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Social Network-Aware Interfaces as Facilitators of Innovation

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Abstract Achieving continuous innovation in organizations requires a balance between exploiting yet acquired knowledge and exploring new knowledge. In addition to having the adequate resources, change and innovation capabilities require specific management support and organizational structures. Recent research has pointed out the importance of social network structure and of the activity of agents that work across domains or disciplines in the innovation-oriented behaviour of organizations. As a consequence, information systems should ideally be able to support the analysis, development and management of such social structure for the benefit of organizational objectives. Current social network interfaces provide an established mental model to workers that can be hypothesized to be adequate for supporting activities that foster innovative behaviour. That behaviour is facilitated through exposing the activities of other workers across organizational structures. This paper reports on the design of a user interface specifically targeted to manage the social aspects of innovation based on some aspects of Hargadon's model of innovation and knowledge brokering. The emergent nature of interactions in social network sites is used as the metaphor to foster situated cognition. The interface design assessment is described and some metrics for innovative behaviour that could be derived for such an interface are sketched.

Keywords information system, innovation, learning, ontology-based information system, social network

1 Introduction

According to the definition of the FRISCO[1] an information system (IS) is defined as "a system in organizational context, serving to provide value by making information available"[2]. This definition puts an emphasis on value as the main driver of an IS. While the notion of "IS value" is currently subject to disparate interpretations and measurement approaches[3], the link from organizational learning to IS value becomes evident when considering information flows. Information delivery is commonly considered as a driver for the increment of personal knowledge, and thus of organizational knowledge, according to the "learning organization" paradigm[4]. In coherence to such view, *learning* is largely driven by the behaviour of the IS, including its internal and external sides. Further, research has showed that organizational learning affects innovation[5], which evidences the need for considering the design of IS as an facilitator of innovation.

The social structure inside the organization is considered as one of the determinants on how learning takes place. Indeed, social structure has been considered as an important element for organizational learning. For example, Argote and Miron-Spektor[6] considered it as a significant element in the context required for learning. While the effect of learning in performance may come also from inter-company collaborations[7] or externalization of knowledge[8] among other factors, here we focus on internal relationships, as they have been identified as a constituent of innovative behaviour and they are subject to explicit modelling in systems supporting information flows in organizations.

In a related direction, *social capital* in organizations is considered to include all the value-producing aspects that emerge from the network of social ties and the dynamics of social interaction. The positive contribution of social capital and particular relational structures to the value of organizations is widely acknowledged nowadays[9-10]. Further, the social structure is considered as an important factor in organizations that have innovation as one of their distinguishing features[11]. In addition, methods like social annotation of research production[12] can also increase organizational knowledge.

Organizations that aim to achieve continuous innovation need to balance the resources devoted to exploiting yet acquired knowledge and exploring new knowledge[13]. Exploitation rests in the knowledge created and accumulated by the firm through competencies, organisational routines, processes and norms. The exploration for new ideas, technologies and knowledge

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requires different organizational capacities that deserve separate attention, or can be provided by specialized structures as think tanks[14]. In consequence, the consideration of *innovation* entails a concrete form of internal organization of the processes that produce, validate, select and target information with an organizational purpose, and as such, they should be considered as important elements in IS design. The external network structure is also known to affect the evolution of the firms[15]. In any case, the consistent and effective management of the change and innovation process is a key capacity in manufacturing and other kinds of activity[16].

Innovation is accounted as one of the factors that critically affect organizational value[17], and it is often measured through R&D (research and development) expenditure and number and impact of patents, among other factors. More comprehensive frameworks like that of Muller, Välikangas and Merlyn[18] introduce resource investment in new business as an additional view on innovation, and they also consider competencies and culture as enablers of innovation, along with providing an emphasis on the role of leaders in innovative behaviour. Under such views, IS design and behaviour becomes a determinant or enabler of innovation and its subsequent conversion into business opportunities. For example, appropriate IS support can be perceived as openness to innovation, which is known to be a factor affecting innovation. Consequently, the notion or conceptual definition of innovation should be present in the design of organizational IS, and in the case of technology-intensive sectors, IS behaviour should be founded on representations and decision procedures that drive innovation-related activities.

