores on the non-linear scale are averaged and the ideas listed in the order of superiority.

Optionally, if the number of ideas is really high, load on the system can be reduced by evaluating the ideas in several phases. First only a small number of users evaluate an idea and only if it gets a high enough score it will be send on another evaluation round. This way the use of resources is dependent on the quality of ideas; promising ideas are evaluated more thoroughly than poor ones.

In theory the advantages of such an evaluation tool are numerous. Emphasis on the ease of use and light workload enable documentation and evaluation of all the ideas emerging during everyday work. Diversity of users increases both the likelihood of new ideas emerging and the accuracy of evaluations by aggregating information from multiple sources. Randomized selection of evaluators makes evaluations independent of each other, which reduces the issues of group decision making. At the same time the accuracy is improved by introducing a random error in evaluations, which can then be eliminated by aggregation. Furthermore the independent evaluations and users unaware of the origin of the ideas or opinions of other users reduce the influence of politics, hierarchies and harmful cascade effects.

By decentralizing the decision making otherwise difficult to transfer tacit and self-transcending knowledge can be utilized. Dividing the evaluation tasks helps to avoid overloading the system and allows faster feedback to users about their ideas. Decentralization also spreads ideas further in the organization, which can stimulate new ideas from other users. Combined with fast feedback and appreciation of employees opinions demonstrated by empowerment the tool can activate employees to participate more enthusiastically in innovation process.

The tool is compatible with cultural requirements of Collaborative Innovation Networks. Sources of ideas can be recognized which is a prerequisite for meritocracy. Treating all the ideas in the same way regardless of the source leads to consistency. Internal transparency can be achieved by making the results of evaluations available to everyone.

Use of non-linear evaluation scale borrowed from bees improves the results of evaluations in two ways: the differences at the top of the scale are emphasized and variance of the evaluations is automatically accommodated. Because of the non-linearity of the scale ideas with high variance receive higher scores than the ones with low variance. This is beneficial for the accuracy of evaluations because the ideas dividing the opinions are more likely to be valuable than the ideas unanimously assessed as average.

The constructed evaluation tool has also its weaknesses. In its current form overlapping of submitted ideas cannot be avoided. The same idea may be posted several times causing unnecessary use of resources. Lack of face-to-face communication increases the possibility of misunderstandings. An idea may be understood completely differently than how it was meant, leading to users evaluating different ideas. Motivating employees to use the system may also turn out to be difficult. Motivation to participate is viewed as one of the most important success factors of collective intelligence systems. In the case of evaluation tool the question how to ensure participation is still open. Open sharing of ideas makes defining copyrights difficult and gives dishonest employees opportunities to steal ideas. Therefore high level of trust in the organization is a prerequisite for the use of the evaluation tool.

7 CASE STUDY: APPLYING IDEA EVALUATION TOOL AT LUT LAHTI SCHOOL OF INNOVATION

Shifts from STI to DUI mode and from closed to open innovation paradigm have been recognized early in Päijät-Häme region located around the city of Lahti. The area does not have its own university and therefore lacks public R&D resources as a source of innovations. Instead Lahti has relied on practice oriented model of innovation since the early years of 21st century and actively created regional multi-actor innovation networks (Harmaakorpi 2004, p. 185). Accordingly the main goal of innovation strategy of Lahti region is to become the best area in Finland at applying practice oriented innovation processes. Characteristic for this model is the focus on the front end of innovation. Ability to recognize promising ideas is crucial. Like the example of Procter & Gamble shows, increasing the effectiveness of the front end of innovation process can reap amazing results. (Tura & Harmaakorpi 2008) LUT Lahti School of Innovation works towards the goal stated by the regional innovation strategy on many fronts and has played an important role in developing the innovation model of Lahti region.

7.1 LUT Lahti School of Innovation

LUT Lahti School of Innovation was established in 1996 in Lahti as a sub-unit of Lappeenranta University of Technology. The unit consists of three professorships, research personnel, management and support services and a center for training and development. The professorships deal with performance measurement, productivity and management accounting (established 1996), entrepreneurship, networks and management and leadership (established 2000) and innovation systems, creativity systems and regional innovation policy (established 2004). LUT Lahti School of Innovation operates on the fields of research and development and educational activities. Focus of the unit is on practice-based innovation research. Research themes include development of innovative capability, performance management and development of innovativeness and productivity in public sector. Among many other projects the unit has participated strongly in development of Innovation Catcher, a toolset aimed at improving innovative activities among the shopfloor employees.

Organizational structure of the unit is typical for scientific units; researchers work more or less independently with centralized management. Formal tools for idea collection or evaluation have not been used in the organization before but instead ideas have been put forward more or less randomly. Like Figure 13 shows, in recent years the unit has grown fast and as a result a need for more formal methods for promoting ideas has arisen.

