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# Supporting Knowledge Creation and Sharing in Communities Based on Mapping Implicit Knowledge[1]

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**Abstract:** This paper discusses some implications of knowledge creation processes in informal social networks for the development of technologies to support them. The principal point of departure are social theories of learning and the theories of organisational knowledge creation. The focus is on models for the exchange and sharing of implicit knowledge. A model of personalised learning knowledge maps is presented as one possible way of addressing the problem of capturing, visualising and sharing implicit knowledge of a community of users. In particular, we discuss how this model resolves one critical shortcoming of the existing socialisation and externalisation approaches: the creation of a semantic representation of a shared understanding of the community which reflects implicit knowledge and incorporates personal views of individual users. Finally, we outline the application to a real-world interdisciplinary Internet platform netzspannung.org**.**

**Keywords:** Knowledge Management, Communities of Practice, Knowledge Discovery, Knowledge Visualisation, Semantic Web
**Categories:** H.5.1, H.5.3, H.5.2, H.3.3

## 1 Introduction

One of the major models of the generation and the exchange of knowledge in today's so-called information or network society [Castells, 96] are technologically supported informal social networks. Such social networks are often referred to as virtual communities [Rheingold, 93], communities of practice [Brown, 91], or knowledge communities. They bring together groups of people based on a shared set of interests or specific concerns (virtual communities), or based on work-related sharing of knowledge and experience (communities of practice). While such social formations have been a major model of knowledge production and dissemination in scientific research even before the Internet, in recent years they have been increasingly acknowledged as major forms of knowledge exchange in professional and work-

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related settings, both within organisations and across organisational boundaries [Davenport, 98], [Cohen, 01].

The term "communities of practice" refers to "informal aggregations of people who share work practices and common experiences" [Wenger, 98]. In contrast to groups and teams that are defined institutionally, participation in communities is voluntary and typically independent of specific projects and formal processes. Rather, the evolvement of such communities is based on spontaneous participation and self-motivated choice, common goals such as shared needs and problems and on a common repertoire (experiences, places and practices) resulting in common sense-making and a common language. According to this view, knowledge is created and reproduced through social relationships and interaction in communities and makes sense only in relation to such communities and their practices.

Some authors see such communities of practice as the basic units of organizations that reflect the "real" functioning of an organization (as opposed to the formal organizational structures). Organizations are thus viewed as "communities of communities" with independent but interrelated "worldviews" whose interaction is seen as the main source of innovation [Brown, 91].

In this paper we discuss the main implications of the social nature of processes through which knowledge is generated in such social networks, for the development of technologies to support them. As the main point of departure we refer to social theories of learning and construction of reality (e.g. [Lave, 91], [Berger, 66]) and to the theory of organisational knowledge creation of [Nonaka, 95]. As a special challenge we consider the problem of sharing implicit knowledge and its particular relevance in the context of increasingly interdisciplinary communities of practice. We discuss three main models for addressing this problem: the „internalisation" model based on individual reflection on the community discourse, the „socialisation" model based on direct face-to-face interaction, and the „externalisation" model based on the explicit construction of a shared conceptualisation. We outline the existing approaches for supporting these processes in networked communities of practice, identify the main shortcomings of existing solutions and point to possible ways of improvement. Finally, we present a model developed in our own work as a possible way of addressing the problem of capturing, visualising and sharing implicit knowledge of a community of users.

## 2 Social construction of knowledge and communities of practice

Social theories of learning (such as constructivism and social constructionism) help us understand how people construct meaning out of information, and how this is related to social interaction and communication with other people. For example, [Berger, 66] describe how people interacting in a certain historical and social context share information from which they construct social knowledge as a reality, which in turn influences their judgment, behaviour and attitude. [Bruner, 90] shows how the construction of meaning can be related to cultural experiences, in a similar way as [Vygotsky, 86] has explained how thought and language are connected and framed by a given socio-cultural context of the learner. In their theory of organisational knowledge creation [Nonaka, 95] describe the processes of the conversion between

explicit and implicit knowledge, and their importance for creating collective knowledge. They refer the notion of tacit knowledge ([Polanyi, 58], [Polanyi, 83]) to highly personal knowledge, which is derived from experience and embodies beliefs and values. The studies of [Lave, 91] emphasise the role of immediate social context for learning a body of implicit and expert knowledge through a kind of apprenticeship they call „legitimate peripheral participation". Similarly, [Orr, 96] demonstrates how knowledge is socially distributed across a network of experts and is shared through processes such as storytelling.