Hargadon[11] proposed a model for innovation and knowledge brokering that includes the consideration of social networks. Such organizational model can be used as the point of departure for the design of supporting IS. Combining the organizational elements with the micro-sociological analysis typical of social network analysis[19-20], it is possible to build social network aware interfaces supporting the analysis and management of value-related social structure. Such interfaces need to consider social networks representing knowledge and learning-related activities and be seamlessly integrated in the working habits of individuals. This latter aspect can be arguably facilitated by adopting the style of popular "Web 2.0" social networking applications as *Facebook*① and some existing design heuristics[21]. Ellison, Steinfield and Lampe[22] have reported evidence on how *Facebook* use is connected to social capital for college students, and other studies have pointed out such kind of relation[23]. Other type of approaches has been sketched to manage social interaction in order to improve knowledge discovery. Kester *et al.*[24] proposed the use of a system to help the composition of transient communities that exist for a limited period of time and stimulate learners socially to interact.

This paper reports on the design of a user interface specifically targeted to manage the social aspects of innovation based on Hargadon's model of innovation and knowledge brokering[11]. The design departs from heuristics of Web 2.0 social systems[21] and is guided by the assumption that these social sites have contributed to forming a kind of shared mental model[25]. The elements of the conceptual model supporting such hypothetical mental model are represented in terms of a Knowledge Management (KM) ontology[26] combined with a graph-based model of social networks. These models come from previous work related to the application of Semantic Web technology, which has been analyzed as a relevant framework for learning organizations[27]. An initial evaluation is also reported, providing some insights on the value of such social interfaces to support the linking of proven solutions or methods to new kind of problems, which are considered key to the process of innovation[11].

The rest of this paper is structured as follows. Section 2 surveys related work in formal models for innovative behaviour and particularly models accounting for social network structure. Then, Section 3 describes the essential elements of the conceptual model behind the user interface presented later, based on the Knowledge Management ontology proposed by Holsapple and Joshi[26]. In Section 4 the main elements of the design of the interface and the rationale for the design are described. Section 5 reports on the evaluation carried out that examines some concrete social network measures. Finally, conclusions and future research directions are provided in Section 6.

2 Related Work

Models for innovation behaviour in organizations emphasize two main elements. On the one hand, the requirement to acquire external knowledge in an efficient way, and on the other hand, the communication and cross-fertilization inside the organization, mediated by the social structure. For example, Hsu[8] presented a model that accounts for innovation indicators regarding the internalization of outside resources and research.

A considerable number of ontology-based information systems have been reported in the literature to date. Ontologies have been used for different purposes, including the implementation of business rules[28],

① http://www.facebook.com/

interoperation of enterprise resources[29] and product design[30] among other uses. Ontologies have also been used to build IT platforms mediating R&D decision-making. For example, Colomo-Palacios *et al.*[31] described RDi-Advise, which accounts for sourcing mechanisms in R&D processes. From the perspective of development of ontology-based IS, Valiente[32] provided a systematic review of approaches using ontologies combined with model-based development.

Previous work related to ontologies and innovation covers different aspects of innovation processes. Rield *et al.*[33] described an ontology for the representation and management of ideas, in the context of open innovation. Their idea ontology supports idea mining, evaluation and tracking their realizations. However, it does not cover the internal processes and organizational structures leading to innovation. In a related direction, Zanni-Merk, Cavallucci and Rousselot[34] described an ontology for computer-aided innovation addressing several aspects of artifact evolution, focusing on characteristics as resources, substances and contradictions, but not including processes and organizational structure explicitly. Adams[35] addressed the governance aspects of the innovation process, focusing on intellectual property issues. O'Raghallaigh, Sammon and Murphy[36] have recently reported an ontology that defines the words and sentences that can be used to represent innovation models. Instead of a formal ontology, their proposal represents an initial list of terms that were found important in describing innovation processes. The ontologies reported later in this paper include these general concepts and provide also detailed models for learning processes and the underlying social structure.

