KNOWLEDGE COLLABORATION ENVIRONMENT FOR SUPPORTING SCIENTIFIC COMMUNITIES: IMPLICATIONS TO THE CONSTRUCTION INDUSTRY

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Abstract: This research is focussed on providing a flexible and configurable infrastructure for Knowledge Management (KM) aspects of distributed collaboration. The new knowledge created through this research will help to close the scientific community's research process, and knowledge creation and dissemination gaps. This will assist geographically dispersed research communities with efficient knowledge creation and dissemination procedures and assist in overcoming the risks and inefficiencies of distributed Knowledge Collaboration process. The proposed infrastructure for collaborative KM connects heterogeneous tools, systems, processes and Intellectual Property (IP) repositories together with an integrated toolset to form a novel Knowledge Collaboration and research facilitation environment. This infrastructure provides scientific communities with secure, centralised access to resources for empowering distributed Knowledge Collaboration process with superior visibility and control. Utilisation of the proposed Knowledge Collaboration environment within the construction industry is becoming a reality due to the extent of collaboration among the stakeholders necessitated in the near future. The issues raised have important ramifications for construction, and are discussed in the paper.

Keywords: knowledge collaboration, knowledge management life cycle, value management infrastructure, knowledge creation process, scientific communities of practice.

INTRODUCTION

Background: The necessity for scientific communities to work as Communities of Practice (CoP) has been expanding for many reasons. Political entities such as the EU are increasingly encouraging scientists to share knowledge and resources within the continent (Ballesteros 2006). Newly established European Institute of Technology (EIT) aims to integrate and boost innovation, research and higher education by pooling the best resources available at European level and beyond. The development of Knowledge and Innovation Communities (KICs), partnerships of universities, research organisations, companies and other stakeholders is focussed in bringing the scientists together more effectively through the EIT (EUROPA 2007). In order to facilitate the concept of CoP the users require ICT tools that can co-exist within their heterogeneous work environments (Wenger 2001) which support Collaborative Knowledge Creation (CKC) and transfer process and social interactions to mention but a few. Building trust and authenticity has also become very important based on the transactions performed. In other words, scientific communities of the future will

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utilise Knowledge Management (KM) infrastructures, which can facilitate CKC and sharing processes.

The construction industry consists of many groups, which require intensive collaborative working in particular within the construction site. Out of site collaboration between different groups is somewhat limited and there is no standard collaboration practice visible. However, for the future, collaboration among different working groups out side of the construction site is becoming a requirement (e.g. supply chain integration, sustainable reuse and disposal) and proposed methodologies and tools are to assist all construction stakeholders. This also means many personnel are required to ascertain know-how of using similar tools on a regular basis. The work presented here refers to scientific CoP and includes various community groups. This research is also focussed on providing a flexible and configurable infrastructure for facilitation of such collaboration where KM has an important role to play.

RESEARCH FOCUS

Knowledge sharing has become one of the most valuable interfaces between CoP. Managing knowledge within a community and what is to be shared with other communities is governed by the community structure and the virtual culture which has been established over time. Knowledge exists at multiple levels within CoP, starting at an individual level then groups within communities and finally extending into large communities that consist of many groups. Such groups can operate globally as distributed CoP (Hildreth et al 2000, Lueg 2000). On the other hand based on the realisation of value or expected value of a piece of knowledge it may not be suitable for sharing for some understandable reasons. This is further explained later in the knowledge processing model detailed. Different individuals with diverse experiences and knowledge within CoP have the ability to innovate and create a competitive advantage if the community could support a framework for those individuals to exchange, evaluate and integrate their knowledge by working towards a common theme or facilitating them into a close working environment (Boland and Tenkasi 1995). When knowledge becomes a valuable commodity, what knowledge to share, when to share it and with whom to share it becomes very important decisions to make (Andrews and Delahaye 2000). A suitable KM framework can control the availability and depth of accessibility of such value attributed knowledge so that only the appropriate content is shared or becomes available among the intended recipients. Such a framework is considered as a community asset, which would help not only to manage knowledge of CoP but also to harness knowledge creation and sharing as a key capability of the community.

The KM framework to support scientific communities will comprise specific characteristics that are different to a framework focussed on CoP. These specific characteristics exist partially due to the processes that scientists are involved in when they communicate with other scientists and the specific requirements that influence or constraint such communication. Drawing on these conclusions and creating the required KM framework that facilitates Knowledge Collaboration among scientific community is the main focus of this research. The research explores knowledge creation, aggregation and reuse processes that support facilitation of knowledge sharing within scientific communities. As a primary issue this research analyses knowledge creation processes within an individual, virtual groups and the community as a whole. This has led in proposing KM related models, knowledge aggregation algorithms and definitions that are applicable for scientific communities. This research contributes towards an investigation of the effective uses of emerging collaborative technologies that are to be adopted within a scientific community for supporting successful Knowledge Collaboration process.