All these studies demonstrate how the construction of knowledge (learning) is an inherently social process in which the „learner" actively constructs meaning, through a process of information exchange and social interaction with other people. Furthermore, both the personal implicit knowledge of the learner (his previous knowledge, interests, values and beliefs), his current context of intention (e.g. a problem or task at hand) and the social and cultural context in which the learning takes place (e.g. networked community of practice) fundamentally determine the possible meanings that the learner can/will construct in this process.

The principal implication of these findings is the notion of a shared cognitive and social context which has to be established in order for the members of the community to negotiate shared meanings, and hence construct collective knowledge. Since the major elements of this shared context include implicit knowledge, which resides only in community members, the critical question becomes how to create possibilities for externalising and sharing this implicit knowledge?

This question becomes especially relevant in the context of communities of practice that increasingly connect experts from different fields of expertise. Such communities are found in research fields that span different areas (e.g. knowledge management, human-computer interaction, EU-IST) as well as in industry contexts such as consulting agencies and innovation management. The exchange of knowledge in such networks is commonly reflected in a collaboratively constructed information pool (mailing lists, project archives, best-practices etc.), which contains heterogeneous domains of knowledge expressed in different terminologies. The heterogeneous domain of knowledge and the decentralised and loosely structured mode of community interaction make it difficult to express the knowledge contained in the community information pool by means of a predefined taxonomy. Furthermore, as knowledge is strongly tied to individual experts, the contents of the information pool that archive the exchange of the community members will merely reflect some externalised part of this knowledge. So, even if cross-connected taxonomies are created by hand through some tedious process of community negotiation, they will fail to capture this highly personal and implicit knowledge of individual users [Nonaka, 95]. Hence, as a central issue for supporting the exchange of knowledge in such communities we identify the following challenge: How can existing but not explicitly formulated knowledge structures of a given community or a group of experts, be discovered, visualised and made usable for collaborative discovery of knowledge in heterogeneous information pools?

## 3 Mapping & sharing implicit knowledge

Existing solutions to this problem can be roughly classified into three main approaches: the „internalisation“ model based on individual reflection on the community discourse (mailing lists, forums), the „socialisation“ model based on direct interaction mediated by CMC & CSCW technologies and the „externalisation“ model based on the explicit construction of a shared conceptualisation (e.g. Semantic Web, ontologies).

The internalisation model is the only model supported by basic community technologies such as mailing lists, bulletin boards and discussion forums. The development of a shared context requires members' extensive and active participation in the community exchange. There is no mode for the shared understanding of the community to be expressed, and the repository of the collective memory is an unstructured space of many interrelated but rather isolated pieces of information. Context is very difficult to establish.

The socialisation model is addressed by approaches based on the use of multi-user networked environments. These approaches typically aim at supporting the sharing of social knowledge through textual chat and through graphical visualisation of mutual presence and activities of users in a shared virtual space (e.g. [Erickson, 01]). This is the so-called awareness and knowledge socialisation approach, which can be related to two basic premises. The first is that by providing mutual awareness of spatially distributed, but contextually related users (e.g. working on same task, or belonging to same community) by means of a shared virtual space, the cognitive distance between them is bridged. The second is that once this cognitive distance is bridged, the conditions are established for the users to enter into conversations through which they exchange otherwise inaccessible personal knowledge.

Another class of approaches that can be related to the socialisation model has investigated the possibilities of using textual virtual environments of MUDs/MOOs as a kind of online learning labs. Here knowledge is exchanged through shared design practices in building and programming the virtual world (e.g. [Bruckmann, 93]). Such approaches are often related to the constructionist theory of learning ([Papert, 80], [Papert, 90]) which emphasises the role of artefacts. This can also be compared to the approach of „learning by doing“ and to situated learning through „legitimate peripheral participation“ as studied and described by [Lave, 91]. Other investigations on communities in MUDs focused on patterns of social interaction with respect to issues such as construction of identity and the self-organising establishment of social norms (e.g. [Turkle, 95]). Yet other approaches have explored the use of MUDs as social information spaces, in which social interaction is embedded within a concrete informational context. Related approaches include social navigation such as collaborative web browsing, populated web pages and collaborative histories.