3 Conceptual Model

The ontology of Holsapple and Joshi (H&J) describes fundamental concepts and axioms of KM. Its specific inclusion of learning as a kind of activity provides the required framework for the modelling of innovation as an activity essentially connected to information distribution. In what follows, a synthesis of the relevant aspects of the formalization of H&J ontology as described in [37] is provided. References to the original H&J paper are provided in square brackets.

The definition of KM in H&J ontology "An entity's systematic and deliberate efforts to expand, cultivate, and apply available knowledge in ways that add value to the entity [..]" [DKMC1] requires the early definition of "entities" capable of engaging in KM, which are considered to include at least individuals, organizations and collaborating organizations, as stated in [DKMC2-5]. The term `oc_Organization` in OpenCyc covers all such entities. Terms in Courier font refer to ontology terms and relations. Those also prefixed by `oc` refer to definitions explained in [37], which in turn refer to terms in the large *OpenCyc* commonsense ontology. The concept of knowledge processor [DKMC10] as a member of an entity can be modelled by the concept of `oc_IntelligentAgent`, which are by definition "capable of knowing and acting, and of employing their knowledge in their actions". Humans are intelligent agents by logical definition and certain software pieces may also be, since they are not restricted to not being able to `oc_know` [AKMC10]. The subtype `oc_MultiIndividualAgent` fits the definition of collective agents [AKMC11]. The definition of Knowledge as "that which is conveyed by usable representations" [DKMC6] can be integrated in OpenCyc by considering usable representations [AKMC2] as information bearing things, i.e., "Each instance of `oc_InformationBearingThing` (or "IBT") is an item that contains information (for an agent who knows how to interpret it)".

The recognizable kinds of knowledge manipulation are referred as Knowledge Manipulation Activity (KMA) [DKMC12]. Activities in OpenCyc are represented as `oc_Actions`, which are a collection of `oc_Events` carried out (`oc_doneBy`) a "doer". This generic concept of action can be specialized to represent KMA executions by restricting them to be carried out by intelligent agents. The predicate `oc_ibtUsed` can be used to represent the knowledge representations manipulated by KMAs. In addition, since KM activities are deliberate, it is better to use the subclass `oc_PurposefulAction` and the predicate `oc_performedBy`. Learning in H&J ontology is defined as "a process whereby KRs are modified; an outcome of a KME involving change in the state of an entity's knowledge" [DKMC17]. This entails that learning is considered as a (positive) change in one or several IBTs, or in some specific cases, in the knowledge attributed to one or several agents inside the organization. This can be expressed by referring to each know-related item through a `learntIn` predicate (a specialized inverse of `oc_eventOutcomes`).

The activity-agent-IBT model provides a basic model for the details of KMA types and other more specialized concepts. This model will be used in the rest of this paper for semantic coherence when describing more specific aspects. Fig.1 provides a depiction of the relationship of the basic notions described, in which the focus is on the activities, irrespective of the domains and contexts in which they take place. The introduction of these latter aspects will be detailed below.

The differences in efficacy and efficiency that different agents exhibit in KMA can be explained in terms

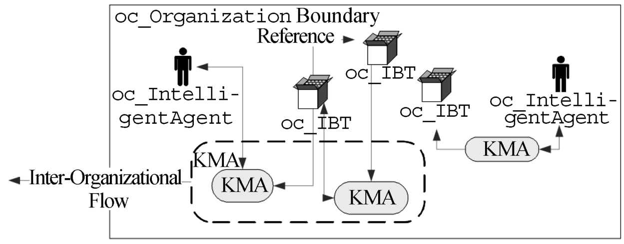

Fig.1. Illustration of the basic activity-oriented KM model.

of competencies. The notion of competency is linked to the concept of human performance, which according to the model of Rummel[38] encompasses several elements: 1) the work situation is the origin of the requirement for action that puts the competency into play; 2) the individual's required attributes (knowledge, skills, attitudes) in order to be able to act in the work situation; 3) the response which is the action itself; and 4) the consequences or outcomes, which are the results of the action, and which determine if the standard performance has been met. This model has been described in ontological terms elsewhere[39].

