Journal of Business & Management (COES&RJ-JBM)
ISSN (E): 2306-7179 ISSN (P): 2306-8043
Publisher: Centre of Excellence for Scientific & Research Journalism, COES&RJ LLC
Online Publication Date & Issue: 1st January 2015, Vol.3, No.1, January 2015
http://centreofexcellence.net/J/JBM/JBM Mainpage.htm

Improving the Effectiveness of Virtual Teams: Tackling Knowledge Management and Knowledge Sharing Issues by Exploring the Benefits of a Context-Aware Knowledge Flow Platform Click here to enter a date *A real case scenario*

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Abstract:
Globalisation has led to the development of new kinds of knowledge work and collaboration schemes. In globalised companies, virtual teams are a phenomenon of critical interest, and to understand the way they manage knowledge flows is becoming more relevant in terms of increased effectiveness, discoverability and reuse. The growing amount of available knowledge poses a challenge of many dimensions to innovative companies. This includes the evaluation their intangible assets that are an essential factor in many corporate initiatives. This research reports on the analysis of a real case scenario in the context of dynamic knowledge retrieval by using the Open plexus framework, a distributed knowledge sharing system that supports knowledge discovery and context-aware knowledge sharing in virtual teams by introducing a 3-tier knowledge sharing architecture. Each tier holds the knowledge of one of the following dimensions: individuals (the personal knowledge created by one knowledge worker), teams (she shared vocabulary and experience-based knowledge that is a result of team processes) and the organisation (the persistent knowledge of the organisational memory that is globally available). Based on a recent management tool, the Knowledge Path Method Model, the system starts recognising and eliminating stale knowledge in the project; thereby reducing the cognitive load of all the agents involved in the development of a new product. These findings allow eliminating the unnecessary interchange of knowledge flowing in the net of knowledge workers, optimising the time to market and increasing the quality and effectiveness of tasks. In addition, it is used to articulate team internal processes which help identifying the agents that are dispensable as members of a specific knowledge flow path. It helps adjusting the use of assigned resources and, simultaneously, identifying the virtual knowledge linked to the product's creation processes. Drawing broadly from our case study, the analysis reveals that Openplexus is able to help identify and monitor important knowledge paths and emergent knowledge flow patterns with their related contexts and thus improves the effectiveness of the employed knowledge worker. The findings have high implications for managers and Human Resources departments, as they can start measuring the traces relevant knowledge leaves in virtual teams.

Key words: virtual teams, knowledge management, knowledge sharing systems, knowledge flow patterns

Citation:
Palma, Prof. Dr. Ana Maria, Giacinto, Robert; Improving the Effectiveness of Virtual Teams: Tackling Knowledge Management and Knowledge Sharing Issues by Exploring the Benefits of a Context-Aware Knowledge Flow Platform Click here to enter a date: *A real case senario* (2015); Journal of Business & Management (COES&RJ-JBM) Vol.3, No.1, pp.316-323.

1 Introduction

Knowledge and its management has been subject of many research endeavours by authors like Hedlund (1994), Nonaka and Takeuchi (1995), Muñoz-Seca and Riverola (1997), Wiig (1993), Marquardt (1996), Van Der Spek and Spijkeruet (1997), Beckman (1997), Ruggles (1997), Holsapple and Joshi (1998) which have led to a detailed taxonomy and understanding. It is an essential building block for enterprises that want to be and stay successful in a globalised world. But more than that it is a product on its own that is produced, maintained and sold. The management of this knowledge and questions about the optimisation of its creation and evolution is getting more into the focus of most globally acting companies. Managers in charge of such knowledge-intensive projects are concerned about questions regarding the amount of newly created and how the effectiveness of related processes can be measured. Brotons (2009) describes the Knowledge Path Model (KPM) that enables the project management to measure and evaluate the effectiveness of existing knowledge transfer paths in teams by introducing a set of metrics that help turning down unnecessary knowledge changes and reducing the time each involved agent has to invest. With the constantly growing amount of available knowledge that an agent has access to, the effort needed to find the right information for a task is increasing as well. To help a knowledge worker discover task-related and relevant information contextual metadata can improve the efficiency of a user in such retrieval tasks which was demonstrated in Dumais et al. (2001). Following the definition by Shkundina et al. (2005) a work context is comprised of the six dimensions (1) information (relevant or used documents), (2) organisation (involved organisational structures or persons), (3) behaviour (performed actions), (4) operation (used tools or applications), (5) cause (task and user goals) and (6) chronology (timeline of events). With the availability of computer supported collaboration tools and many electronic devices like mobile phones, laptops or sensors, it is now possible to keep track of these contexts in virtual environments. In this paper we argue that it is important to improve the attitude towards the sharing of (virtual) knowledge with two parallel strategies: (1) identifying and introducing optimised knowledge sharing processes in teams with KPM and (2) incentivising knowledge sharing by using additional metadata for context-aware services supporting the individual knowledge worker in distributed teams where the context in which virtual knowledge was used is often lost. The paper is organised as follows: in the remainder of this first section we will present related work that influenced the our research, give an overview of our research objectives and the methodology we adhered to. Section 2 introduces the case study and presents the major problems in distributed knowledge work that could be identified and describes how the Knowledge Path Model can help in this setting. Section 3 concentrates on the application of Openplexus by introducing a constant feedback loop module to the system that maps the KPM to processes in a computer supported collaboration environment. Section 4 discusses the results from the KPM analysis and the Knowledge Path Extraction with Openplexus and section 5 concludes this paper.

