Abstract

Today's software tends to become more complex and is under competitive pressure, thus raising the need for new development practices. Strong geographical and organisational distribution in a Virtual Software Corporation seems to be a solution to many aspects, but leads to new problems as well. Software development is a knowledge intensive task. Geographical distribution makes effective knowledge mediation difficult, thus demanding well-designed Knowledge Management. The processes in software development have been widely studied and appropriate means of structuring and managing them are available, i.e. detailed process models. For the area of Knowledge Management such means are missing. We will introduce the Knowledge Management Process Model that we are developing as a means of properly integrating Knowledge Management with business processes. As a demonstration, we will deploy the model to a Virtual Software Corporation. We will describe initial and ongoing validation, identify areas for further research and draw conclusions from the work done so far.

Keywords

Knowledge Management, Software Process Improvement (SPI), Process Model, Concurrent Enterprising, Virtual Software Corporation (VSC)

1 Introduction

Software Engineering (SE) has changed a lot since its beginning and there are more changes coming up. Increased competitive pressure, more complex projects, new requirements, corresponding methods and with them pitfalls demand new solutions. To stay competitive, software companies will have to incorporate new organisational concepts and software development methodologies. A Virtual Software Corporation (VSC) operating in an organisationally and geographically distributed environment is a way theoretically offering a solution to most of today's problems by allowing more flexibility, extension of one's own competence with external knowledge, and even 24-hour development by utilising time-zone differences. But deploying such a strategy is difficult.

Another widely discussed management principle is Knowledge Management (KM). By creating, capturing and sharing knowledge more effectively, general efficiency can be reached and pitfalls like e.g. the dependency on specific people can be decreased. SE is a knowledge intensive work and the appropriate creation, distribution and use of knowledge becomes even more important when development is performed with reuse, concurrently and/or in distributed environments.

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We will describe our approach to Software Process Improvement (SPI) by paying special attention to KM. We start by first describing the background and defining how we use the terms (chapter 2), then we clarify our research approach (chapter 3) followed by an introduction to the KM Process Model that we are developing (chapter 4) and its possible utilisation in VSCs (chapter 5). We will continue by describing verifications we have made and are currently undertaking and take a look at further research topics (chapter 6). We will end up with conclusions from the work done so far in chapter 7.

This work is conducted at VTT Electronics – a unit of the Technical Research Centre of Finland – within TOTEM, a strategic research and development project dealing with KM in SPI.

2 Background and Definition

2.1 Knowledge Management

KM has been a much-discussed topic throughout the past years [Nonaka, Takeuchi 1995, Davenport, Prusak 1998, Cameiro 2000]. There is an ongoing argumentation about what knowledge and therefore KM are (a summary is provided in [Spiegler 2000]) or should be. It is difficult to differentiate knowledge from information as they are closely related to each other [Leonard, Sensiper 1998]. According to [Nonaka, Takeuchi 1995], knowledge can be externalised into information. Therefore, management of both knowledge and information is needed. The reversed knowledge hierarchy as presented in [Tuomi 1999] also suggests that both have to be taken into account. We therefore see Information Management (IM) and KM as closely related, i.e. KM has to cover Information Management (IM). After all, KM is a Business Process Reengineering (BPR) activity to improve current processes with respect to better utilisation (creation and sharing) of knowledge [Scheer, Allweyer, Ege 1999]. Accordingly, experiences from BPR and SPI activities can be applied to KM.

2.2 Virtual Organisation / Virtual Software Corporation (VSC)

With enhanced information and communication technologies being available, new organisational models are possible. Development towards Virtual Corporations performing close co-operation between a number of organisations is a general trend [Davidow, Malone 1993]. In the software business such Virtual Corporations are called Virtual Software Corporations (VSC): a number of organisations dynamically link their processes to achieve business goals [Mowshowitz 1997]. The potentials are synergy effects (diversification potentials), economies of scale and scope, enforced market positions, and quality improvements, thus bringing the best of two worlds - markets and hierarchies - in some situations, while showing limitations in others [Gebauer 1996]. But transaction costs can get higher and culture becomes a more important issue in such an environment [Lee, Varey 1999]. As SE is a highly knowledge intensive task [Hilburn, Hirmanpour, Khajenoori, et al. 1999], also the mediation of knowledge becomes critical.