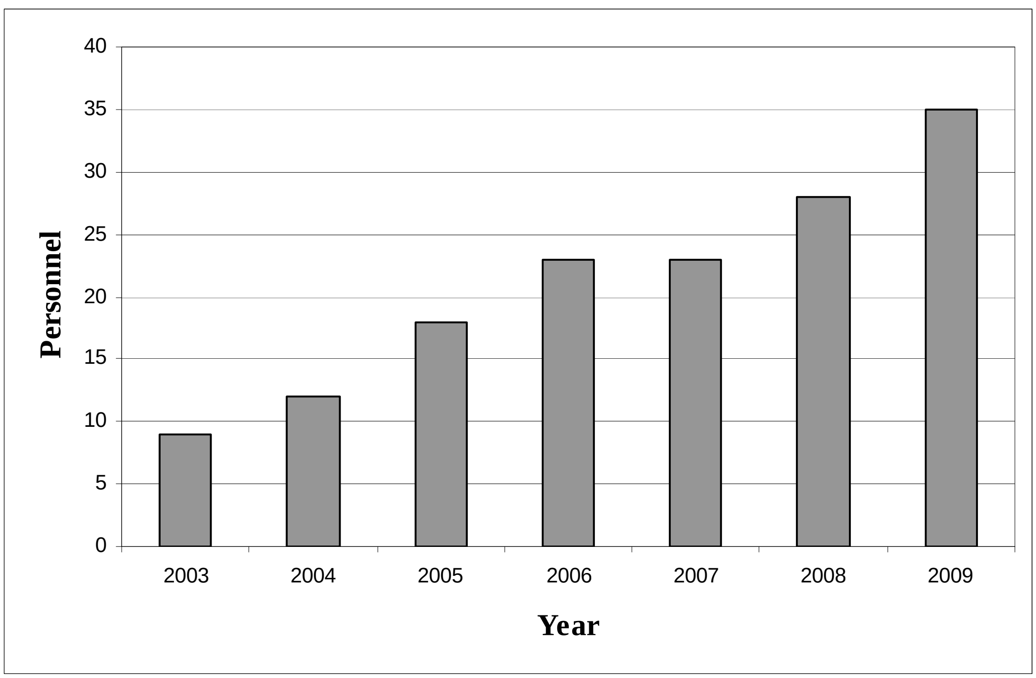

Figure 12. Development of staff resources at LUT Lahti School of Innovation

The changed situation has been recognized by the management of the unit. In this study LUT Lahti School of Innovation was chosen as a case organization where the developed construct was used as an Innovation Catcher.

7.2 Innovation Catcher

Innovation Catcher is a toolset implemented by employees of an organization with a goal to change the innovation activities more open and practice oriented and to improve the performance especially at the front-end of the process. Focus is on shopfloor employees who have the most accurate tacit knowledge about the production processes and are often the largest group of employees in a company. Additionally they are end users of most process innovations. Researches show that innovations created in close cooperation with users tend to be well accepted and of high quality (Hippel 2005, p. 30). This innovation potential is largely unutilized in the companies at the moment. (Paalanen & Konsti-Laakso 2008)

Framework of Innovation Catcher is formed by idea collection, idea evaluation and feedback from ideas. Structure for these processes is created individually for each company in very close cooperation with the employees. (Paalanen & Konsti-Laakso 2008) Typically an Innovation Catcher consists of defining new meeting practices and roles for personnel and creating “collision zones” for employees from different levels of organization. Cooperation over the organizational boundaries is also emphasized. Even though the used methods or tools are not really new or radical, for many companies they form the first step towards a more innovative organization. (Paalanen & Parjanen 2007) In the Innovation Catcher the small changes and ideas are appreciated and creativity of individuals is focused in generating new solutions. Like in TQM, together all the small upgrades result in significant overall improvements. (Paalanen & Konsti-Laakso 2008) The framework of Innovation Catcher is depicted in Figure 12.

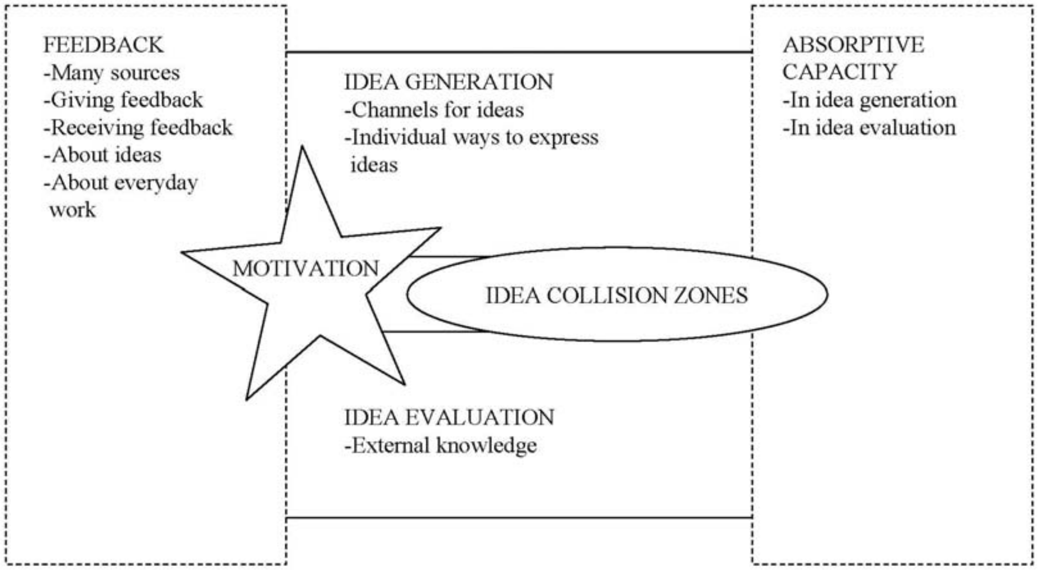

Figure 13. Framework of Innovation Catcher
(Paalanen & Konsti-Laakso 2008)

7.3 Adjusting the Catcher

In order to test the developed construct at LUT Lahti School of Innovation a manually operated prototype of an Innovation Catcher was set up. Email was used to facilitate idea collection and evaluation processes. Items submitted by the users were divided in four categories: ideas, problems, observations and development ideas. Ideas category consisted of ideas and general suggestions for improvements. Problems category was used for announcing detected issues demanding further attention. Interesting findings from newspapers, television, Internet or other sources could be posted in observations category. Development ideas category was used for suggestions concerning improvements of the Innovation Catcher. A random number generator was used to select ten users to evaluate each idea. Users evaluated the ideas on a linear scale (1, 2, 3, 4 or 5). These evaluations were collected on a spreadsheet and then transformed to a non-linear scale (0, 0.5, 1.5, 3 or 5) according to the specifications of the tool and the average scores for each idea were calculated. Finally the ideas, problems and observations were listed in order of superiority in corresponding categories.