1.2 Objective of the research study

The objective of this paper is to reflect the applicability of two recent models developed to measure and optimize the knowledge that flows in a team of a department of a company. All in all, the research paper provides a basis for identifying and resolving three emergent problem areas in companies with virtual knowledge teams:

1. To eliminate (by using KPM) the unnecessary interchange of knowledge working in a concurrent engineering environment. This way it is possible to avoid the deterioration of wisdom that flows through unnecessary steps from the source to the final destination. It is possible to cut the time spend in a task cutting the time of the agents involved in the develop of new products optimizing the time to market and increasing the quality of the tasks due to the new amount of knowledge.
2. To identify (by using the KPM Model) the agents (members of the project team) that are dispensable as members of the cognitive nets in the knowledge teams, adjusting the use of resources assigned to the teams. Simultaneously the model gives information about how every

worker is doing his job regarding the knowledge, which is a key indicator to evaluate aptitudes and solidarity within the team. Eventually, the KPM model allows to identify the virtual knowledge linked to the new products generation processes.

3. To support the reuse and to improve the discoverability of existing knowledge artefacts in a specific context, computer systems can support the knowledge worker a great deal to not only to understand the work habits of one individual but has to take the context of the whole team into account. The Openplexus System offers ways to gather contextual information without disturbing the team in their routine. This context information is used to identify the flow of digital knowledge artefacts through the virtual team and to provide detailed feedback to the KPM analysis and thus enables the evaluation of knowledge sharing processes.

Results shed light on how in a net of knowledge is feasible to discover the virtual knowledge; and, also assisting the highest profitability of the current knowledge in the enterprises.

1.3 Method of the research study

KPM and Openplexus have both different stages of application. This section shows a mere summary of the most relevant aspects of the use of both models. On the one side, KPM required to establish the paths where the knowledge is moving, what is called "knowledge paths", then it is set up the "trains of knowledge" what is the number of remittance knowledge in between the agents and immediately the knowledge known till now as explicit or tacit is catalogued in wide a range of taxonomies depending on the target got and the source it comes from. These categories can divide the knowledge in standard, exclusive, virtual, decisive, illustrative, fixed, variable, generated and spread. Table 1 and Figure 2 define and show the theoretical concept of each one. Once the knowledge is identified, it is introduced a parameter that defines the movement of the knowledge through the paths, and allows to know if the knowledge is generated or spread.

Openplexus is an event-driven, semantic middleware that offers a set of functional components that support the knowledge work of distributed teams in virtual enterprises. It integrates into existing operating systems and tool chains by an open event-consuming platform designed improves the knowledge workers' efficiency by making context-aware recommendations available to the user without enforcing a specific workflow. Using this infrastructure it is possible to gain access to real interaction patterns that emerge in teams over time. This way it complements the top-down approach of the KPM methodology by giving the company possible tools that help the management understand existing team interaction structures or deficiencies from the individual up to large-scale patterns.

2. Case Study

The scenario we present here is the result of interviews and contextual enquiries that were conducted at a big American company in the IT and network sector, let's call it ACME Telecommunications. Since the insights that could be gathered during this time contains sensitive information, we will present to you the generalised version of common problems that could be identified in this problem scenario. Here we will concentrate on the knowledge flow patterns that can be found in companies with distributed teams that work from different places where a large amount of knowledge is accessed as digital artefacts that are shared with team members.

Consider a Project Manager at ACME Telecommunications, Susan. Her competences within the enterprise are, exclusively, supervise the customer projects, but, nevertheless, due to a lot of irregularities in the flows of knowledge of other agents involved in the system, she has to develop extra activities that does not belong to her; due to this she is increasing in stress, anxiety and time of work. The questions Susan makes herself are why is she making tasks does not belong to her and no one can realize it, why the work in group is now working, why is so difficult to check where the system is failing and which agent is dispensable, etc. Unfortunately this is not an isolated case, this is happening continuously daily in many departments, many companies. The solution to all these questions can be reached by the

application of the KPM Model and the Openplexus System which allow identifying through the knowledge generated how each worker is doing the work. These models are not only a window to look through the daily posts but, also, an important and advanced model for Human Resources Departments to detect the commitment of the workforce with the environment.