3 Research Approach

The evolutionary engineering research method as described by [Glass 1994] has been applied in guiding this constructive research. The engineering research method provides good structure for this type of research due to in-built concept of evolution and improvement. We assume that KM is a management model of future of software development. To understand the topic in overall, KM literature has been studied [Nonaka, Takeuchi 1995, Brooking 1996, Stewart 1997, Boisot 1998, Davenport, Prusak 1998, O'Dell, Grayson 1998, Liebowitz 1999]. Presentations of KM models in various abstraction levels from diverse angels can be found in literature and on the
web, e.g. [Nonaka, Takeuchi 1995, Davenport, Prusak 1998, Allweyer 1999, Liebowitz 1999, Wiig 1999, "How It Worx" 2000, "Knowledge Management Framework" 2001]. However, no detailed models were available. Therefore, combining our knowledge about SE, SPI and measurement with the results of literature research, we have been developing a process model for KM-based activities as a first step towards a KM-based SPI framework. This KM Process Model enables a detailed understanding of the processes needed to be performed within KM and can thus assist in analysing, planning, and conducting KM for SE. Our experiences with VSCs suggest that the problems appearing can be widely related to insufficient information and knowledge mediation, thus a KM-based approach to VSCs might be a solution. We theoretically apply the KM Process Model to the idea of VSCs here.

4 Introducing the KM Process Model

While knowledge is created in the minds of people only, it can still be transferred in different ways [Nonaka, Takeuchi 1995]: Socialisation (tacit-to-tacit), Externalisation (tacit-to-explicit), Combination (explicit-to-explicit) and Internalisation (explicit-to-tacit). Also, there is the collective knowledge that is formed by different people and the way (processes) they work together (organisational knowledge). Figure 1 introduces the KM Process Model on a high level and illustrates the Pr2imer improvement model [Karjalainen, Mäkäräinen, Komi-Sirviö, et al. 1996]. Although "storage" sounds technical, it by no means can be restricted only to technical tools. It also has to cover collective knowledge of groups, knowledge maps, etc. in combination with technical solutions. According to [Davenport, Prusak 1998], the technical part in KM projects should, however, never be more than a third.

![Figure 1: The KM Process Model and Pr2imer Improvement Model](image-url)

These basic processes of KM are described in the following:

- **KM Co-ordination**: The KM Co-ordination is implemented according to the principles of the Pr2imer model used for guiding and controlling improvement initiatives. The current state is analysed and a target state is defined based on the scope of the improvement project. In the analysis phase knowledge processes, cultural environment and technical means related to SE processes, e.g. software reuse processes, are subject to
analysis. Based on found problems and needs the improvement goals and better practices are defined. During pilot operation and commissioning improved KM and SE processes are monitored by analysing collected metrics. Pr’imer processes build up an improvement cycle (Analyse - Define - Plan - Effect) to address the need to take an incremental approach (starting with pilots, ending up with comprehensive systems) and to be able to adopt to changing requirements [Davenport, Prusak 1998, Liebowitz 1999]. Assuming that knowledge about KM itself is also taken into account, the Pr’imer improvement cycle incorporates ideas as in the IDEAL model ["The Ideal Model" 2000], i.e. by updating the system, "Learning" is performed as an embodied process.

- **Identification of Need for Knowledge:** Before existing knowledge can be (re)used, the need for knowledge has to be identified and requirements for the desired knowledge have to be determined. While self-initiated identification depends on culture, these activities can at least partly be supported or automated by appropriate use of technology, see e.g. [Staab, Schnurr 2000]. Any sharing activity depends on the successful identification and determination of needs on knowledge.

- **Sharing of Existing Knowledge:** Whenever the required knowledge is already present, it is to be shared. To determine whether this is the case, corresponding knowledge has to be searched for, i.e. knowledgeable people or explicit knowledge has to be found. Sharing can take place in different ways: "Knowledge Pull" (people search for knowledge) or "Knowledge Push" (people are provided with knowledge they are known to need). Knowledge can further be shared outside the organisation (Knowledge Brokering). A major enabler for sharing knowledge is the social and cultural environment [Davenport, Prusak 1998], which is addressed in "KM Co-ordination". If the supporting culture has been built, technological assistance should be introduced.

- **Creation of New Knowledge:** If the knowledge found to be needed by "Identification of Need for Knowledge" is not available, it needs to be created. Creation of knowledge can be performed in various ways [Nonaka, Takeuchi 1995]. Cycles of convergent and divergent thinking are performed in creating innovations [Leonard, Sensiper 1998]. Knowledge coming from outside the organisational context needs to be re-created in conjunction with the existing knowledge to achieve adoption to the actual environment. Therefore knowledge coming from the outer context in the figure goes to knowledge creation and not directly to utilisation (sharing or storage).