The paper contains research questions, related works, characteristics of scientific CoP and the derived KM framework. Research justification, progress to date, proposed implementation plan and future activities are also presented.

This research aims to address the following questions:

- What are the requirements that affect a knowledge collaboration environment which could influence collaborative working among the distance community members?
- How can the effective use of emerging technologies, systems and tools be adopted and implemented within an ICT infrastructure for supporting knowledge collaboration?

CHARACTERISTICS AND SPECIFIC NEEDS OF S-COP

S-CoP (Scientific Communities of Practice)

Scientific CoP in this paper is used in its broadest sense. It refers to those who are involved in scientific activities, i.e., those who employ scientific methods for seeking, interrogating, and creating processes and systems in doing and advancing their work. For example, an architect in creating a building facet with tempered glass may be required to use steel frames so as to allow the building to receive maximum lighting. He/she may also need to closely collaborate with structural engineers with specific boundaries and limitations of his/her vision of this design. Therefore, these community groups employ the scientific methods throughout their design process and elaborate to achieve a new, safer and sustainable product. In this case the community groups noted, and who employ the scientific method in the building design process can be referred to as S-CoP.

Characteristics of Scientific Communities of Practice

There are many ICT tools (Mihindu et al 2006) available for facilitating a CoP and Wenger (2001) classified them into eight categories. He also pointed out that although the ideal system for supporting CoP did not exist at the time, such tools must be easily integrated with other softwares that community members can use for their regular work, and that this must be inexpensive and easy to learn since CoP is not the members' main job. Most tools rely on web communication technologies and take the form of web server /browser client architecture. Table 1 compares the details provided by Wenger et al (2003) regarding CoP against the characteristics of Scientific CoP that this paper focuses on. Therefore this analysis partially distinguishes the requirements of specific nature for supporting such specialised communities. More detailed analysis to follow.

Table 1: Comparison of CoP (Wenger et al 2003) vs Scientific CoP

	What is the purpose?	Who belongs?	How clear boundaries?	What hold them together?	How long does it last?
CoP	To create, expand, and exchange knowledge, and to develop individual capabilities	Self-selection based on expertise or passion for a topic	Fuzzy	Passion, commitment, and identification with the group and its expertise	Evolve and end organically (last as long as there is relevance to the topic, value and interest)
Scientific CoP	To address scientific method and to develop unique expertise	Specialised groups by introduction or spreading the word	Clear	Responsibility and commitment for providing specifics and proofs at a global level	Mid to long term based on the ability to produce as a community

Specific requirements of Scientific Communities of Practice

Although communities in general are focussed on exchanging knowledge (Hildreth 2000, Wenger et al 2003) the scientific community are constrained by various factors of which some have been discussed above. Scientific community is moving away from traditional "information spread" model for the dissemination of scientific information (Klein and Gwaltney 1991) into an emerging paradigm of scientific knowledge dissemination and collaboration (Kondratova and Goldfarb 2004a: 2004b). Kondratova and Goldfarb proposed a Knowledge Portal that enables collaborative research work on common artefacts, databases, projects, and clarifies the requirement of accessibility to domain-specific software tools.

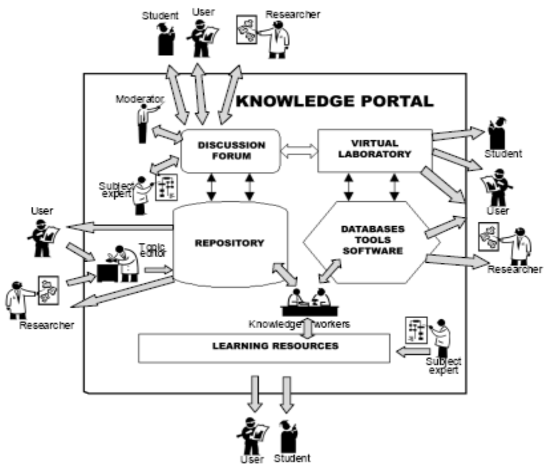

Figure 1: Knowledge Portal: users and players interactions (Kondratova & Goldfarb 2004)

However, the features and functionalities described by them provide only a base line for supporting community Knowledge Portals (Fig. 1) but in the focus of scientific communities, further integration with specialised tools are required. This research is focussed on providing an adequate support by defining a KM framework which addresses specific requirements of the scientific community for facilitating knowledge collaboration and hence further expansions are discussed.