The described model focuses on a level of description in that requires further elaboration to account for innovation according to theories based on brokerage[40], which considers recombination of ideas and their social support as key innovation drivers. The consideration that organizations innovate by "recombining their past knowledge in new ways" puts an emphasis on opportunities for lateral knowledge dissemination. Even though the analogical reasoning required to innovate is to date a unique, distinctive attribute of the human mind, the organizational structure and management of knowledge resources and activities condition the possibilities for the phenomenon to take place. Innovation and innovativeness can be integrated in the above described ontological framework by the definition of innovation as a target of learning behaviour, and by describing innovation-oriented culture and organizational elements. These are described in the subsections that follow.

3.1 Consideration of Social Structures and Domains

The Knowledge and `oc_IBTs` represented explicitly in the ontology must be structured in defined `Domains`, located in particular `SocialStructures`. Here the term "domain" is a defined concept used to describe the knowledge resources that surround a concrete group of `Agents`. Thus, the aggregated competencies of the social structure formed by the agents are available resources for innovation. This corresponds to the *Access* preconditions of Hargadon's model. These domains are organization-specific mappings of social structure and knowledge. In addition, the tasks of brokering across domains include brokering across the boundaries of a single organization. In any case, domains include explicit references to the domain ontology terms that are key concepts of interest. These will be used by the IS as the hooks from which potential recombinations of knowledge items will be obtained. Since ontologies are not limited to the representation of a single aspect of reality, casual discovery is fostered. For example, techniques in very different domains will be linked by the fact that both are instances of the `oc_Method` concept, facilitating discoveries as the one that occurs in the development of mass production at Ford.

The `oc_RelationshipBetweenTwoPeople` term is sufficient to represent the components of a `SocialStructure`. This dyadic representation can be used for graph-based representations of social networks as is common in current research practice[41]. The interactions that result from the application of these models to Web applications have yet been used as a source for the automatic measurement of the strength of relationships as described, for example, by Sicilia and García[42]. Then, social structures can either be defined a priori or induced from actual activity, which capture the formal and informal aspects of a micro-sociological view.

The mapping of domains to social structures again can be approached from at least two perspectives that we will call "a priori" and "inductive" respectively. Aprioristic mappings are advisable as a form of representing the organizational structures, e.g., the different functions and interest areas (as marketing, quality, financial, and so on) can be mapped as domains to the respective organizational units. Inductive procedures for mapping domains to social networks include tailoring of social filtering techniques[43] — in which "neighbourhoods" of users with similar interest are computed — and also clustering techniques that could derive common interests from the contents of the used `oc_IBTs`.

3.2 Consideration of the Agents of Innovation

Knowledge browkers (K-Brokers) are the subset of `oc_Agents` that act as conduits for multiple `Domains`. agents is consistent with the need for self-awareness of being a mean to connect several domains. From an IS perspective, the identification of brokers is critical to automated activities of project team building or even for strategies to foster the creation or strengthening of (informal) social relationships. IS behaviour should ideally give access to brokers to information resources in several domains, as a way to increase opportunities for transfer of ideas or problem-solution patterns. A basic activity of these agents is that of transferring potentially useful resources across domains (a special kind of KMA). The KMAs arranged or allowed should therefore account for the availability of brokers, as a guarantee for the enablement of innovation opportunities. This can be considered as a supporting tool for the *Bridging* part of Hargadon's model.