7.4 Applying the Catcher

The prototype of the Innovation Catcher was tested at LUT Lahti School of innovation by employees of the unit. Before the test the users were provided with instructions for the prototype, which can be found in appendix 4. Types of accepted ideas were not limited in any way and evaluation criteria were left vague on purpose. All submitted ideas were accepted and users were asked to evaluate the goodness or importance of each item using their best personal knowledge. The items were collected via email and from informal conversations. Each idea, problem or observation from the users was sent to ten randomly chosen users for evaluation. These users did not know where the idea originated because all the evaluation requests came from the same email address, but could see the names of other evaluators on the address bar. Completed evaluations were sent only to the facilitator of the prototype, leaving users blind to opinions of others until the results were published. Users evaluated the items on the linear scale. The facilitator of the prototype transformed the evaluations on the non-linear scale, averaged and organized them in a list in the order of superiority. The updated list was published weekly.

Even though further development or implementation of ideas was not in the scope of this study, it was found necessary to take actions on surfacing issues during the testing period. Each week a couple of the best new ideas were discussed at a meeting with all the employees and decisions were made about the further actions.

Effectiveness and efficiency of the prototype was evaluated using three methods. Performance of the prototype was observed, users were asked to fill in a questionnaire after the test period and two representatives of the unit's management were interviewed.

7.5 Results

The prototype of the Innovation Catcher was tested from the 17th of March until the 15th of June 2009. 29 employees of LUT Lahti School of Innovation participated in the test by evaluating ideas at least once. Ideas, problems and observations originated from 24 different employees. 31 ideas were submitted via email while the rest came up during informal face-to-face conversations and were submitted for evaluations by the facilitator of the prototype. Each item was sent to ten randomly chosen employees for evaluation. On average 7 of them responded.

The Innovation Catcher managed to collect and evaluate 48 ideas, 14 problems, 7 observations and 5 development ideas, totaling 74 items altogether. Idea and problem categories yielded the most of useful content. Observations did not lead to any further actions and due to limited number of development ideas an own category for them was quite unnecessary. The average score on the non-linear scale was 2.88. At the moment 24 of the items collected by the Catcher have proceeded to implementation phase or are seriously considered for further development. 19 of these items have scored at least 3. The average score of items in implementation phase is 3.42 as opposed to 2.62 for the items which have not caused any actions. The difference between the scores is statistically significant (one-tailed t-test, $\alpha = 0.0001$). An item is considered to have proceeded to implementation phase when a decision about implementation has been made, the proposed actions have been taken or the search for a solution to announced problem has begun. A summary of theses results is provided in appendix 5.

Types of submitted ideas were not limited in any way during the testing period, but only divided in the categories mentioned above. After the test items in idea and development idea categories were assessed by the researcher based on their type and degree of novelty (appendix 5). In the case organization the vast majority of ideas were related to processes. Two ideas could be categorized as product improvements suggesting incremental improvements to services offered to customers and two as position innovations bringing an existing solution to a new context. All items under the development ideas category were product related. 64 percent of all items suggested incremental improvements, 32 percent dealt with matters new to the organization and only two ideas could be considered to be quite radical. It should be noted that these categorizations of ideas are only suggestive, providing a view on what sort of ideas were generated during the test.

A non-linear scale was used in assessing the quality of submitted items. Figure 14 presents the scores of all the items in the idea category on linear and non-linear scales and standard deviations of the evaluations on the linear scale. Users evaluated items on the linear scale and evaluations were then transformed to the non-linear scale for comparisons. As predicted, this increased discrimination between good and mediocre ideas; the scores on the non-linear scale are clearly spread out more than the scores on the linear scale. Variations in evaluations are also taken into account automatically; the non-liner scale peaks in unison with standard deviations on the linear scale. It is logical to assume that ideas dividing the opinions are more likely to be valuable than the ideas unanimously assessed as average. For these reasons it can be argued that the non-linear scale is more useful at capturing users' knowledge about the quality of ideas than the linear scale.

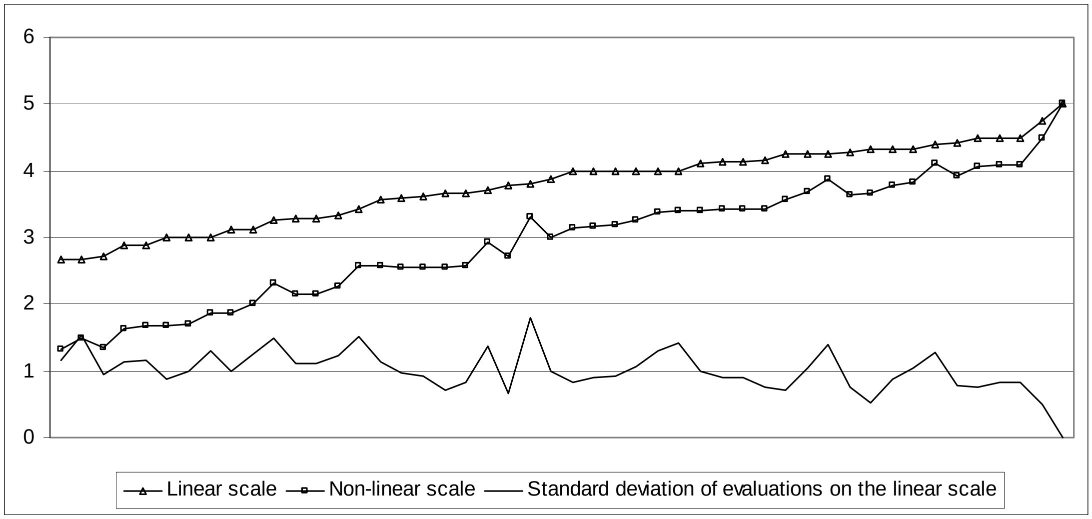

Figure 14. Comparison of scores on linear and non-linear scales

7.5.1 Comparison of results and requirements

Functionality of the developed construct can be evaluated by comparing the results from the Innovation Catcher prototype testing to requirements for idea evaluation tool. Validity of the requirements was ensured by deriving them from current scientific literature. Therefore the main question here is whether the prototype is able to fulfill these requirements.