The explicit externalisation model is addressed by approaches aiming at supporting the formulation of shared conceptualisations in form of knowledge taxonomies. The currently most notable approach here is the development of technologies for metadata frameworks that allow the modelling of the semantic „meaning“ of information in a way both processable by computers and usable for the communication of meaning between human users. An example are ontologies, as a model for formal descriptions of concepts and named relationships between them, that

describe how a given individual or a group of people understands a particular domain of knowledge. Ontologies have to be created explicitly by hand and require a process of explicit community negotiation for achieving a consensus about the shared understanding that is to be expressed. Once created they can be used to access and navigate the community information pool, as well as to visualise the semantic structure of the shared community understanding. An example of existing efforts for building such ontologies in different disciplines but interrelated to each other is the DublinCore initiative (http://www.dublincore.org), while the Open Directory Project aims at collaborative definition of a somewhat simpler taxonomy for manually mapping the content of the whole Web (http://dmoz.org).

The most typical case in practice is the combination of the internalisation model based on information exchange through mailing lists and bulletin boards, with the socialisation model supported through textual chat. The main problem of such approach is that the sharing of knowledge requires extensive interaction within the community. Recently, approaches have been developed that try to combine all three models. An example is the SocialWebCockpit system [Gräther, 01] that combines a shared workspace for building up a collaborative information repository with socialisation mechanisms such as awareness and textual communication, and with the possibilities to explicitly build up and externalise a shared vocabulary without explicit negotiation.

The main shortcoming of computer-mediated socialisation approaches is that the sharing of implicit knowledge requires extensive interaction between individual members, and the resulting exchange still resides only in individual users. There is no possibility to visualise the resulting structure of shared understanding. On the other hand, existing approaches to creating externalised representations of a shared conceptual structure, require explicit negotiation for achieving consensus between the members. Similarly, it is not possible to visualise the dynamics of the creation of the shared knowledge structures as the community evolves, and develops new knowledge. There is no or little support for expressing the personal points of view of individual users and putting them in relation to the shared structure. At the same time, one of the essential mechanisms of knowledge creation is the ability to change perspective and see the world with „different eyes“. Finally, the challenge remains of how to provide insight into the underlying values and beliefs shared by a group of users, as fundamental elements influencing their thinking, judgment and the creation of new knowledge.

We believe that one possible way of approaching this challenge is to explore the possibilities of the techniques of cognitive and perceptual mapping such as those commonly used in strategic decision making and social modelling (e.g. customer segmentation, voting behaviour analysis). Since these techniques are based on the idea to capture not only patterns of rational reasoning but rather implicit elements such as affective and emotional responses, values and beliefs, they could be used to provide a completely different perspective on the structure of the community knowledge, than in the existing approaches. Previous experiments along these lines include the use of methods inspired by personal construct psychology [Kelly, 55] such as the repertoire grid elicitation, for extracting conceptual structures of individuals and groups of users [Shaw, 95]. Also computer-supported social network analysis based on statistical and linguistic analysis of texts has been used for visualising the

social and semantic networks based on implicit patterns of community interaction contained in newsgroup postings [Sack, 00]. On the other hand, the approaches of collaborative filtering and recommender systems provide a way for putting in relation perspectives of different users, based on explicit expression of their judgment and preferences (e.g. ranking) or on implicit statements such as bookmarks or patterns of interaction with information. Typically, they allow to identify members with similar interests and can recommend items of relevance to a given user based on the fact that they have been highly rated by other users with similar interests. Experimental applications for supporting communities include collaborative filtering of postings in Usenet news ([Resnik, 94]), the Firefly system for recommending movies [Shardanand, 95] and purchase recommendations such as „related books" recommendations of Amazon.com.

Such techniques could be used to create both personalised views on the community knowledge as well as to construct a shared structure. In our work we have explored the combination of such methods as a way for capturing, visualising and sharing implicit knowledge of a community of users ([Novak and Wurst, 03a], [Novak and Wurst, 03b], [Novak, 02]). The main idea has been to create a form of perceptual maps, which both capture personalised views on the community knowledge as well as relate them to a shared conceptual structure, in a way which does not require explicit negotiation and interaction between the individual members.