3.3 Consideration of Learning Across Domains

In common approaches to modeling IS-directed learning[39], a "learning for the need at hand" is often considered. In innovation-oriented IS, a concrete kind of learning activity must be carefully considered and integrated into the overall behaviour: learning "what others in the organization do". Formally, a class `CrossLearning` could be specified and characterized by 1) being enacted by KBrokers, 2) involving IBTs or engagement with Agents in different domains. This is the specific kind of learning that is described as distinctive of innovation in Hargadon's model (see Fig.2). The "learning what others know" can be supported by giving K-brokers access to full-fledged and detailed competency models[39].

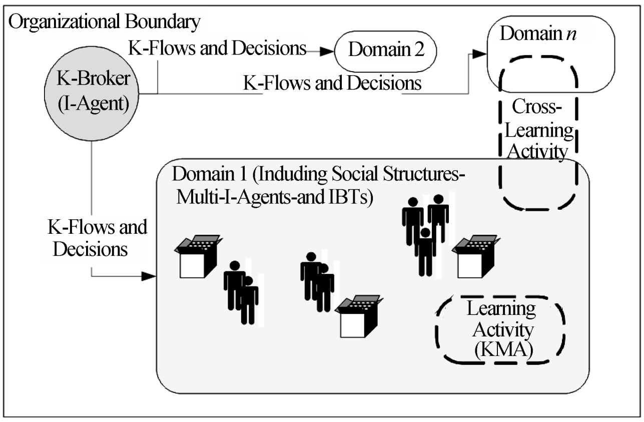

Fig.2. Overall view of Hargadon's elements as related to KM and learning concepts.

The analogical reasoning considered in the *Linking* part of Hargadon's model represents a challenge to current knowledge-based IS systems. Even though the automatic finding of analogies may be considered as a hard artificial intelligence problem, IS support impact on how knowledge is made available, giving possibilities for agents to innovate to a diverse extent. At this point, flexibility in the arrangement of KMAs is the key to enable brokers to direct their knowledge and intuition to fostering potential recombinations of existing resources (i.e., by building supporting ties). In any case, there is a need to clearly formulate the drivers for solutions (the problems). These can be represented as Requirements of a various kind, some of a technical and others of an organizational nature. This definition has been deliberately left open to allow for formal and informal statements.

The last important element is the recognition of innovation as a distinctive element supported explicitly in the ontology. Since innovation results in new resources or processes, a defined term "Innovation-Result" can be formalized in terms of the trace of KMA(s) that resulted in it (and eventually to the originating Problem). In a fully supported KM IS that records KM activity enactment, this can be accomplished by comparing the domains that are sources of the Knowledge applied to the design of the new process or product. The competencies or knowledge of participants in KMA or other work activities can be used to derive the domains that were of influence on the given innovation. In a similar way, the innovation-oriented activities of brokers can be traced and identified from the specific learning or linking activities initiated by them.

The localization of the interchange in knowing in a social structure offers the opportunity to add a dimension to competency management that entails certain teleology to innovation. This model can be easily realized in IS behaviour whenever social structure awareness has technological support. Additionally, in an ontology-based IS that supports the above concepts, metrics can be gathered directly from quantitative indicators related to the ontological structures. For example, an estimation of innovativeness in learning activities obtained from problem-focused teams may be obtained by considering the degree of complementarities of the member's background and competencies.

4 Case Study: Interface Design

The main interface structures have been wrapped around the notions discussed above and considering context building issues that are relevant for organizational learning[44]. These elements provide the basic mapping of the above ontology to a conventional organizational structure. The five heuristics for on-line communities proposed by Gallant, Boone and Heap[21] were considered in the design. These heuristics — interactive creativity, selection hierarchy, identity construction, rewards and costs, and artistic forms — were identified as drivers of on-line sociability in general. Since our objectives are of a more specific nature, they have been adapted to fit the context of work in an informal team setting. This type of setting provides a context of trust that can be hypothesized to increase information disclosure[45], thus giving an appropriate context for data gathering.