The Innovation Catcher should be compatible with the current innovation policy which emphasizes open innovation paradigm and DUI mode of innovation. The main principle of open innovation paradigm is that valuable ideas can emerge from anywhere and DUI mode emphasizes users as a major source of knowledge. Everyone in the case organization had the possibility to participate in idea generation, the ideas processed by the prototype originated from employees and evaluations utilized the tacit knowledge buried in the organization. It can be concluded the Innovation Catcher managed to capture the essential principles of the above mentioned paradigms.

Documentation of ideas emerging from everyday work should be fast and easy. Considering the number of participants the Innovation Catcher managed to collect reasonably high number of ideas. Many of them were unfinished, indicating a low threshold for submitting ideas. Together these findings suggest that the documentation of ideas is effective.

Effectiveness and efficiency of evaluations can be divided in three factors: accuracy of evaluations, speed of evaluations and processing capacity of the system. The results of Innovation Catcher prototype testing show that ideas receiving high scores are implemented much more frequently than ideas with low scores. Out of the ten highest scoring ideas six have proceeded to implementation phase at the moment while out of the ten lowest scoring ideas none have received the same treatment. Similarly the problems receiving high scores were interfered much more often than the issues at the bottom of the list. Additionally the problem with the second highest score was found to be of high priority in a completely separate development project. The Innovation Catcher seems to be capable of recognizing promising ideas and important issues with sufficient accuracy.

Results from evaluations were usually gained in a few days after submitting an idea. An updated list of evaluated items was published every Monday; users got feedback about their ideas within a week. The number of ideas did not load the Innovation Catcher notably during the testing period. A typical user had to evaluate a maximum of only a few ideas per day, one evaluation taking approximately a minute. Users also mentioned ease of use and low workload as advantages of the Innovation Catcher. The manually operated prototype was not even near the limits of its capacity during the testing. Sufficient accuracy and speed of evaluations with adequate processing capacity indicate the Innovation Catcher is efficient and effective in its task.

Technical functionality alone is not enough for a tool to be useful. Users' willingness to participate to idea generation and evaluation is one of critical factors determining the success of the Innovation Catcher. The prototype managed to collect 74 items altogether. This number is quite high considering the size of the organization and the facts that no one was personally responsible for generating ideas and external rewards were not offered for users at any point. On average each submitted item was evaluated by 7 users out of maximum of ten. In the case organization the lack of motivation to participate was not found to be an issue.

The Innovation Catcher was found to be able to stimulate idea generation. Many times the participants responded to evaluation requests by submitting new ideas for evaluation. Unfinished ideas were improved and solutions were suggested for problems. Testing the prototype of the Innovation Catcher also provided unexpected anecdotal evidence about emergence of a Collaborative Innovation Network (COIN) inside the organization. In one case submitting an idea for evaluation generated a chain of new ideas about varying topics. Some of these ideas were then developed further by suggesting improvements on them. The end product of this emergent process was a fully developed concept ready for implementation. Even the people with necessary skills and willingness to take care of the execution were found during the successive idea evaluations. The whole process was fast, easy and effective and it seemed to emerge very naturally.

7.5.2 Acceptance of Innovation Catcher in case organization

Acceptance of the Innovation Catcher in the case organization was evaluated with a questionnaire for employees and more detailed interviews of two professors: Timo Pihkala, who is in charge of the unit and Vesa Harmaakorpi, who is responsible for the operational management of the unit. The questionnaire and interviews took place after the prototype testing was finished. 19 participants (including the two professors) responded to questionnaire giving the response rate of 66 percent. The questionnaire consisted of three multiple choice questions and an open question, in which the participants were free to comment the Innovation Catcher and prototype testing. In addition to these questions the interviews contained questions about idea management prior to introduction of the Innovation Catcher, what differences in idea management could be noticed afterwards and what were the perceived benefits and disadvantages of the Catcher.

Before the implementation of Innovation Catcher the process of idea generation at LUT Lahti School of Innovation was undefined (Harmaakorpi 2009). There was also a lack of an organization wide viewpoint to idea generation; only issues related to ones own work were familiar (Pihkala 2009). Ideas were brought up randomly for example at coffee table conversations (Harmaakorpi 2009). Idea generation was mostly a business of the most active people and only ideas that could be implemented by a single individual were put into practice. (Pihkala 2009) When the size of the unit was small formal methods for idea management were not considered necessary, but now as the organization has grown the cognitive distances have become longer (Harmaakorpi 2009). A systemic approach is seen as necessary for crossing these distances (Pihkala 2009).

In consequence of implementation of the Innovation Catcher the whole issue of idea generation has surfaced leading to many beneficial changes in idea management (Harmaakorpi 2009). The process is now much more visible giving everyone a possibility to participate in idea generation regardless whether they are in contact with the management or work on the spot at all (Pihkala 2009). Productivity of employees in idea generation has noticeably increased (Harmaakorpi 2009). Innovation Catcher allows the development of ideas to be spread further in the organization; tasks that previously were in the responsibility of a single individual can now be divided. Measuring the innovation performance has also become easier. Documentation makes it possible to observe the types and the amount of ideas the organization is able to produce. (Pihkala 2009)

Comments from the questionnaire:

"A fast, good way to generate and evaluate ideas."

"The tool has helped to rise up and implement some development proposals that had become eternal issues."

"In my opinion it is great that an easy and simple way to generate ideas also inside our own organization has been developed. Everybody's work is quite hectic, so the best thing about the tool is its ease of use."

"The evaluation tool is great in my opinion; collective intelligence comes true well and everyone has a change to have an influence."