## 4 Personalised Knowledge Maps & Sharing of Knowledge

As a practical context for our work, we take the process of information seeking and semantic exploration of a document pool. Within the context of networked communities of practice, this is typically the unstructured repository of community information exchanges (e.g. mailing list archives, project descriptions, best-practices etc.). The access to this information pool can be understood as a process in which the users' interaction with information both reflects their existing knowledge and produces new knowledge structures.

In order to develop a practically feasible solution for capturing and visualizing implicit knowledge structures of human users based on their interaction with information, two basic problems need to be solved:

1. A context for user actions has to be created in order to be able to interpret the meaning of user interaction with information items. The lack of a sufficiently clear interaction context is the main difficulty of general "user-tracking" and interaction mining approaches such as in [Chalmers, 01].
2. A form of visual representation has to be found that communicates to the user both the semantics of the information space in itself (content, structure and relationships) and relates this to the meaning of his actions.

To this end we have developed a model of personalised learning knowledge maps [Novak and Wurst, 03a]. A knowledge map presents a semantic structuring of an information pool. It consists out of two main elements: the DocumentMap and the

ConceptMap. The DocumentMap (Fig 1, left) presents the information space structured into clusters of semantically related documents. This provides an overview of topics and relationships in the information space. The ConceptMap (Fig. 1, right) visualizes a concept-network that provides both a navigation structure and insight into the criteria that have determined the structuring in the DocumentMap. In order to construct such knowledge maps based on a user's personal point of view we combine methods for statistical text-analysis and clustering based on Self Organizing Maps ([Lin, 91], [Kohonen, 00], [Honkela, 97]) with methods for supervised learning of user-induced templates based on the Nearest Neighbour algorithm (e.g. [Aha, 91]). First the user is presented with a system-generated structure, which she can explore and rearrange in an unobtrusive manner (moving documents between groups, creating new groups and adding new cluster labels). In this way the user provides a template, which reflects her personal point of view and the insights she discovered and internalised as knowledge. This template is learned by the system and can be used as a model to automatically classify information into user defined clusters. In the resulting map, not only the users interests are reflected but also her way of structuring information, providing a personalised view on the information space. Such learned personal maps can dynamically classify arbitrary new information even as the community pool evolves. Furthermore, based on the analysis of the user's personal DocumentMaps, the system extracts a personal ConceptMap, which displays a network of most relevant terms and connections between them, „seen" from a user's perspective. To this end, the most relevant terms for the document clusters from all personal maps of a given user are put in relation to user-defined labels of the clusters in question. The cluster labels are selected as main concepts and the calculated terms of relevance for the given cluster are assigned a weighted relationship to the corresponding label (Fig. 1, top right).

## 5 Collaborative Discovery and Sharing of Knowledge

The described model of personal knowledge maps provides an unobtrusive way of creating dynamic artefacts that reflect the implicit knowledge of a user. Moreover, the user directly profits from creating personal knowledge structures. This can be seen as an important motivation factor, which is crucial in collaborative information systems.

The learned user maps offer two possibilities for the user's knowledge to be used by others. Firstly, a map can be called up *explicitly* by another user and applied to classify an information pool from the viewpoint of the map author. Secondly, we can statistical analysis to the maps of all users, in order to *implicitly* create an overall knowledge structure that considers the relationships between viewpoints of all users. We also infer relations between concepts e.g. stemming from user defined cluster labels that draw connections between a term and a set of objects. The resulting ConceptMap provides a way for constructing a semantic representation of shared understanding of the community: it presents the main concepts and relationships describing the community knowledge without the explicit expression and negotiation by the users, and puts it in relation to individual views. As this collaborative ConceptMap is created dynamically based on user interaction with information it will evolve together with the patterns of the community exchange.

For creating this overall structure from personal maps created by the members of the community, we use a combination of text-based measure and the co-occurrences of objects in user created clusters. Initially text-based measures are used to estimate the similarity between objects and terms. After some user interaction is available, we can replace these measures by the co-occurrence measure, which provides a direct user-based indication of relationships between objects. The switching from text-measure to co-occurrences is automatic. This combines the advantages of text-based methods (applicable independently of any user interaction), with the advantages of collaborative methods (directly related to user views and independent of the objects content).