Fig.3 depicts an example of interaction with the interface. The interface basically supports steps 2 and 3 of Hargadon's model, i.e., it provides opportunities for K-agents to gain access to multiple domains, and they are able to distribute resources and links to people or activities to other agents in the organization, using for that a kind of social search[46]. An example of this is described in what follows. Layout elements and a general loose arrangement have been borrowed from the interfaces of existing social sites in an attempt to reduce effort by hypothetically reusing existing mental structures, also the amount of status elements displayed has been reduced to facilitate attention[47].

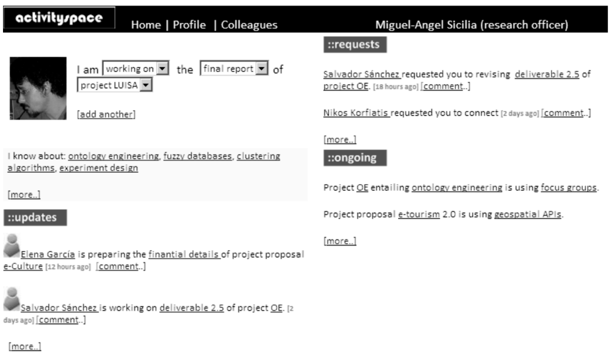

Fig.3. Example screenshot from the *activityspace* prototype.

The heuristics about interactive creativity lead to include free-text commenting options for requests and updates, so that individuals are flexibly allowed to communicate in the context of these events. The heuristics about selective hierarchy were deliberately not accounted for, since the interface is aimed at blurring the boundaries of domains and making the hierarchy more visible (e.g., assigning special privileges to project leaders) could be detrimental to transversal communication. Identity construction in the work environment considered is built by the self-identification of competencies and skills. The rewards to be analyzed were essentially the improved awareness of the work of peers and enhanced possibilities for on-line communication and dissemination of knowledge, which is considered as a tool in particular situations. This is reinforced by the use of the "ongoing" panel as the place in which these situated applications are exposed. Finally, personalization in this case is bounded to the social structure determined by co-participation in projects or similar competency profiles.

In Fig.3, the elements of the conceptual model can be recognized. Since the interface is devised for a project-oriented group of people, domains are projects (or project proposals), IBTs are artefacts as documents that are generated in the course of the activities of such projects, and actions are the kind of activities (KMAs) declared by the users. Users should say "what they are doing" much in the style of applications as Twitter② for social awareness. Each user also declares his/her competencies in the "I know about" area, and in the "ongoing" frame, users are able to see which competencies or concrete skills are being exercised in other projects (domains).

The *Accesses* or structural preconditions are given for granted in the Knowledge brokering (K-brokering) system. This entails that resources of all the kinds are yet described in ontological terms. These connections are either responsibility-based (or formal) "Project Activities" or general purpose (informal) "Linkages". The former are constrained to the duties and responsibilities formally assigned to the K-agent, while the latter are intended for casual discovery or connection of ideas.

Different degrees of flexibility can be realized through varying ranges of action given to K-agents or other agents that decide on their bridging activities. The basic level used in the example above is that of being capable of informing or communicating relevant resources, activities, people, or domains. Nonetheless, this could be expanded to add the possibility of starting targeted learning activities, or even initiating cycles of knowledge claim evaluation as those described in the KMCI KLC[48]. Furthermore, an aspect not considered in this interface is that of "combination" of several elements into single units, since in this environment that was considered a matter of merging IBTs or resource profiles through other application interfaces.

The above described model and kind of application enable the automatic collection of indicators for innovation as a result or for innovativeness as the behaviour that eventually produces it. The elaboration of these indicators into metrics has the potential to become the source for self-adaptation of the IS itself. In contrast to the common focus on metrics related to the effects of KM — e.g., [49], metrics gathered through the use of the ontology described are able to measure the actual activities of the organization, thus serving for the surveillance of the behaviour of the organization[4]. These measures could be subject to correlation with typical outcome-related measures (e.g., growth, renewal or customer-related) as a form of validation or inquiry regarding the elements of models as Hargadon's. Table 1 summarizes the different kinds of metrics that could be gathered.