Implementation of the Innovation Catcher was not considered to have serious disadvantages. A few participants viewed aggregating personal knowledge to a single numeric evaluation as difficult and possibly too simplified to capture often complex nature of problems (Harmaakorpi 2009). Evaluating ideas in simplified form was also suspected to increase the risk of misunderstandings, especially if the user is not familiar with the context of a particular idea. Some of the evaluations were viewed as unnecessary; duplicates, minor issues or ideas that can be put into practice straight away would not require a formal evaluation process. This raised suspicion about organization losing some of its spontaneity and creativity if things are not just done anymore. All these previous issues were each mentioned only a few times in interviews and questionnaire. On the other hand the lack of effective implementation after the evaluation process was brought up in both interviews and it was the most often mentioned issue in questionnaire. Ineffective implementation makes even the best ideas worthless and can reduce the motivation to participate in idea generation. The important question here is what happens after the front end of innovation process

(Pihkala 2009). This topic should definitely be examined more thoroughly in the future (Harmaakorpi 2009).

Comments from the questionnaire:

“All the participants of idea evaluation may not see the benefits of a particular idea, if the frame of reference is unknown or has not met the problem to which idea offers a solution.”

“Sometimes it feels like the same idea is rotating many times in evaluation. So if it has been supported, just put it into practice. I don’t believe that all the little changes should be asked from everyone. There are also ideas that could be implemented straight away, no need to evaluate.”

”Sometimes it feels like that the spontaneity disappears and nothing is just put into practice anymore”

“The tool is suitable for evaluation, but something related to implementation is needed to support it.”

Continuation of the use of the Innovation Catcher in LUT Lahti School of Innovation is supported by the organization and the management of the unit. The prototype is viewed as very promising but it naturally requires further development (Harmaakorpi 2009). Idea generation and evaluation should be made even more visible and implementation issues should be resolved allowing a smoother transition from the front end to later phases of the innovation process (Pihkala 2009).

A comment from the questionnaire:

"Conversations also with an outside service provider? Here we have a good and compact (and also simple) product for idea evaluation. Lots of potential!"

Generally the results of both the questionnaire and interviews were very positive and encouraging and indicate acceptance of the Innovation Catcher in the organization. Results of the questionnaire and interviews are summarized in Figure 15 and a more detailed presentation can be found in appendix 6.

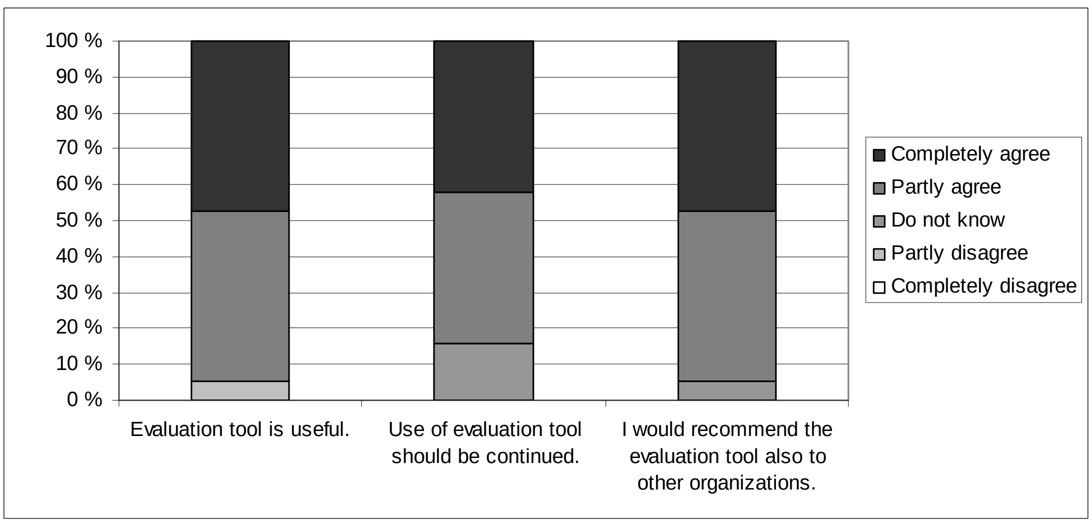

Figure 15. Summary of the results from questionnaire and interviews

8 DISCUSSION

The focus of this study was at the front end of innovation process. Recent shift from STI mode towards DUI mode and the changing paradigms demand new approaches to management of the front end of innovation. Documentation and evaluation of emerging ideas is of crucial importance. The main objective of this study was to construct an effective tool for collecting and evaluating ideas at the front end of innovation process. The developed construct was based on insights gained from literature review on knowledge creation, innovation management and collective intelligence.

The developed Innovation Catcher operates in externalization and combination phases of the knowledge creation process. Ideas are transformed from tacit to explicit form when they are documented in externalization phase. Evaluations take place in combination phase. In cyber *ba* knowledge about the quality and feasibility from multiple perspectives is combined and attached to ideas and more complex sets of knowledge can be formed: lists of ideas organized in the order of superiority.

Documentation and evaluation of ideas was found to be of major importance for successful front end of innovation process. This was demonstrated when several old issues surfaced during the testing of Innovation Catcher prototype. Many of the issues had been known for years and discussed every now and then in the organization, but without effective documentation and evaluation they were forgotten before any actions were taken. Additionally without prioritization it can be difficult to decide on which issues to concentrate on. Introduction of the Innovation Catcher managed to provide some formalization to the chaotic front end of innovation process.

Based on the results of the prototype test the Innovation Catcher seems to be able to bring up especially process innovations. It is difficult to tell though, whether this is a feature of the tool or the case organization. The main focus of the work done at LUT Lahti School of Innovation is on research and it is possible the results would have been different in an organization aimed strictly at product or service development. The degree of novelty involved in ideas was generally low. Majority of them were incremental improvements or solutions that are broadly used outside the organization. Even though radical innovations should be expected to be much rarer than incremental ones, the lack of wild and outstanding creativity among submitted ideas suggests the Innovation Catcher might be better suited for facilitating gradual improvements. This is in line with the literature stating that different methods are needed to support incremental and radical innovations.