Hierarchical requirements model

Drawing on previous works by Kondratova and Goldfarb (2004a: 2004b), Wenger (2001), Wenger et al (2003) and USAID (2004), table 2 summarises the high level requirements of scientific CoP in a form of 'shared spaces' and facilities targeting the management of these spaces. The basis for defining these 'shared spaces' has been initiated by the requirements for supporting successful knowledge collaboration. The descriptive names provided below detailing six types of spaces will provide clarification based on the utilisation of specific space in knowledge collaboration.

Types of shared community spaces based on their use:

- Transactional spaces (generic and specific)
- Shared static spaces (objects not require constant change)
- Shared group working spaces
- Synchronous collaboration spaces (objects require real-time synchronisation)
- Shared private spaces (shared among specific members only)
- Private spaces

Table 2: Requirements analysis: Shared spaces and facilities

Community requirement	**Underling supporting feature**
Space for describing community domain & activities	Shared space
Space for holding conversations	Record voice and text
Space for floating questions (to all/to a group)	Record questions, answers or suggestions
Space for holding documents	Shared space
Space for holding objects & artefacts	Shared working space
Space for synchronous collaboration	Shared working/synchronous collaboration space
Space for holding members expertise details and interests	Shared space
Facility to extract knowledge from spaces	Effective key word search
Facility to obtain statistics & manage spaces	Effective information mining algorithms
Facility to create sub spaces for subcommunities	Shared space
Facility to capture & find members availability	Shared private space
Facility to schedule collaborative events & tasks	Shared event calendars & task management
Facility to easy integrate the proposed system with members working environment	Co existing independent working spaces or environments
Facility to provide adequate security for member transactions	Membership and authorisation control
Extendibility to support other primary community requirements	Add-on working spaces & facilities

Figure 2 is the hierarchical requirements model derived from table 2 that illustrate the requirement of many types of shared community spaces discussed.

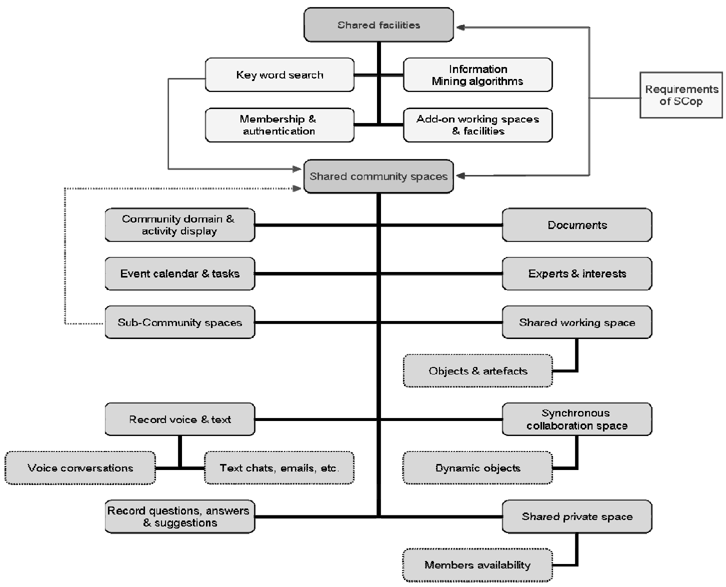

Figure 2: Hierarchical Requirements Model

Therefore these spaces are categorised into static, group working, transactional, synchronous, shared private and private based on the use. Shared facilities provided to manage and to operate on these various spaces are expanded. Figure 2 shows key facilities; search, information mining, membership and authentication and the ability to add spaces and facilities based on the specific community requirements. The facilities provided for search and mining, extract details from shared community spaces as required. The sub-community spaces are a replication of shared community spaces model for perhaps supporting various projects or community groups. This requirements model will be applied in the conceptual design of the system at a later section.

Supporting knowledge collaboration, creation and sharing process

It is necessary for knowledge sharing systems and tools to support the baseline features described in the Knowledge Portal (Kondratova and Goldfarb 2004) while facilitating the scientific communication life-cycle model (SCLC) described by Björk (2005). Such a combined system is to be implemented utilising the hierarchical requirements model defined above to achieve the required success in knowledge collaboration. Due to many constraints faced by the scientific community the utilisation of SCLC within this environment is a necessity. The speed of progress in science depends on how efficiently the communication process can take place and how effectively lay persons implement these findings in new technology and practices (Björk 2007). Björk utilised a process-modelling technique to model the scientific communisation process that has evolved through scientific knowledge dissemination and collaboration. The SCLC model includes thirty three separate diagrams with 113 activity boxes arranged up to seven levels deep. In order to address gaps in creating systems, tools and infrastructures for supporting full KM lifecycle with the focus of scientific communities (Mihindu, Fernando and Khosrowshahi 2008) it is crucial to integrate these findings. For example, on a construction site, knowledge associated with daily activities, will be recoded through the implementation of the Hierarchical Requirements Model.

