Towards a Holistic Personalised Support for Knowledge Sharing in Virtual Learning Communities

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Abstract. Virtual learning communities bring together people from diverse backgrounds and provide the basis for knowledge construction and sharing. Important processes for the community to function as a whole have been identified and examined through existing systems. Although existing systems attempt to support these processes, the absence of a complete community model, and the personalisation and adaptation to the individual rather than the community compose the main obstacles to their holistic success. A computational framework is proposed, to support the community to function as an entity rather than concentrating to the individual person.

Keywords: Virtual Learning Community, Transactive Memory, Shared Mental Models, Cognitive Centrality, Cognitive Consensus, Knowledge Sharing

1 Introduction

During the last decade, academics and practitioners have been searching for techniques to support knowledge expansion and sharing [1]. Online communities appear to be an exceptional approach which brings together people from diverse backgrounds, provides support for collaboration, and – through collective knowledge sharing – provides a basis for the creation of shared understanding [1, 2]. The term Online Community has been used in a broad context for Virtual Community, Community of Practice, and Learning Community. Authors coming from different disciplines vary in their perception of what constitutes a 'community' [3]. For this study, we consider Virtual Learning Communities (VLCs) that may exist in either organisational or educational context and have the following characteristics: common purpose, identified by the participants or a facilitator; commitment to the sharing of information and generation of new knowledge; shared resources; participants are more likely to be at different stages of their professional/academic life; high level of dialogue, interaction and collaboration; equal membership and leadership; knowledge construction. The above characteristics can be part of both Learning Communities [2], and Communities of Practice [2, 4]. Indeed, as shown by Lewis and Allan [2], many communities of practice function as learning communities, where learning is a result of interactions within a particular social context.

However, learning within VLC may be hindered by several technological factors (e.g. communication barriers, diverse technical background, technological constraints)

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and social factors (e.g. different background, interests, and understanding of the problem). A common misconception is to believe that VLC will be effective when people and technology are present. As stressed by Fischer and Ostwald [5], appropriate support for the effective functioning of online communities is needed. This requires a good understanding of what is happening within a community, and what processes influence the success of knowledge sharing.

A review of existing systems that support VLCs will be presented here. We will examine how these systems facilitate knowledge sharing and effective functioning of a community as an entity. The discussion will be based on processes which are crucial in successful VLCs, and therefore should be supported by the computer systems. Based on the review, we will point at future research directions and will outline our plans for utilising techniques from user modelling and user-adapted interaction to provide personalised support for knowledge sharing in virtual learning communities.

2 Support for the Functioning of VLC

This section outlines processes identified by research in organisational psychology and considered as essential for the effective functioning of teams, groups, and closely-knit communities. We will show, with the help of scenarios, how these processes relate to integrating newcomers, motivating existing members, improving resource organisation, and facilitating collaboration in VLCs.

2.1 Processes which should be supported

Research in organisational psychology has identified that effective teams and groups operating in the boundaries of an organisation build transactive memory, develop shared mental models, establish cognitive consensus, and become aware of who their cognitively central and peripheral members are [6-11]. These processes can also be applied to a broader context to inform what support should be provided to a VLC.

Transactive Memory (TM) deals with the relationship between the memory system of individuals and the communication that occurs between them [11, 12]. The focus is on encoding, storage and retrieval of information. Therefore, a transactive memory system can provide the ability to recall previously visited areas and subjects, and to identify relevant knowledge [10, 11].

The notion of transactive memory and the development of transactive memory system has been proven to be very promising for the functioning of teams and groups [6, 7, 10, 11]. Wegner [11] points out that transactive memory is concerned with “the prediction of group and individual behaviour through an understanding of the manner in which group processes and structures information”. Transactive memory helps group members to divide responsibilities for different knowledge areas and be aware of one another’s expertise. The key for a transactive memory system to function is that the divergence of information held in members’ heads must be known to the others. To illustrate, assume that member A’s memory can act as an extension of member B’s memory. If B is aware of what A knows, he/she should be able to get access to A’s knowledge and the information A possesses.

Shared Mental Models (SMM) are defined as the "team members' shared, organised understanding and mental representation of knowledge about key elements of the team's relevant environment" [10]. Studies confirm that collaborative knowledge exploitation can be improved if group members have a shared understanding of the environment, situation and task at hand [13]. One of the main objectives of community formation is through knowledge sharing and communication to develop a shared understanding of the context in which community members act, and to create a shared understanding of the world [1, 14].