2.1 Analysis with KPM

The KPM target consist of managing the knowledge to reduce the time to market in Susan´s posts; what is, to eliminate the unnecessary process of knowledge. Also, it allows identifying the agents that are dispensable within the project, adjusting the use of resources assigned to the projects. With is will be possible to create High Profitability Teams. Figure 1 shows the five agents involved in the scenario: Project Director (Susan), Customer, General Supervisor, Intermediate Commission and Committee and the codification of the knowledge that flows in the system. To make easier the comprehension of the project tasks and the agent's competences, the picture has been divided in three steps (the paths regarding the initial supervision of the project, the paths regarding the bureaucracy, and, the paths regarding the production time when the project has been checked and is ready). The paths of knowledge are codified with numbers. In our case we have 25 paths. Each path collects the knowledge that flows through it and also knowledge is classified as standard, exclusive, decisive or illustrative. The TS-01-KST-D means: Total Support (TS), knowledge number 1 (01), Knowledge standard (KST), Decisive (D).

3 Knowledge Path Extraction with Openplexus

The Knowledge Tracker implementation in Openplexus follows the idea of the Knowledge Path Model by assigning a unique identifier to every knowledge artefact that is registered with the system. From that point on, the system is capable of tracking the interactions (e.g. reading a document, sending a file to a team member or writing an email) of the users with the system.

Figure 3 depicts the most important components of the Openplexus architecture that are necessary to implement the knowledge path tracking. Openplexus is implemented around two major design decisions:

1. It is a semantic middleware that offers knowledge-work related services by helping aggregate all relevant knowledge from different distributed sources in one unified data model.
2. It is an event-driven, reactive middleware that is built from several loosely coupled components that consume knowledge-work related events and are used for proactive and context-aware recommendations supporting the extension of the base system by adding additional components that process the events made available through the event bus .

These events are published on the event bus which acts as the central communication component between the other modules. The source of a n event can be another module within Openplexus, a running process of the underlying operating system or a reaction to a user interaction that fired an event to notify the Openplexus middleware. Context-related events are consumed by the local module, keeping track of interactions with documents or team members. Interactions like document sharing or team messages are supported through the team handling component. This module manages the access to the vocabulary owned, created and shared by a team and offers ways to access knowledge or documents of connected team members.

Every time something is shared with a member, Openplexus adds knowledge path related information to the shared data model that is described as an ontology in RDF (Resource Description Framework) statements. Figure 4 shows an excerpt from the data model that is part of the case scenario. The green nodes represent the involved users, orange nodes are the knowledge flow representation which hold the necessary metadata that is needed to keep track of the knowledge sharing activities and the blue nodes which are the documents with their respective metadata (lighter blue). The grey box around a sub-graph highlights the metadata that represents one knowledge route in the KPM (in this case route 1 and 3 from Figure 2). Each node in the Openplexus team network has only partial knowledge about the flow of a

document. To be able to visualise the full path of an artefact, the distributed information has to be gathered and aggregated by the knowledge path tracking module which sends out a process that visits every member being connected with the team network at that time and asks every available node for additional flow information.

4 . Results

4.1 KPM Results

This research with a real case brings the possibility of knowing how each roll of the enterprise is working. In our scenario, as expected, Susan is developing an extra percentage of her responsibilities. She was really upset and worry about how to find the solution to this. It is really difficult to prove, just with a perception what is happening in some departments regarding who is in charge of knowledge, who is using it effectively, who is dispensable, who is committed and who is generating and creating knowledge from the source. From this perspective we can asset that:

- Taking into account Susan's results it is demonstrated that she is doing a 33% of work that does not belong to her. Consequently, while she is doing these tasks, she is not spending time on her own issues.
- The General Manager only develops a 17% of work regarding knowledge classified as illustrative, what means that is failing in this issue. The result is that the work is done, but with lacks of excellence and high quality. This work is done by the Project Director.
- The Intermediate Commission is more focused on the decisive work, what is required to the good way and fluid flow of the knowledge through the structure.
- Customer and commission are not required to do more than what they do. They are a necessary figure for the help of the project. Their knowledge and their support are essential, but, they do not create new knowledge (not expected anyway).