This study contributes also to network management by providing hints on what kind of processes could be used for managing networks and how principles of self-organization can be put into practice. The use of the Innovation Catcher did not require any single person to understand the system level effects or see the big picture, which in this case means knowing the relative priorities of ideas before the evaluations. The features of the Innovation Catcher are in line with demands of fifth generation innovation process and Collaborative Innovation Networks. Flat and flexible structure supports rapid and effective decision making and cultural requirements of COIN are fulfilled; the Innovation Catcher is transparent and consistent and allows meritocracy. Furthermore it can be seen as a method of parallel information processing where electronic and human information processing are used in a complementary manner.

Findings of this study are in line with the theoretical background of collective intelligence. The Innovation Catcher aimed at outreach, additive aggregation and self-organization all of which could be reached. Diversity of users contributed to emergence of new ideas and viewpoints. Modularity of the system allowed decentralization of evaluation tasks and combination of results in a meaningful way. Usability of self-organization was demonstrated when only two simple rules (1.

submit an idea if you get one, 2. evaluate an idea if you are requested to do so) were needed to collect and organize ideas emerging from the organization. In this case the intrinsic motivation of users was enough to ensure sufficient participation as no forms of external rewards were offered. Still, the feedback from the users suggests that the lack of effective implementation could greatly reduce the motivation to submit ideas. This issue should be contemplated more thorough. In theory the independence and decentralization of evaluation tasks should reduce the biases of decision making and utilize tacit knowledge, but without comparison to a more centralized and dependent system these effects could not be measured. Genome of collective intelligence was found to be useful for understanding the structures of existing systems, but using it to design a completely new system from scratch would still be very demanding. More knowledge is needed about the ways how different genes should be combined.

Experiences from testing the prototype of the Innovation Catcher are encouraging. The next logical step for further development of the Innovation Catcher would be the development of a real software system instead of a manually operated prototype. Simultaneously some new features could be added. A possibility to comment ideas would be essential based on the feedback from the users of the prototype. Some method of grouping or combining ideas could also be useful. Many ideas do not work as stand-alone solutions, but could be feasible when combined with other similar ideas. Tags or categorizing could help facilitate this function as well as improving the usability in larger organizations. In addition to collecting only emerging bottom-up ideas the system should allow requesting ideas on pre-specified topics and using problems to direct idea generation. A fully developed version of the Innovation Catcher should include a search function and alternative listings of ideas based on e.g. category, tag or age, allowing easier browsing of the collected content. In large organizations it could make sense to create user profiles and divide the employees in different groups. Instead of purely random allocation users with specific profiles could be chosen to carry out evaluations; an idea connected closely to a production line could be evaluated solely by the production line employees, or certain amount of evaluators from each group could be chosen to ensure sufficient representation of all the relevant viewpoints.

The Innovation Catcher can be scaled to fit organizations of different sizes and the trade-off between speed and accuracy adjusted by changing the parameters, namely the number of users evaluating each idea and the number of evaluation rounds. This feature is important as scalability is required for effective facilitation of Collaborative Innovation Networks. Scalability might also allow the tool to be used to transfer ideas from network to network. Ideas that are not utilized in one organization could be transferred to other cooperating organizations for re-evaluation. The Innovation Catcher could work as an external link, leading to more effective utilization of outside knowledge.

Even though the first experiences about the Innovation Catcher tested in LUT Lahti School of Innovation are very promising, more research on the topic is definitely needed. Especially the transition from evaluation to implementation phase was found to require more attention. In its current form the Innovation Catcher is able to collect and prioritize ideas and problems emerging from everyday work. The big question now is what happens after the front end of innovation process?

9 VALIDITY AND RELIABILITY OF THE STUDY

Relevance

Relevance refers to importance of the topic of the study and to the contribution to the existing knowledge. According to recent literature on innovation management and statements made on public policies, the DUI mode of innovation and related topics are generally seen as significant. On the other hand the interest on collective intelligence seems to be rising in scientific community. To my knowledge similar construction as the one presented in this study has not been tested before. Both the topic and the contributions of the study are therefore relevant.

Construct validity

Construct validity deals with utilizing correct operational measures when carrying out the research. In this study the development of the construction was based on theoretical analysis. Multiple sources of evidence were used to evaluate the construct in order to minimize the effects of researcher bias. It can be considered that sufficient construct validity has been reached.

Internal validity

Internal validity refers to the establishment of a causal relationship. Even though internal validity is not the main concern in constructive research approach, sufficient care was taken when making implications about causal relationships.

External validity

External validity refers to generalizing beyond the immediate research. The developed construct was tested and found useful at LUT Lahti School of Innovation. It is therefore likely that the construct would work in other similar organizations too.

Reliability

Reliability refers to sufficient documentation of phases of the study, so that the same results could be obtained by repeating the operations. The operations taken during the research are documented in detail in this thesis. It should be possible to repeat the study by following these instructions, making the study reliable.

Market based validation

Validity of a constructive study is determined by market tests. At the moment only a weak market test can be considered. To pass the weak market test the construction must be adopted in one organization. A prototype of the Innovation Catcher is adopted in use at LUT Lahti School of Innovation. The tool is viewed as useful and it is generally accepted in the organization. It can be argued that the criteria to pass the weak market test have been successfully met.

10 CONCLUSIONS

Changes in innovation policies and paradigms have major effects on the front end of innovation process. Customers, users and shopfloor employees are becoming increasingly important sources of knowledge, which has lead to emergence of a need for new tools for processing information and ideas coming from multiple sources. In this study one such tool was constructed and tested in a case organization.

Problem of idea evaluation was approached from collective intelligence's point of view. Interest on this relatively new multidisciplinary field is rising and it is not surprising that many alternative approaches are explored at the moment. Only time will tell which solutions are the best, but one thing seems obvious already; attention to details is crucial when designing a system aiming at facilitating collective intelligence. Most systems include at least some self-organizing properties and as a result apparently trivial changes in details may generate huge differences on the system level. Millions of years of evolution have optimized the decision making process of bees, which was therefore chosen as a model on which the development of the constructed Innovation Catcher was based.