Cognitive Consensus (CCs) deals with shared conceptualisations between members and shared understanding of the meaning concepts encapsulate [10, 15]. The idea is for the members to agree, or be aware of the different definitions behind a concept and come at a compromise on how that term is used inside a given community.

Cognitive Centrality (CCen) considers the importance of the contribution of individual members with regard to the community's context [8]. Members who share a significant amount of valuable information for the whole community become cognitively central and play a vital role in the smooth functioning of a community. On the other hand, peripheral members can sometimes hold unique knowledge, and can also be important for effective knowledge sharing.

2.2 Support needed

The above processes can affect the functioning of VLC, and can point out what support may be needed. This will be illustrated here with several scenarios. We will show that support to a VLC has to be tailored to the community's needs and serve both newcomers and oldtimers [16]. Furthermore, personalised support should add value to the creation and sharing of knowledge between members and facilitate the functioning of the community as a whole.

Support to Newcomers

Newcomers are newly joining members who need to identify their role in the community and what they will gain from it. Support is needed to quickly integrate these members to the community's knowledge processes, which can improve their learning experiences and can have a positive effect on the overall functioning of the community.

For example, consider a person named Chris who is interested in social tagging for e-learning and is joining a VLC where members share information about technology-enhanced learning. Chris has no background of what was happening previously in the community, does not know about the interests and knowledge of other members, is unsure whether there are any relevant resources on the topic he is interested in, and does not know what he can contribute to the community. Chris should be helped to identify people or knowledge important to him in this community. Support should be provided also to introduce Chris to the community by identifying what he knows and making other members aware that he is holding valuable knowledge, which refers to *transactive memory*. Furthermore, because social tagging is identified as a peripheral topic for this community, Chris may be encouraged to elaborate on its relation with personalised learning, which is the main focus, i.e. *cognitive centrality,* of this community. This will be beneficial for him (he may discover relationships he was unaware of and may become a more central member to this community) and for the community (new topic will be connected to the community's context which can improve the processes of knowledge sharing and construction).

Support to Existing Members

Existing members (oldtimers) should also be helped to integrate and become active participants in the community's knowledge processes.

For example, consider Jane who is an existing member of this community and is interested in intelligent tutoring systems. She is regularly uploading and downloading resources and is actively engaged in discussions with other members. Jane is one of the *cognitively central* members of this community. Assume that another member – Mark – is interested in student modelling which Jane is familiar with (because she has participated in discussions on the topic and has uploaded relevant resources). Support should be provided to help Mark and Jane discover that they have joint interests, so that they both, as well as other members of the community can benefit from combining their knowledge and extending the community's *transactive memory*.

Jane is now working on a new project and needs to find information on ontologies - a topic she is not very familiar with. She can be helped to allocate relevant resources within the community and establish contacts with members knowledgeable in the area, which is related to the community's *transactive memory* system. Jane may also be encouraged to upload more resources on ontologies and discuss the link of this topic with technology enhanced learning. If the new topic is of interest to many members, it will become close to the community's *cognitive centrality.*

The community has to adapt to changes in its environment which may lead to a shift of the central area of interest and transformation of participation. [16]. Consequently, active contributors may become passive members, while others who used to be peripheral participants may become cognitively central [8, 9]. For example, Jane may gradually reduce her participation or stop contributing to the community. If changes over time are detected, *cognitively central* members like Jane who are moving to the periphery can be encouraged to participate more actively in the community's knowledge processes.

Support to Improve Organisation of Resources

People categorise and organise their resources differently according to specific characteristics, different conceptualisations, searching habits, etc. [17, 18]. Confusions may happen and disagreements are inevitable [19], which can have an impact on the effective functioning of an online community [17, 20, 21]..

Consider for example several members of the community interested in the use of context in systems for technology-enhanced learning. Each member uploads resources important to them and relevant to the projects they are engaged in. Jane considers context from an Artificial Intelligence perspective and links it to encoding different viewpoints in an ontology. Chris associates context with the conditions in a learning environment, while Mark is engaged in a mobile learning project where context is used to represent location-based information. Appropriate support for effective knowledge sharing would encourage members establish common procedures how to categorise and locate information, which can be part of a *shared mental model*. Furthermore, discrepancies in individual members' conceptualisations, which refer to the lack of *cognitive consensus*, and how they affect the organisation of resource (e.g. a paper may be belonging to more than one category or similar papers may belong to disconnected categories) should be detected and pointed to the community.