KM Life Cycle and knowledge operations

Four basic steps of KM Life Cycle (KMLC) consist of capture, development, sharing and utilisation of knowledge. The IT systems developers have created many application tools for supporting KM operations that cover KMLC to some extent and those tools could not provide a complete facilitation of all the above steps (Lee and Hong 2002). This has forced communities to adapt a set of KM tools to cover the full lifecycle of KM. The KM architecture model defined by Lindvall et al (2003) describes the requirement of using multiples of tools for supporting the full lifecycle of KM. Engaging multiple set of tools may not fully guarantee for supporting every and each aspect within all steps of KMLC. Therefore it is paramount to derive a KM framework and associated tools which can provide the necessary Knowledge Operations (Mihindu 2007b) for the facilitation of knowledge creation and sharing which targets the collaborative activities of distributed groups. Nevertheless other previous EU projects such as KIWI, OSMOS, GLOBEMEN, etc. have created much valuable analysis and ICT infrastructure for virtual enterprise collaboration which has been constructive.

Knowledge creation process and state diagram

Knowledge creation activities relate to individual and group human processes in light of quantifying the Knowledge Creation Process of scientific communities is a novel idea. Tacit and explicit knowledge transferred among individuals in a group and different modes of knowledge creation (Alavi and Leidner 2001) have been explored by researchers and this research extends their work. Alavi and Leidner described a ‘web’ of knowledge management activities in organisational settings and proposed a conceptual foundation of a KM framework. The Knowledge Creation Process (KCP) within an individual, how this process inter reacts with the community setting, and the knowledge aggregation within an individual or a community knowledge pool have not been explored in detail and many gaps in the literature was evident. In order to fulfil this requirement previous work by Mihindu, Fernando and Khosrowshahi (2008) presented the KCP within an individual and provided a knowledge creation state diagram. Further a knowledge aggregation algorithm was presented for quantifying aspects of KM within a community knowledge pool and within community members. This insight into KCP has facilitated advancement in the definition of a successful KM framework.

Knowledge processing, codification and reuse model

Combining the factors that have been identified by Ipe (2003) as factors influencing knowledge sharing (nature of knowledge, motivation to share, opportunities to share and culture within work environment) and the other valued factors (codifying, storage, access control, estimating the appropriate time for sharing and means of sharing) within the complete knowledge creation and management cycle provided the basis for defining overall characteristics of the KM framework. In other words this framework captures all the factors that influence CKC at a wider perspective.

On a software development point of view, the access control system within the complete tool set that supports implementation of the collaborative KM framework will provide the required trust and confidence for knowledge owners and for the community in general. The goal is to support the community for easy management of codified knowledge objects, opportunity for knowledge creation and integration, access control and ownership, and timing of sharing and discarding, by the utilisation of derived tools that incorporate the KM framework. This synthesis has led to the proposal of a knowledge processing, codification and reuse model that has taken into consideration most of these factors (Mihindu, Fernando and Khosrowshahi 2008). Based on pragmatic grounds the above factors were grouped into three key areas within the model proposed as: (1) recognition and valuation, (2) codifying, development and utilisation, and (3) mass sharing. The implementation strategy of this KM framework and a methodology for integrating suitable best practice server tools are discussed in the next section. The implementation research carried out to date confirms the viability, efficiency and stability of this novel methodology within the targeted application environment. This ICT environment can be used in the construction site environment to provide information and to allow collaboration to take place between site personnel.

SYSTEM IMPLEMENTATION

Implementation of the system is detailed with conceptual design and infrastructure design in this section. The implementation strategy provides an environment to effectively integrate the KM framework as previously discussed.

Conceptual design

Conceptual design captures the core requirements of the scientific community in the context of CKC and dissemination. Considering the state of the art of collaborative tools, developers and researchers are collating various features that facilitate effective communication via various tools that enhances CSCW (Mihindu et al 2006). Above all an interesting Sakai Project (sakaiproject.org) continues to develop Sakai Collaborative Environment that targets the educational communities by bringing similar tools to the users' disposal. Agora tool (agora.lancs.ac.uk) from University of Lancaster has extended some capabilities of Sakai for effective online meetings and their management. While similar developments and tools are evolving, this research proposes new generation of novel implementation methodologies for facilitating CKC and dissemination environments.