The prototype of the Innovation Catcher was tested in a case organization and the results were encouraging. The prototype managed to distinguish promising ideas from mediocre ones and point out important issues effectively and efficiently. Additionally spreading ideas around the organization was found to stimulate generation of new ideas. The common wisdom about the importance of proper implementation was backed up once again; even the best ideas are worthless if they are not properly put into practice. The usability of the developed construct was demonstrated by the acceptance of the Innovation Catcher in the case organization.

11 DIRECTIONS FOR FURTHER RESEARCH

The development and testing of the construct presented in this study highlighted several interesting questions for further research.

- The construct has passed only a weak market test at the moment. Further research should try to prove the effectiveness of the Innovation Catcher more reliably. This could be achieved by testing the tool in larger organizations or in open networks constructed of many individual organizations. Main question here would be how well the Innovation Catcher copes with massive amounts of ideas; is it scalable enough to solve the issues of information overload?
- It would also be interesting to find out what effects the Innovation Catcher has on innovation performance. Even though the tool seems to be effective at bringing up issues and ideas, it does not necessarily mean that this actually improves the innovation performance of an organization. Methods to measure innovation capability and performance could be used to answer this question.
- How effective the Innovation Catcher is at assessing ideas compared to alternative evaluation methods?
- The constructed evaluation tool could be combined to other applications utilizing collective intelligence. In addition to front end of innovation process, what other applications would benefit from such an evaluation method?
- The Innovation Catcher is usable at collecting inputs inside an organization. Could it also be used as a link to external knowledge from customers, users and other organizations?
- Implementation of ideas is an issue of crucial importance and should definitely be paid more attention. Innovation process would benefit from a smoother transition from idea evaluation phase to implementation. Could some kind of a self-organizing process be

utilized for the purpose? One possible solution to facilitating the implementation phase could be adding another scale measuring the willingness of users to participate in further development of an idea. The ideas gaining high scores both on importance and participation could then be put into practice rapidly.

- If a software version of the prototype is developed some new features could be tested. Would it be useful to use different user profiles in large organizations to allow the evaluations to be assigned specifically to people with most accurate knowledge? Can the evaluation process be improved by making it more dynamic? The number of evaluations could be made dependent on the goodness of idea; items gaining highs scores would be send to additional users for further evaluations. This way the poor quality ideas would be processed fast while more promising ideas would receive more resources and more accurate assessment.
- In order to improve the suitability of the Innovation Catcher for different size organization it could be possible to make the software self-scaling. If the number of active users is monitored constantly the parameters of the tool could be adjusted automatically depending on the available resources.
- Utilizing collective intelligence turned out to be a suitable approach to solving issues at the front end of innovation process. What other organizational processes can be improved by facilitating collectively intelligent or self-organizing features?
- In this study much attention was not paid on motivational factors despite the crucial importance of the issue. More research would be needed in order to find out what factors motivate people to participate in collective intelligence systems.
- Genome of collective intelligence was found useful for understanding structures of existing systems, but designing a new one from scratch

would still be very difficult. More knowledge is needed about how different genes can be combined. What combinations of genes used in existing systems are the most successful?

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Appendix 1. Conditions when genes of collective intelligence are useful (Malone & al. 2009)

Question	**Gene**	**Conditions when useful**
Who	Crowd	- Required resources are widely distributed or their location is not known in advance - Activities can be divided into smaller pieces satisfactorily
	Hierarchy	- Conditions for Crowd are not met
Why	Money Love Glory	Many complex factors are relevant. Generally: - Appealing to Love and Glory may reduce costs - Appealing to Money and Glory may speed things up
How - Create	Collection	Conditions for Crowd and - Activity can be divided into pieces that can be taken care of independently
	Contest	Conditions for Collection and - Only a few good solutions are needed
	Collaboration	- Activity cannot be divided and - Dependencies between individual inputs can be managed
How - Decide	Group Decision	Conditions for Crowd and - Everyone in the group needs to abide by the same decision
	Voting	- Group needs to be committed to decision
	Averaging	Conditions for Voting and - Decision consists of estimating a number - The crowd does not have a systematic bias
	Consensus	Conditions for Voting and - Consensus can be reached in reasonable time (small group with similar views)
	Prediction market	- Decision consists of estimating a number - Crowd has some information about number (biases are ok) - Some members have high quality information - Continuously updated estimates are useful
	Individual Decision	Conditions for Crowd and - Different people can make their own decisions
	Market	- Money is needed to motivate people to provide effort and resources
	Social network	- Non-monetary motivators are sufficient for people to provide effort and resources - Individuals find opinions of others useful

Appendix 2. Requirements for idea evaluation tool

	Requirement	Viewpoint	References
1	Users as a source of knowledge	DUI, innovation policy, user-driven innovation	Valtioneuvoston innovaatiopoliittinen… 2008, Berg Jensen & al. 2007, Paalanen & Konsti-Laakso 2008, Von Hippel 2005
2	Effective documentation, evaluation and processing of ideas emerging from knowledge creation process	Knowledge creation, innovation process, user-driven innovation	Harmaakorpi 2004, Forssen 2001, Tidd & al. 2005, Paalanen & Konsti-Laakso 2008
2	Support for bringing up problems and incomplete ideas	User-driven innovation	Paalanen & Konsti-Laakso 2008
4	Capacity to process large amount of ideas	User-driven innovation	Paalanen & Konsti-Laakso 2008
5	Feedback from co-workers	User-driven innovation	Dominic & al. 1997
6	Integration of organization and systems	5th gen. innovation process, COIN	Rothwell 1994, Gloor 2006
7	Flat and flexible organizational structures	5th gen. innovation process, collective intelligence	Rothwell 1994, Gloor 2006, Malone 1997, Surowiecki 2004
8	High connectivity and interactivity	5th gen. innovation process, COIN	Rothwell 1994, Gloor 2006
9	Decentralized decision making	5th gen. innovation process, COIN, collective intelligence	Rothwell 1994, Gloor 2006, Malone 1997, Surowiecki 2004
10	Motivation to participate	Knowledge creation, COIN, collective intelligence	Harmaakorpi & Melkas 2005, Gloor 2006, Malone & al 2009, Bonabeau 2009, Gloor & Cooper 2007, Tapscott & Williams 2006
11	High levels of trust	COIN	Gloor 2006
12	Open knowledge sharing	COIN	Gloor 2006
13	Diversity	Collective intelligence	Surowiecki 2004, Bonabeau 2009, Hong & Page 2004
14	Independence	Collective intelligence	Surowiecki 2004
15	Modularity	Collective intelligence	Malone 2004
16	Self-organization	Collective intelligence	Bonabeau & Meyer 2001, Camazine & al. 2001, Gloor 2006