Support to Encourage Collaboration
People participating in a VLC share an information space and may be engaged in active communication. These are preconditions for collaboration, which is often associated with effective VLCs where members either work together on a joint project or share a common desire to produce better services [22]. Collaboration among community members can be encouraged in two ways. Firstly, support should be provided to help members build a common understanding of what the purpose of the community is, who is involved and what their interests are, what tasks people are involved in, what is happening in the community and how it progresses over time. These issues relate to building a *shared mental model* and developing a good *transactive memory* system.

Secondly, interaction between community members can be encouraged to create more opportunities for collaboration. Possible situations when members will benefits from communication with others can be identified. For instance, when a lack of *cognitive consensus* is suspected, members may engage in clarification interactions. Referring to the above example with different use of context, Chris, Jane, and Mark may be directed to discuss the different interpretations of the concept. Another possibility to encourage interaction is when members are found to share common interests or to have complementary knowledge. For example, Chris and Jane may be encouraged to discuss the similarity between folksonomies (linked to Chris' interest in social tagging) and ontologies (related to Jane's new project).

To sum up, TM, SMM, CCs, and CCen relate to the effective functioning of a community and are critical in defining personalised support tailored to the needs of the community. TM is important for quickly integrating newcomers to the community, improving the benefits of existing members to motivate their participation, and encouraging collaboration. SMM is a prerequisite for effective knowledge sharing and is directly linked with document organisation and information localisation; it is also an important factor for facilitating collaboration among community members. CCen can be helpful for relating the knowledge of newcomers and existing members to the community's context, and monitoring changes happening within the community over time. CCs can point at similarity and difference of individual members' viewpoints, which can affect resource organisation and can trigger interactions that may result in collaboration activities.

3 Existing Technologies to Support VLCs

We will now review what computational methods have been developed to address TM, SMM, CCen, and CCs, by using several representative systems:

- **Answer Garden** [23] supports the building of organisational memory by helping people find and share answers to questions they come across;
- **BSCW** [24] is built as a general tool for cooperation over the web and supports the main knowledge sharing activities, e.g. upload/download/search for resources, synchronous/asynchronous communication, version control;
- **Comtella** [25] is a small-scale application for sharing of class-related web resources among students, it focuses on motivating participation;
- **GIMMe** [26] is a web-based system that serves as a central repository for storage and access to email conversations within an organisation;
- **KSE/Jasper** [14] is knowledge sharing environment of information agents which are associated with each user and are capable of organising, summarising and sharing knowledge from a number of sources ;
- **MILK** [27] supports communities of interest within an organisation by integrating knowledge associated with people, communities, and informal knowledge, its core component is a metadata management system;
- **NuggetMine** [28] is an intelligent groupware application that facilitates opportunistic sharing of information nuggets (e.g. URLs, book titles, articles, information about an event) among a group;
- **OntoShare** [29] is an ontology based knowledge sharing environment which makes extensive use of advanced Semantic Web technologies to provide individualised support for members of a community of practice];
- **TeamWorks** [30] is a collaborative environment to support communities of practice which provides tools for communication, storage and capturing of data, and maintains document recommendation based on loyalty.

These systems are selected because they address, to a certain degree, the concepts presented in Section 2.

Transactive Memory

The building of transactive memory is supported, to a certain degree, by all systems. *A search facility* to help users allocate relevant knowledge and people is the most common technique used to facilitate the development of TM. BSCW [24] provides a standard search function through resource titles, while MILK [27] allows searching for experts or information in the community based on the information stored in people's profiles and on the metadata associated to resources. However, this approach is prone to inaccuracy: metadata is defined by members who upload the resource and the profiles are based solely on the users' interactions with the system. These problems are addressed in KSE/Jasper and OntoShare which provide enhanced search facilities based on keyword extraction from the entire documents [14, 29]. Moreover, KSE/Jasper and OntoShare enable users to search for other members with similar interests based on dynamically maintained user profiles open for inspection and change by the users. Answer Garden and GIMMe also illustrate the use of natural language processing techniques to provide support for the development of transactive memory [23, 26]. Answer Garden uses text retrieval engine to allocate "expert" answers to a user's question, and employs simple dialogue to clarify that question. Although identifying expertise can be related to TM, Answer Garden maintains anonymity of user contributions which does not allow allocating community members who hold that expertise. GIMMe uses latent semantic indexing to facilitate search through a vast repository of email conversations, and extracts group categories based on previously visited issues, which can be important for TM,

While search relies on users pulling for information, *notifications and recommendations* are push techniques. BSCW notifies users every time changes are made to the community space (who uploaded what and who read what), which may implicitly help for developing awareness of who knows what. However, users may not notice important information because the notifications are not tailored to the user's current interests, as this is done in OntoShare based on simple content-based filtering mechanism. TeamWorks [30] also provides tailored notifications by recommending resources relevant to the current topic under discussion. While recommendations have been found as useful personalisation techniques, their current application in VLC focuses solely on support for an individual and the benefit for the development of TM is yet to be shown.