The sharing of exclusive knowledge must be encouraged. The difficulties of doing this, used to be the distance between the agents of the project and the reluctance to share the key knowledge each one possesses and learned through the long time. Knowing the figure that is doing the unexpected works is easy to speak about which kind of lacks are found in order to improve the arisen situations. Speaking with Susan was easy to know that she was doing a work that should be done by the General manager, such as: staying in contact with the committee (competences belonged to the General Manager), staying in contact with the customer in management tasks (competences belonging to the General Manager), even, being the link between the General Manager and the Intermediate Commission (both should work together by their own with any contact in the middle). This scenario arises the picture of this department day of work. The General Manager is not doing what is expected and the reasons can come from different reasons, such as:

- The person is not qualified for the post and should renew the knowledge or acquiring new one and eliminate the obsolete one. Knowledge management is the key aspect in this situation.
- The person has got level enough to develop the competences but is not committed with the post. Human Resources Management should manage this scenario.

4.2 Openplexus Knowledge Path Extraction Results

For this scenario, a data model was used that simulates the interactions with the Openplexus System based on the problem description in the previous section. This model is distributed across the team members (director, commission, supervisor and so on) and loaded into the system on start up. Each model contained the description necessary to simulate the interactions between the agents, the documents that were exchanged along with their required metadata and the knowledge flow metadata. The distributed knowledge graph could then be analysed by the knowledge flow module of the system to answer the general question, which artefact was sent to what agent. The result of this query can be seen in Figure 6 and presents a possible visualisation of the returned data from the analysis. The boxes represent the involved individuals with their respective role. Currently there are three roles that the system is able to

recognise. The author or creator of a new artefact is displayed in red. An individual that edited an existing document creates a child version of this artefact and is called a commiter. Commiters are presented in green. The standard role does not involve any active participation and is displayed in grey. Standard users received a document and worked with it but never shared new knowledge with the organisation or the team. The colour of the arrows that connect different nodes represent the different document or versions of it that were indentified in the interactions within the system. Part of a knowledge management dashboard is the knowledge path module able to give an overview of the current knowledge sharing situation in the system and can indicate possible bottlenecks or efficiency problems in a current team configuration. Feedback that would otherwise be hard to get. In combination with the KPM methodology it is an instrument that enables the management to optimise knowledge sharing in virtual knowledge teams and get instant feedback of the actual changes within the team's knowledge sharing processes.

5 . Conclusions

In this paper we have described a novel approach to the problem of improving knowledge sharing in virtual teams by a combination of a top-down knowledge management methodology and a bottom-up computer supported collaboration tool focussing on context-aware knowledge sharing services and therefore being able to manage and optimize the knowledge of the companies, these new models have developed solutions to help enterprises increase the profitability of their workers under the perspective of knowledge management. Both applications are a means to tackle the effectiveness of knowledge work by considering knowledge as a tangible resource. To stay innovative and highly profitable, the creation and interchange of new knowledge within the organisation has to encouraged with managerial instruments and incentivised with tools that take advantage from this additional knowledge and its metadata.

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Figures and Tables

KNOWLEDGE	DEFINITION	TARGET	ORIGIN (SOURCE)
ESTÁNDAR	No specific Inherent to an activity	Cover a necesity	Unknown knowledge
EXCLUSIVE	Mix of experiences and training (capacities?)	Enrich and complete the estándar knowledge	Amount of estandar knowledge
VIRTUAL	Immediate, amount of individual experiences	Join to tacit and explicit knowledge	Multiagent
DECISIVE	Immediate use. Facilitate	No stop the next tasks	Amount of estandar and exclusiv knowledge
ILLUSTRATIVE	Contains information to carry out the task with excellence and quality	To complete the necessities of the decisive knowledge	Decisive knowledge
FIXED	Independent of the task developed Never change	To be always there	Each activity of the project
VARIABLE	Changes with each activity	To keep the knowledge updated	A dinamic change
GENERATED	Created and linked to the system immediately	To increase new knowledge	Innovative processes
SPREAD	Received from a previous source	To share knowledge	Prior to the agent

Table 1. Taxonomies of the knowledge

Source: Own elaboration

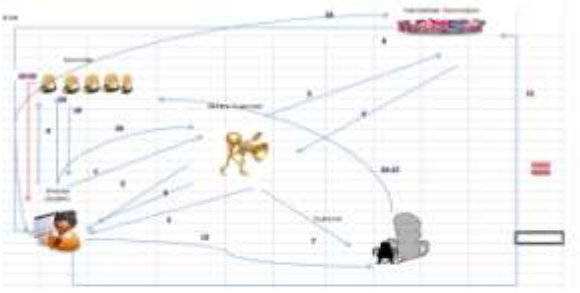

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Figure 1: Susan's real case. Source: Own elaboration

Figure 2. Knowledge real case codified

Source: Own elaboration

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