Appendix 3. Examples of systems utilizing collective intelligence

Example	Description
Amazon Mechanical Turk	A marketplace for work developed by Amazon.com
Collective Intellect	Aims to summarize information from blogs and other web pages to produce usable knowledge for marketing
Digg	A news discovery service integrating submissions and evaluations of many people
Google	Search engine based on aggregated implicit human evaluations
Gwap	Games with purpose of training computers to solve problems
IBM Innovation Jam	A massive scale collaborative innovation session
InnoCentive	A marketplace for innovations connecting solution seekers to problem solvers
Lego Mindstorms	A robot toy. Users can participate in development trough a forum
My Starbucks Idea	A web page for collecting ideas from customers of Starbucks
P&G Connect & Develop	A model for utilizing open innovation
Prediction markets	Exchanges in which people buy and sell predictions about the future
reCHAPTCHA	CHAPTCHA service that helps to digitize books
Salesforce IdeaExchange	An open and direct channel of communication for Salesforce customers
Sermo	A closed community of health care professionals
SourceForge	Leading open source software community environment
Swarm intelligence	Artificial intelligence based on collective behavior of decentralized self-organizing agents
Threadless	Clothing retailer selling t-shirts designed and chosen by users
Wikipedia	Free encyclopedia that anyone can edit
YourEncore	Connects companies with retired scientists and engineers

(Handbook of Collective Intelligence 2009, Bjelland & Wood 2008, Huston & Sakkab 2006, Bonabeau 2009, Tapscott & Williams 2006, p. 130-131)

Appendix 4. Instructions for the users of Innovation Catcher prototype.

Translated from the original Finnish instructions used in the test.

Idea evaluation tool

Instructions

Purpose of the tool is to collect all the occurring ideas which most of the time are forgotten instantly. Forget self-criticism because all thoughts are accepted. The ideas are divided in four categories:

1. Ideas; all general development suggestions and ideas
2. Problems: observed problems and things requiring improvements
3. Observations; notices about the surrounding world that others might find interesting, for example newspaper articles
4. Development ideas; Suggestions and observations concerning this evaluation tool

Submitting an idea
Follow these instructions when you are submitting an idea for evaluation:
1. Write either IDEA, PROBLEM, OBSERVATION or DEVELOPMENT IDEA to the topic of a message
2. Describe the idea, problem, observation or development idea shortly in the message
3. Send the message to (address of facilitator)

Evaluating an idea
When you receive a message with IDEA, PROBLEM, OBSERVATION or DEVELOPMENT IDEA on topic, follow there instructions:
1. Evaluate the goodness/importance of the idea, problem, observation or development idea according to your best knowledge on a scale from 1 to 5. 1 means poor/unimportant and 5 means good/important.
2. Send your reply to (address of facilitator)

Results
The evaluated ideas can be viewed in a common network folder.

Appendix 5. Summary of results from the Innovation Catcher prototype testing

Quantitative results:

	All			In further development				No action				
	Number	Average score	Standard deviation	Number	Percent of all	Average score	Standard deviation	Number	Percent of all	Average score	Standard deviation	One-tailed t-test: probability of avg. of In further development = avg. of No action
Ideas	48	2,95	0,91	15	31,25	3,51	0,64	33	68,75	2,70	0,90	0,0005
Problems	14	2,82	0,95	6	42,86	3,17	1,21	8	57,14	2,56	0,66	0,1474
Observations	7	2,52	0,60	0	0,00	0,00	0,00	7	100,00	2,52	0,60	0,0000
Development ideas	5	2,83	0,93	3	60,00	3,43	0,44	2	40,00	1,92	0,59	0,0527
Total	74	2,88	0,89	24	32,43	3,42	0,78	50	67,57	2,62	0,82	0,0001

Qualitative results:

	Product/ Service			Process			Position			Paradigm		
	Incremental	New to organization	Radical	Incremental	New to organization	Radical	Incremental	New to organization	Radical	Incremental	New to organization	Radical
Ideas	2	0	0	30	13	1	0	1	1	0	0	0
Development ideas	2	3	0	0	0	0	0	0	0	0	0	0
Total	4	3	0	30	13	1	0	1	1	0	0	0

Appendix 6. Results from questionnaire and interviews.

Multiple choice questions	Completely disagree	Partly disagree	Do not know	Partly agree	Completely agree
1. Evaluation tool is useful.		1		9	9
2. Use of evaluation tool should be continued.			3	8	8
3. I would recommend the evaluation tool to other organizations.			1	9	9

Recurrent themes in open question and interviews	Incidences
Evaluation tool is useful	11
Implementation	10
Development of the prototype should be continued	5
Some evaluations are unnecessary, duplicates or minor issues	3
Innovation Catcher gives everyone a change to participate in idea generation	3
Evaluation tool is easy to use.	3
Spontaneity and creativity are reduced; things are not just done anymore.	2
Giving a numeric evaluation is challenging.	2