- **Knowledge Collection and Storage:** New knowledge is not only created by demand, but also by innovations during standard work procedures, without explicit intention [Leonard, Sensiper 1998]. Whenever knowledge is created, this needs to be identified. Knowledge can then be evaluated to determine how it should be stored or distributed via the processes of "Sharing of Existing Knowledge". Storage beside mediation to other people can be performed by externalisation to explicit knowledge [Nonaka, Takeuchi 1995]. In this case the process has to cover the selection of media, codification, generation of meta-data for searching etc.

- **Knowledge Update:** Knowledge is context-specific and thus changes with changing environments. This requires the knowledge to be kept up to date, otherwise the whole KM system is endangered [Davenport, Prusak 1998]. Thus, changes need to be identified and analysed from the point of view of their impact on existing knowledge. If needed, appropriate updates should be undertaken.

As mentioned, there exist high-level models as presented in Figure 1. In detailed KM Process Model we have defined sub-processes in order to give detailed framework for the practical improvement work. At the time of writing, the process model consists of a total of 39 processes:
14 processes in "KM Co-ordination", 2 in "Identification of Need for Knowledge", 7 in "Sharing of Knowledge", 6 in "Creation of Knowledge", 6 in "Knowledge Collection and Storage", and 4 in "Knowledge Update".

5 Knowledge Management in VSC

The most significant problem raised by distribution is limited communication, which often has to take place over technical means. The general impact of computer-mediated communication on culture has been studied, concluding that culture is a needed precondition for successful performance [Lee, Varey 1999]. Concerning knowledge transfer, the role of supporting culture is even more important [Davenport, Prusak 1998]. But a common culture is almost impossible to achieve if a VSC is of temporary nature. This makes it hard to share knowledge with partners. Possible solutions to this are either a common standard for organisations participating in VSCs or actions to be taken to build a minimum level of trust between partners and transfer of knowledge. We will deal with the latter here.

A KM system assisting the idea of a VSC has to address the following issues:

- Building an entry-level of trust between all potential partners.
- Managing the pool of potential partners and assisting in getting the right combination of partners for specific purposes.
- Building a required minimum level of trust between partners performing a project together.
- Providing means of mediating knowledge between the co-operating partners in a project (collecting, storing, finding and transferring) according to the performed tasks.

This suggests a differentiation between connecting all possible partners (VSC-Dimension) and connecting a number of partners building a concrete, goal-oriented VSC (VSC-Project-Dimension). In the following we will show that the KM Process Model can be applied to both of these dimensions and demonstrate its possible role.

5.1 VSC-Dimension

A VSC has to establish a common basis for the potential partners (the partner-pool). In this, standards to be used, processes for forming projects and general information and knowledge about VSCs need to be dealt with. The connections on this level are shown in Figure 2. A coordinating instance is needed to arrange and maintain the infrastructure for this level, which could e.g. be a web-site providing a list of available projects and their statuses, a glossary of terms and general description of how to co-operate in projects. Regular meetings between all partners are desirable to exchange experiences and build a general level of trust, but can be hard to realise. However, occasional meetings, e.g. at the location of exhibitions or conferences all partners are likely to attend, could be arranged. Also the coordinating partner can promote the building of common understanding by providing success-stories (codified knowledge) etc.

5.2 VSC-Project-Dimension

Depending on the projects a different system might be used in this dimension, e.g. the content might be confidential so that access cannot be granted to all potential partners. It seems desirable to have one instance managing both dimensions. However, the connections between partners engaged in a common project are tighter than in the VSC-Dimension, therefore different functionality is needed. The connections in the VSC-Project-Dimension are shown in Figure 3, i.e. all partners are connected by the outgoing knowledge-brokering processes ("Knowledge Sharing") to the incoming knowledge-acquisition processes ("Knowledge Creation"). This is a
representation of the network the partners build on the knowledge level to create and share knowledge. After the project this knowledge must be considered for distribution in the VSC-Dimension.