The structural description metrics described in Table 1 are related to the basic descriptive capabilities

②http://twitter.com/

of the innovation-supporting IS. Other work[52] has described additional inquiry in quantitative approaches for such measures, but qualitative assessments are still required to compare the degree of flexibility in definition provided by different ISs.

Table 1. Proposed Metrics for Innovative Behaviour

Metric	Perspective
Structural description	Measuring the representational capabilities of the domain-social structure representation. Function point analysis methods[50] can be used as a reference framework. At the level of a single organization, characterizations of the permeability to access can be gathered. For example, the average number of domains per social network can be used to estimate the degree of interconnection of the knowledge in the overall organization. Note that these measures have a particular model-based interpretation, since Hargadon's model considers "isolation" of ideas in "small worlds" (i.e., a degree of differentiation of domains) as a precondition for knowledge creation
K-agent enabled access	Following the idea of "weak ties across many domains", measures of the capillarity of K-agents between domains should be gathered. This can be done by measuring betweenness[51]. At the level of a single K-broker, a measure of resource dissemination across domains is an obvious quantitative measure of innovation-oriented behaviour
Use of enabled resources	The effective use (in the context of KMAs) of the resources transferred to a domain from others represents the raw measure for knowledge use
Combination of enabled resources	Effective innovation from the perspective of performance should focus on the ratio of Innovation Results per use of enabled resource (a form of productivity metric)

5 Evaluation

Two different research groups evaluated the interface described in the previous section in a concrete setting involving its use. Each of the groups was responsible of several ongoing R&D projects and other tasks, as for example elaborating project proposals. The evaluation was twofold. On the one hand, usage data was analyzed and contrasted with a previously recorded model of the two groups. On the other hand, the users were asked about how useful they found the application for their regular activity, focusing on the exploratory aspects of daily work. The former evaluation was aimed at gathering evidence about to which extent the application would be able to detect interesting patterns in the network structure of the groups.

5.1 Contrasting Quantitative Data

For the first part of the evaluation, two loosely structured research groups were used as case study. They used the interface for four months, reporting their daily project activity (including project proposal tasks). The researchers created an a priori social network model for both groups elicited from the participants with a standard questionnaire technique[20]. The resulting non-directional social graph featured strength of connection as perceived by participants related to joint activity. Two individuals were identified as brokers between the two groups. The quantitative study was based on the two following measures of social connection related to the interactions with the interface:

- Measure 1 ($M1$): tie strength as co-participation in domains (projects).
- Measure 2 ($M2$): tie strength as number of interactions (counting requests and comments to status reports).

For $M1$, a bipartite graph representation with agents and projects as sets was used. The two-mode network was reduced to a one-mode network with link counting as the weights of the actor-only network. This was later normalized in the [0, 1] interval for the contrast. $M2$ was also normalized for comparability.

The a priori information was represented in graph $G = (N, E)$, with N the people in the application and E the set of relationships so that given $i, j \in N$, $value(i, j) \in [0, 1]$ was the tie strength resulting from the questionnaire (having a zero value representing the absence of social relationship). The contrast of the a priori information (G) with each of the measures was done by the following absolute difference with each of the measures $M1$, $M2$:

$$c(G, G_M) = 1 - \frac{\displaystyle\sum_{(i,j)\in N\times N} |value(i, j) - value_M(i, j)|}{W},$$

with W standing for the number of possible ties (arcs in the graph). In the formula, G_M stands for either G_{M1} or G_{M2}, i.e., the same formula is applied for the two measures described above, and $value_M(i, j)$ stands for the estimated values of that tie strength via each of the measures (M standing for $M1$ or $M2$). In consequence, for a graph of maximum difference the contrast will yield 0.