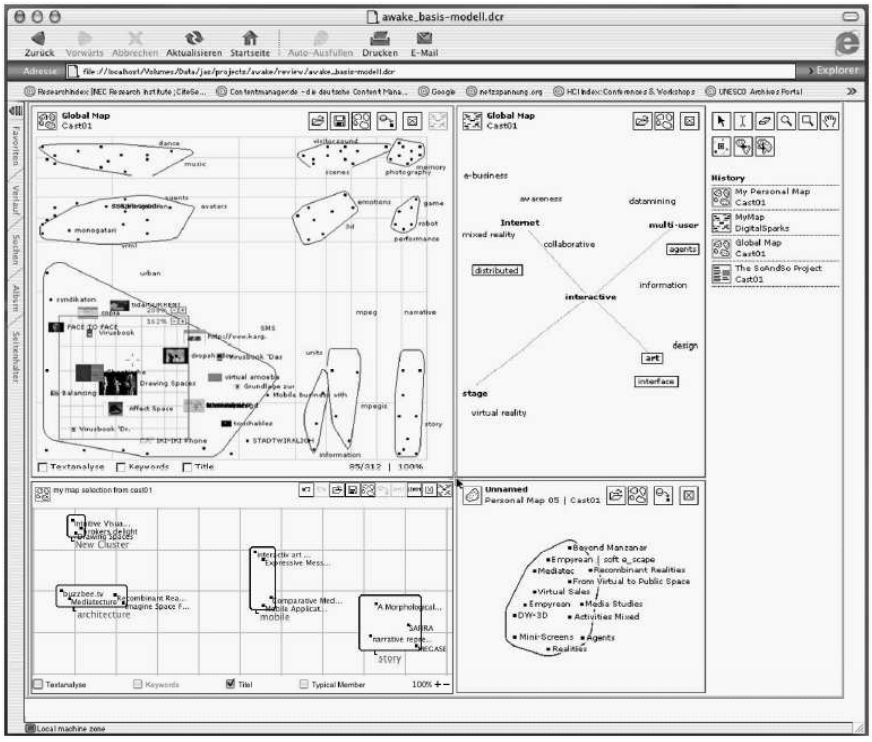


*Figure 1: The Knowledge Explorer Interface*

The inference of relations between concepts from personal maps is based on the fact that by labelling clusters, the users draw a connection between a term and a set of objects. Two concepts to which related objects are assigned by many users can be considered to be related themselves. Using this relationship, a ConceptMap can be created that represents the users' shared understanding of the information space. Using both similarity of objects and similarity of concepts in combination with text

based methods[2], allows the shared structure of the information space to emerge step by step, avoiding the cold-start problem of collaborative filtering.

The knowledge represented by the created maps can be also used for dynamic contextualisation of search results. To this end we have created an intelligent search functionality based on the idea that a user has a current as well as a long-term information need. By entering some keywords the user expresses her current information need. The long-term information need is extracted from the maps the user has created so far. The search results then contain both the list of retrieved objects based on keyword match, as well as a list of most relevant personal maps of different users. The first map from the list of most relevant maps is automatically visualized and the objects from the result list are highlighted. In the DocumentMap the user can thus identify clusters of related documents, which his search query otherwise would not have retrieved, while in the ConceptMap the corresponding concepts are marked. Thus the user also discovers new concepts that might better describe the possible knowledge spaces to which his query might refer.

In the described way, a semantic representation of shared understanding of the community is constructed, which presents the main concepts and relationships describing the community knowledge without the explicit expression and negotiation by the users. The members of the community can now share knowledge through exchanging their personal maps or by navigating the shared concept structure. As the collaborative ConceptMap is created dynamically based on user interaction with information it will evolve together with the patterns of the community exchange. In this way we have realised a possible solution to some of the main problems of other approaches to sharing implicit knowledge presented in the previous chapters: in particular the problem of the creation of a shared structure based on implicit knowledge of the community that incorporates personal views of individual users, doesn't require negotiation of consensus and that evolves with the dynamics of community development and interaction.

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2 Fig. 2 shows some preliminary results concerning the combination of text-based similarity and co-occurrences. The evaluation criterion in this case is the expected nearest-neighbour classification error as derived through leave-one-out-testing. While text similarity shows not to be dependent on the amount of user interaction, similarity based on co-occurrences strongly improves with an increasing number of maps. The combination not only chooses the best of both methods at each point, in some interval it is actually superior to both methods. Though the result has been derived with a very small document pool and few users, which makes it not fully representative, it still shows that our approach is very promising.