5.3 KM Process Model Utilisation

The possible utilisation of the KM Process Model in building and improving a VSC is described in the following. A first analysis phase would address what knowledge exists at the involved potential partners building the pool of partners. To make this knowledge map available to all partners, a presentation on a web-site maintained by a co-ordinating partner could be created. The management of possible projects and means of finding partners with suitable knowledge to put up a team could also be realised this way. Some face-to-face meetings could be organised to build up trust, furthermore knowledge about how to build and manage teams in a VSC can be provided. Deploying these initial high-level processes starts up the KM system. By defining and analysing appropriate metrics and feedback, improvements and enhancements can be identified and enhancements can be implemented.

![Figure 2 - Connections in VSC-Dimension](image)

Concrete projects in a VSC could utilise different levels of processes. Regular meetings can extend the trust-level and the exchange of knowledge. Generated in the VSC-Dimension, knowledge on how to improve communication utilising technology thereby addressing security issues, can be utilised, e.g. how to establish a common workspace including video-conferencing and utilising encryption. After each project, experiences can be gathered with the assistance of the partner that has had the project manager role. Experiences should be made available for all e.g. via the partner pool. Codification either into processes, general material or project level knowledge would need to be performed. A rating system where each partner rates all other partners of the past project could provide input to the pool management allowing (co-ordinating) partner to steadily improve the selection of other partners for a project.
6 Verifications and Further Research

An initial verification of the KM Process Model with respect to its usefulness in the analysis of KM processes has been performed at an industrial partner. This company is developing, supplying and providing services for extensive measurement and control solutions used for measurement, analysis, monitoring, automatic control, and process information management tasks e.g. at mills and plants. Our purpose was to get a first impression and feedback how useful the KM Process Model is for analysing and planning KM activities in the SE application area. We interviewed several managers and carried out an analysis of their software development processes as well as their software tool that includes some knowledge functionality. The result was encouraging, questions about the detailed sub-processes allowed an easy identification of knowledge related processes both in the SE processes and in the tool itself. This study provided important feedback for model development and after some modifications we are now in the process of starting an extensive use of the KM Process Model to support SE improvement initiatives at another industrial partner. The co-ordination process work will follow the Pr2imer improvement model (Analyse, Define, Plan, Effect) over a time period of about two years. The experiences gathered here and from other planned projects will be reflected to the model enhancement.

SE is loaded with complicated, knowledge intensive work starting from requirements gathering and analysis phases and ending to a final software product even if executed within one company and one site. When moving towards software development organisations temporary in nature the importance of proper knowledge management grow prolifically. An example of what a VSC can look like is ["Asynchrony: Where Great Ideas Meet Their Potential" 2001]. A co-ordinating partner provides the infrastructure and performs central tasks, i.e. the marketing and selling of developed software. The actual software development is done by registered users, who get shares when the product that contains their software is sold. Who is familiar with SE understands the challenging problem area that is ahead when moving towards VCSs: even normal everyday communication and data transmissions between partners include pitfalls. KM may be performed in the VSC-dimension by providing discussion lists, frequently asked questions and a support team. The teams involved in a project can also set up own mailing lists and discussions, just to name few specific actions related to general communication infrastructure. From the viewpoint of the KM Process Model, some processes seem not to be addressed, however, e.g. the gathering of knowledge after a project is fully dependent on the initiatives of the peoples involved.

Already before the results from the verification project are available, some areas needing further research can be anticipated. Firstly, the model is on an abstract level and needs to be fitted to the
needs of possible application areas. In the area of SE these areas could include e.g. software reuse, multi-site software development and the VSC concept discussed here. In addition, detailed guidance in the form of question lists, good practices, suitable methods and suitable technology should be linked to the different processes on each development application area to allow broader utilisation.

7 Conclusion

In this paper we presented our approach to KM by introducing a KM process model and the main processes of this model and their interoperability. The co-ordinating process includes an ongoing Pr2imer improvement cycle (Analyse, Define, Plan, Effect) and the operational processes of creating, collecting, storing, updating, and sharing knowledge. As the process model is on an abstract level it can be deployed in various ways. We demonstrated this by applying the model to the idea of VSCs, showing the capability of the model to address different levels of KM (VSC- and VSC-Project-Dimension) as well as coping with the different means of KM (inter-human communication and computer mediated communication). Currently, a promising glance at the usability of the model is possible based on the verification carried out so far. It can be predicted that extensions towards a framework and refinement towards specific areas of SE are needed to enable effective planning and performing of KM activities. The verification we are starting is going to assist herein and will provide directions and issues to address in future model enhancement.

References


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