Semantic-enhanced technologies have also been applied to support the developing of TM. NuggetMine and MILK use metadata about resources to associate newly added pieces of information with old ones [27, 28]. However, this approach relies only on metadata and does not take into account information about people who shared/read the resources, which is crucial for the construction of TM. GIMMe and BSCW maintain a hierarchal structure of categories that can facilitate knowledge allocation. However, the categories are feely constructed by users and become messy, which may hinder resource allocation and expertise finding, and is not very helpful for the development of TM. OntoShare instead uses ontology of domain categories to identify knowledge and similarities between users.

Shared Mental Models

Making members aware of what is happening in the community considered important and supported by the majority of the systems in different ways and up to a level. *Visualisation* techniques to allow users become aware of what is happening in the community in general have been used for the development of SMM by two systems. The development of SMM is promoted in Comtella [31] by galaxies visualisations which illustrate the convergence of topics. BSCW also uses visualisation techniques to support the development of SMM. Users can explore a map of the information space which shows each folder and the activities in it, indicated with small rectangles. Another visualisation shows how many papers are in a folder presented as towers in a city. Visualisation techniques are useful for an overview of what is happening in the community but appear insufficient for a deep understanding of the conceptual processes within the community.

Semantic – aware techniques have been explored to support the development of SMM in Jasper II, MILK, and TeamWorks. Jasper II supports the creation of shared understanding by capturing the individual perspective in the form of annotations typed in by the users [14]. Similarly, MILK supports contextual awareness in the community based on meta-information users are typing [27]. However, meta-data provided solely by users may be inaccurate, incomplete, or contradicting. A shared ontology is used by MILK to allow users to associate documents uploaded to the terms on the ontology tree. In this way, users have to agree to a specific point of view represented in the ontology, which may not always be shared by all community members. TeamWorks [30] facilitates the development of shared understanding by recommending resources to community members based on what others are reading.

Cognitive Consensus
A shared ontology has been used in two systems in an attempt to support CCs. OntoShare and MILK are both using an ontology from where users can choose words to assign to the resources they upload. If a relevant word cannot be found, users can enter a new work that is added to the existing ontology. Using a shared ontology dynamically expanded by contributions from community members can help the community establish cognitive consensus. However, understanding ontologies can be a challenging task for VLC users who are likely to lack knowledge engineering skills.

TeamWorks provides a *controlled vocabulary* [30] for users to categorise their resources. The interface is more intuitive and the users are not burdened with complex ontological structures. However, none of the approaches takes into account that subjective views that are not necessarily agreed within the whole community can be put mistakenly in the shared ontology/vocabulary. Moreover, both approaches appear to work at a surface (word, phrases) level, while CCs requires considering the understanding community members have about a concept [10].

Cognitive Centrality
Cognitive centrality is addressed partly in Comtella by a *reward mechanism* aimed at encouraging participation in online communities. Each member earns points based on how others are rating the resources he/she has uploaded [25]. Comtella uses *visualisation techniques* to present cognitive centrality. In a recent version of the system, stars with different size and brightness give an indication of who is contributing valuable resources (judged by the ratings). In an earlier version of the system, galaxies represent topics that may be of interest to the community. The closer to the centre of the galaxy a member is, the more central (judge by the number of papers uploaded) he/she is considered to be [31]. The mechanisms used for calculating cognitive centrality in Comtella are quantitative and do not take into account the cognitive influence of a member and the relevance of their contribution to the community's context.

Table 1 gives a condensed summary of the technologies reviewed.

4 Discussion

Although systems attempt to support TM, SMM, CCen, CCs, the absence of a complete community model, and the personalisation and adaptation to the individual rather than the community compose the main obstacles to their holistic success. Our research aims at the development of a framework for holistic personalised support based on a community model and using that model to support the building of TM, SMM, and CCs. The computational framework will consist of two major parts. The first will deal with the development of a community model, which will represent the whole community and will focus on the processes discussed in Section 2. The second will deal with offering adaptive support to improve the functioning of the community.

Fig. 1 illustrates the architecture of our framework following the general architecture of user-adaptive systems defined in [32].