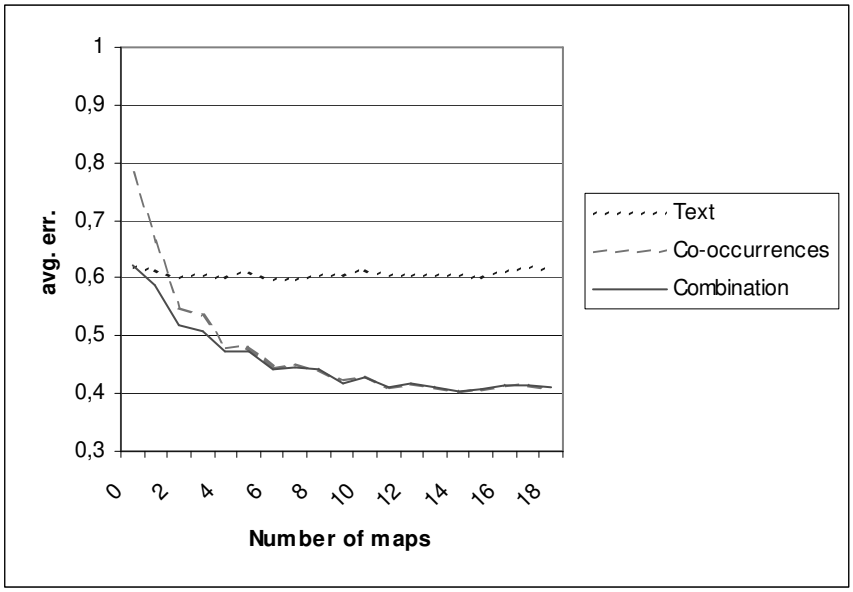


*Figure 2: Effectiveness of the combined text and co-occurrence measure*

## 6 Knowledge Maps as Community Artefacts for Reflective Awareness and the Creation of New Knowledge

While the previous chapter focused on the pragmatic usefulness of the developed model of personalised knowledge maps for sharing knowledge in groups of users, another important aspect is what we call „reflective awareness". The basic idea here is that one of the critical elements influencing the potential for the construction of new knowledge is the existing knowledge of individuals and groups of people. Thus becoming aware of this knowledge is a prerequisite for processes involving the creation of new knowledge. In other words, one of the critical aspects of learning is the ability to change perspective and discover hidden assumptions and mental models underlying a given point of view.

From this aspect the personalised knowledge maps can also be seen as a kind of knowledge artefacts that can be interactively manipulated and discussed by the community members (exploring maps of other users, applying them to different situations, comparing a personal concept structure to other individual and shared concept maps) in order to get an understanding of different mental models and interpretative schemas. The idea is that rather than just through automatic inference of relationships it is through one's interaction with the maps that one can develop an awareness of and insights into implicit structures - such as mental models, values and beliefs - of one's own or shared by the community. The hypothesis is that by achieving this kind of reflective awareness the processes of communication and sharing of knowledge especially in heterogeneous user communities can be

qualitatively improved in order to stimulate the emergence of new knowledge previously *not* consciously considered or perceived by the community as a whole.

## 7 Relationship to Related Work

The basic idea of generating user-specific templates and applying them for personalized structuring and filtering of information has been previously realized in several different ways. In one class of approaches the users have to express their preferences explicitly and as their primary task, such as by voting, preference profiling or initial selection of items from a given information pool (see [Herlocker, 00] for an overview). One critical issue here is the bootstrapping problem: the available orientation for users' initial identification of relevant items in an information pool (which they are not familiar with) is based solely on already available profiles of other users (e.g. [Resnick, 94]). A related problem is that of communicating the intention and meaning behind user choices that contributed to the creation of a given profile to other users: the profiles themselves are typically neither "explained", nor visualised, nor put in relation to the semantic structure of the underlying information pool. Another class of approaches attempts to analyse the users' actions in form of click streams and navigation patterns on the web (e.g. [Joachims, 97], [Chalmers, 01]). The critical issue here is the lack of a clear context for interpreting the meaning of users actions.