The relevant models and concepts that are identified in the previous section have been integrated in the conceptual design (Fig. 3). Shared community spaces for learning resources, web portals and sites, repositories and discussion forums; and shared facilities for searchers, membership resources and content filters and moderations are shown in figure 3. Some items are also presented in the figure to clarify some of the functions, which are not discussed in this paper. More importantly, application servers that provide much of the functionality within the system are broken down into example cases (e.g. email server, instant messaging, and calendar server). Shared community spaces (as presented in Fig. 2) are integrated with the services provided by these application servers in a more transparent way to enhance the usability of the overall system. The integration of the required new application servers as discussed here is novel, and has not been done elsewhere. It is used for satisfying specific requirements of the community by connecting other application servers.

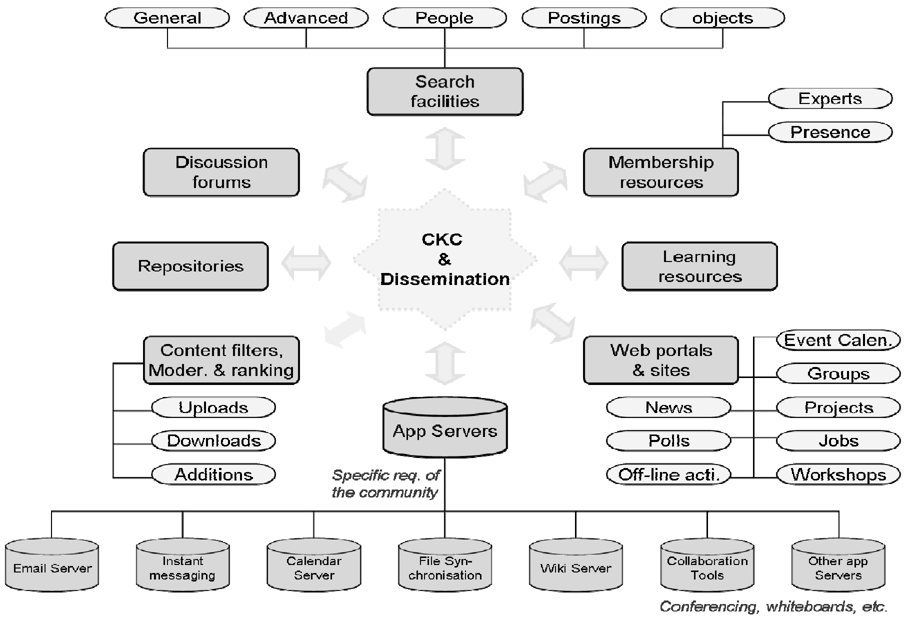

Figure 3: Conceptual design of the proposed system

Infrastructure design

The architecture utilised here is based on previous works where the technology infrastructure consists of computer hardware, high-speed networking, virtualisation management ubiquitous server, purpose built virtualised application server farm and virtualised user desktop (Mihindu 2007a). It is necessary to elaborate on the fact that Virtual Machines (VM) reside inside one physical computer and can communicate or transfer data at very high speeds so that various servers operating within VMs as a way forward for an effective solution to achieve high speed data rates between servers and to minimise external traffic between computers within an installation. Application servers selected are virtualised and common repositories are created for application interoperability. The virtual machine server farm is created based on the virtual networking technology and further details of the implementation of VM client side will be described in future publications. A few case studies in different community settings were conducted to ascertain the applicability of the VM technology integration methodology and to assess the technological readiness within such collaborative environments. A rapid prototyping approach was engaged for the development of live prototypes. The analysis of case studies conducted and the recommendations drawn will be published in future. Based on the nature of case studies conducted which are in a variety of settings, the maturity and suitability of the proposed infrastructure integration methodology for any given scientific community can be assured (Yin 2003).

CONCLUSIONS AND RECOMMENDATIONS

This research investigates the design and implementation of a flexible and configurable ICT infrastructure for supporting knowledge collaboration within scientific communities. The requirements that affect knowledge collaboration and influence collaborative working of such communities have been explored. Further, in order for utilisation of emerging technologies within this environment for supporting knowledge collaboration an integration methodology was proposed. Therefore, this research provides an infrastructure integration methodology for supporting the knowledge collaboration process of distributed community groups. The issues raised afford construction personnel and stakeholders an infrastructure to improve collaboration on and off-site. There is also an opportunity to integrate project management systems with the proposed infrastructure on knowledge collaboration environment. However, some element of training is needed if the infrastructure discussed is to be fully utilised and exploited. There is also the issue of strong leadership and commitment to take the ideas raised forward if potential benefits of the system are to be realised.

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