Table 1. Summary of the technologies that support TM, SMM, CCs and CCen

Process	Technologies to support this process
TM	**Search**: Basic search through document titles {BSCW} Search through metadata using user profiles {MILK} Extract keywords from resources and link with user profiles {OntoShare, KSE/JASPER II } Text retrieval techniques based on keywords {Answer Garden} Latent semantic indexing {GIMMe} **Notifications and recommendations:** Notify about changes {BSCW} Recommend resources and people on user profile {OntoShare} recommend based on current task {TeamWork} **Semantic-aware techniques:** Metadata to associate information {NuggetMine, MILK} Category hierarchy {GIMMe, BSCW} Ontology {OntoShare}
SMM	**Visualisation** Clusters of common interests {Comtella} Awareness of what is happening in the community {BSCW } **Semantic-aware techniques** Metadata to identify common interests {KSE JASPER II, MILK} Shared Ontology to create connections between people {MILK} Recommend resources to be read by everybody {TeamWorks}
CCs	**Shared Ontology** {OntoShare, MILK} **Controlled Vocabulary** {TeamWorks}
CCen	**Reward mechanism** {Comtella} **Visualisation** {Comtella }

For the development of the community model, we will focus on the analysis of tracking data collected from an existing VLC application. Two year tracking data from an existing VLC with some 25 researchers with common interests working together on virtual research projects and sharing documents with the BSCW system that supports resource sharing and collaboration over the web will be used[1]. The BSCW data consists of information on who uploaded what resource on the community's space; who accessed which resource and when, who ranked and modified it; which members joined and left the community and when. This information is in an xml like format and is being processed with data mining tools**.** The tracking data is being analysed to see what information we can get to identify existence of TM, SMM, CCen, and CCs. Learning or knowledge construction, information sharing and collective efficacy (i.e. how much the group members believe that they can be successful as a group) will be examined in relation to the development of SMM, TM and CCs in the community. Having this done, we will enhance what we have with semantically enriched information such as metadata of the objects, considering the specialisation area of the person who posted that object

[1] The tracking information is taken from the BSCW interface, available to all members of the community. The experimenter is a member of this community. Aliases have been used instead of users' real names to comply with privacy regulations concerning data analysis and presentation of results.

and keywords provided. We will also use existing ontologies of areas relevant to our community (for example, the VLCs we are analysing are focusing on issues related to the Semantic Web for which example ontologies have been developed[2]) to compare against the data that we have. Ontological reasoning techniques will be used to identify relations between topics and to decide what interventions from the system may be needed.

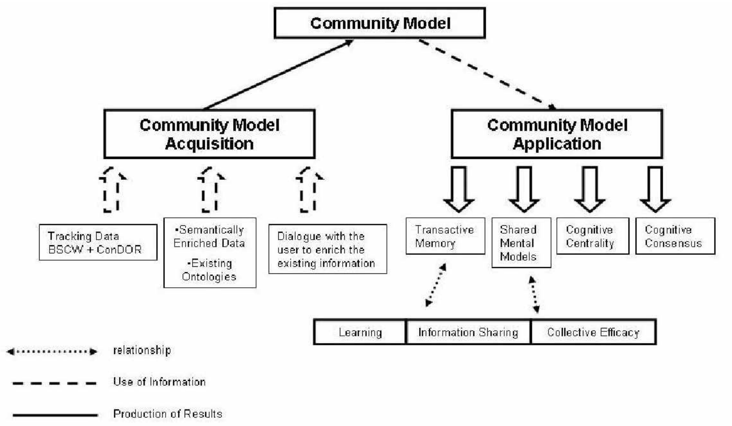

Fig. 1. General Structure of the Community Modeling and Adaptation Framework

Only analysing tracking data and ontologies will not be sufficient to find consensual knowledge and shared mental models. To model these, we will use in addition a system-user interaction to get additional information and complete the community model. The dialogue approach has been successfully used in our research group to gather knowledge of individual users [33] and can be adapted to capture and clarify aspects of collective knowledge.

As pointed by one of the reviewers, security of the system is an issue that inevitably will have to be dealt with. As the system has not yet designed or implemented, an initial thought is that registration and use of log-in names and passwords will be mandatory for users to enter the community's space.

Once the community model is developed, it will be used to provide support to the community and to help its members improve the TM system of their community, develop SMM and CCs between them and become aware of cognitively central or peripheral members. This will help us point at issues that support information sharing, learning and development of collective efficacy, and to help the community build a good TM system and a shared understanding of the domain they are working in.

[2] For example, https://wiki-sop.inria.fr/wiki/bin/view/Acacia/KnowledgeWeb

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