In our approach both of these problems are addressed by introducing a system generated map as 1) a clear initial context for user actions, 2) a structure for semantic navigation in an unknown information pool, 3) form of visualising users personal knowledge structures in relation to the original information space. This approach also allows us to make the expression of personal points of view unobtrusive and not distracting from the users main task: that of discovering relevant information and internalising it into knowledge. Furthermore, the personalized maps in our approach provide an easy and understandable way for communicating and sharing knowledge between different users both through explicit selection of different maps by the users themselves, as well as through implicit inference mechanisms of the agents that analyse the relationships between individual maps.

In the context of knowledge management for communities of practice such an approach can be most closely related to the personalisation strategy, although it contains some aspects of loosely structured codification (representation of knowledge maps). But instead of trying to codify knowledge through explicit extraction into strongly structured forms of description (codification strategy), our approach supports the creation of knowledge-based networks that allow knowledge to be communicated between different experts (personalisation strategy). The particular innovation is a personalisation technique, which supports the creation of knowledge-networks as side effects of user actions. The combination of techniques for self-organised clustering and supervised-learning resolves the bootstrapping problem typical for collaborative filtering, recommender systems and probability-based topic map extraction. It also provides a context for interpreting user actions and allows a usable level of expression and codification of individual knowledge, in a way, which is unobtrusive for the users and non-distracting from their primary task. Moreover, the learned knowledge

structures are related to the context of user actions, and visualised and applied in a way, which enables intuitive understanding of the criteria governing their behaviour - a common shortcoming of other approaches [Herlocker, 00].

The ability to connect different personalised structures into a shared concept map based on global patterns of knowledge exchange in the community also resolves some limitations of methods for ontology extraction which are applicable only within very specific knowledge-domains and tend to suffer either from overkill in complexity or underkill in practical relevance. The tight integration of the visualisation model with the underlying model for extracting and describing knowledge structures ensures that the resulting level of semantics is both powerful enough to represent significant relationships between concepts, context and individual items of information, as well as simple enough to be intuitively understood and used by the users. Finally, the ability to interactively manipulate the maps in ways which allow the user to „take on" dynamic perspectives of different users and put them into relation both to his own viewpoint as well as to the shared community structure, supports the user in developing an awareness of implicit structures, such as mental models, values and beliefs shared by a given community.

An important issue regarding the integration of the described model with other applications is the ability to automatically export the discovered knowledge structures in the RDF and the Topic Map format. This not only allows for knowledge exchange between different applications, it also provides an approach to the problem of generating Semantic Web meta information automatically. This is an essential point, as one of the main reasons for the relatively small acceptance of the Semantic Web, in comparison to its predecessor the World Wide Web, can be seen in high effort of creating Semantic Web information manually.

## 8 Application to the Internet platform netzspannung.org

The practical test bed and first application context of the described work is the Internet knowledge platform netzspannung.org [Fleischmann, 01]. netzspannung.org aims at establishing a knowledge portal that provides insight in the intersections between digital art, culture and information technology. Typical netzspannung.org users are artists, researchers, designers, curators and journalists. The basic requirement of such an interdisciplinary knowledge portal is: a continually evolving information pool needs to be structured and made accessible according to many different categorization schemes based on needs of different user groups and contexts of use. By using the described system this heterogeneous user group will be able to interactively compose and collaboratively structure an information pool, to visualise and explore it through personalised knowledge maps, and to construct a shared navigation structure based on the interconnection of personal points of view.

Following the methodologies of participatory design and user-driven innovation an early proof-of-concept prototype of the system has been evaluated in a netzspannung.org workshop with a heterogeneous group of target users: curators, artists, information technology researchers, media designers and representatives from

museums, cultural institutions and media industries[3]. The users had the possibility to explore system-generated maps and restructure them according to their own understanding and thus to create personal maps. Since the learning functionalities haven't been implemented at that point yet, the resulting maps could only be saved as a kind of personal static semantic views on information space. Nonetheless, the received feedback was extremely positive and justified the envisioned overall model. In particular the users reacted very well to the idea of an initial system-generated map not only as an overview, but also as an exploratory interface and a means of inspiration for discovering unexpected relationships between different thematic fields and projects.

Furthermore the users explicitly highlighted the importance of the provided ability to express personal views and the planned functionalities of creating a shared but connected multi perspective structure. This had been repeatedly pointed out as an essential feature of a model aiming at supporting the exchanges in such a heterogeneous and loosely connected community as theirs. Another very much discussed issue has been the users' need to understand the criteria of the system functioning (clustering) which is incorporated in the current model by the pairing of a system-generated DocumentMap with a corresponding system-generated ConceptMap that provides insight into the clustering criteria and enables its interactive parameterisation by the users themselves. Finally, the users received enthusiastically the envisioned possibility of publishing and exchanging their personal maps with each other.

The current system prototype has been internally deployed as information access interface to the submissions of the cast01 conference and of the competition of student projects digital sparks. This simulates the use scenario in which users can explore possible relations between information usually isolated in separate archives of different communities in the fields of media art, research and technology. The results can be tried out in the guided tour and partially online available interactive demos[4]. An early visualization prototype for browsing system generated maps is still in day-to-day use as a public information interface in netzspannung.org[5].

## 9 Critical issues and further work

We are aware of several critical issues of the presented model. One is the classical problem of collaborative aggregation methods, which tend to suppress minority views. In consequence, when the collaborative analysis dominates the similarities from the text-analysis, only mainstream patterns of relationships might emerge in the shared concept structure. Furthermore, editing personal knowledge maps, the user can arrange objects only in flat structures, which is very intuitive and easy to handle, but not always sufficient. Therefore, our colleagues are exploring the integration of a

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3 This very early proof-of-concept workshop took place in 2001. See http://netzspannung.org/workshops/knowledgemaps.

4http://awake.imk.fhg.de/guided_tour.html http://awake.imk.fhg.de/prototypen.html

5 http://netzspannung.org/cast01/semantic-map

second editor, capable of creating hierarchical structures and other relations between objects in order to explicitly formulate an ontology [Ziegler, 02].

Another critical point is also the question of privacy. Since our concrete application context is an interdisciplinary professional community of experts (netzspannung.org), the assumption is that the users will be willing to share their maps, as a motivation for gaining expert reputation within the community. But in other cases this might be a non-trivial problem to consider.

Another question is how it would be possible to determine the amount of the influence that implicit knowledge has had in the created maps, and how much is still a factor of explicit reasoning? In particular, to which extent can such a model allow us to incorporate or discover values and beliefs shared by a group of people? One assumption is that they are supported implicitly through the exploratory mode of the use of the system, where the user doesn't have to explicitly formulate a query to communicate the meaning and intention of his actions. The other is that they can be deduced by human users themselves by reflecting on the concept maps and the relationships that appear between the individual concepts in the personal maps and the shared structure. Currently we are also working on adding a PeopleMap based on the relationships that can be induced between personal maps of different users. Further issues include: What kind of social mechanisms develop or become amplified in this process (e.g. reputation economy)? What role plays the possibility of reflection on the hidden assumptions and beliefs shared by the community? Can we use such maps as tools of analysing the knowledge flows in existing social networks (e.g. of scientific research, EU-IST programmes) in order to identify which implicitly shared values govern current trends ?

## 10 Conclusions

In this paper we have discussed the main implications of the social nature of the processes through which knowledge is generated in social networks such as networked communities of practice, for the development of the technologies to support them. We have focused on the problem of sharing implicit knowledge, outlined and inspected the suitability of existing technological approaches, and identified possible ways of developing new models. We have discussed how the social theories of learning and theories of organisational knowledge creation can inform this investigation. In doing so, we have demonstrated how such an inquiry requires an interdisciplinary approach integrating the insights and methods from disciplines as different as informatics, sociology and organisational science. In particular, we have presented a model of personalised learning knowledge maps for capturing, visualising and sharing implicit knowledge of a group of users. We have shown how this knowledge map model resolves some of the main problems of the existing socialisation and externalisation approaches: in particular the creation of a semantic representation of a shared understanding of the community, incorporating implicit knowledge and personal views of individual users.

Furthermore, we have presented possibilities to use knowledge maps as medium for explicit and implicit exchange of knowledge between different users. As pointed out, our system differs significantly from so called "collaborative filtering" systems,

as items are not just rated by the users, but are put into context, in a way which is unobtrusively embedded into users' primary activity. Finally, we have discussed the application within the interdisciplinary Internet portal netzspannung.org, the critical issues and open questions of this model, and how they will be addressed in the further work.

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