Table 2. Measures for Co-Participation for Each of the Groups

Group	Size	$c(G, G_{M1})$	$c(G, G_{M2})$
Spanish group	10 of which 2 female	0.72	0.81
Greek group	7 of which 2 female	0.59	0.64

The results show that both estimations are able to detect the kind of social relationships identified to some extent. This correlation serves the purpose of evaluating that the activities are actually responding to the underlying work structure as perceived by the participants. However, the second one has resulted in this case as a better predictor, which points out work and domain relationships that are relatively independent of the more formal project participation structure used in the first measure. The estimators do not perfectly fit the a priori assessments, however, the data is limited and comes from a short time span, so it is worth for future studies to investigate such estimators in longer time periods. The two groups were connected through two concrete individuals who acted as brokers and this strong cross-group link was also well estimated by $M2$.

5.2 Thinking Aloud Evaluation

The second part of the evaluation was aimed at getting some feedback on the properties of the interface and how it could foster situated cognition and sensemaking[53] by exposing the capabilities and work context of peers. The selected evaluation approach was using the thinking aloud protocol, with the aim of identifying the tactics of the researchers in browsing the information and the reasoning about reusing knowledge (contacting peers with the required expertise), techniques or methods that are known to have been used as solutions for existing problems.

The method is as follows. Seven users (five from the Spanish group and two from the Greek group) were asked to verbalise everything that they were thinking and describe what they were trying to do so that the observer could keep a written protocol. This data capture method is often called the Verbal Protocol Analysis or the "thinking-aloud" method[54]. Each participant performed the test on the same laptop computer to ensure similar conditions for all the participants. Finally the participants had to fill in a rating questionnaire and give their opinion about how useful the system was for the purpose of "reusing" techniques, knowledge or solutions. The questions were five-point Likert-type, and they were targeted to have a general assessment on the perceived usefulness of the interface ($Q1$) and the extent to which it covered work in different domains. Concretely, these were the questions, and the result average (*avg*) and standard deviation values (*std*):

- $Q1$: To which extent the interface is useful for your daily work activities? ($avg = 3.82/std = 0.95$)
- $Q2$: To which extent have you discovered new knowledge, techniques or methods from the activities of your colleagues? ($avg = 3.29/std = 0.91$)
- $Q3$: To which extent your record of competencies and activity in the application covers your actual work activity? ($avg = 3.8/std = 0.78$)
- $Q4$: Has the interface triggered any face-to-face interaction that you think it would otherwise have not occurred? ($avg = 2.88/std = 0.92$)

There were no significant differences across the responses in the two groups. $Q3$ was a control variable, since a precondition for the interface to be useful is the previous recording of competencies. A chi-square test contrasting the frequencies of $Q3$ with $Q1$, $Q2$ and $Q4$ confirmed that they are not independent. $Q1$ had high correlations with both $Q2$ and $Q4$, which points out that perceived usefulness is associated both to the discovery of knowledge and to its use in face-to-face interactions. $Q2$ and $Q4$ resulted also non-independent, even if the error was higher than with the other contrasts. The lower average value in $Q4$ may be indicative that only some of the people in the groups actually behave as brokers according to the theoretical model considered. However, more detailed information is required to assess such aspect.

Since the evaluation was focused on the contribution of the interface to the transfer of knowledge between domains rather than on a general usability exploration, the test contained no specific tasks but rather points of interest in the use of the interface. Also, the usual gathering of background information was omitted, since the evaluator already was familiar with the work context, as it was available as part of the quantitative evaluation described above. Training in operating the application was also not required, since the test took place after the use of the interface. Thus the test consists of the following steps:

- A brief introduction to the test.
- Describing expectations and assumptions about each of the main aspects of the interface to the participants.
- Commenting on how user interface features promote cross-fertilization and how they could be improved.
- A final post-test questionnaire.

The concrete questions for describing expectations and assumptions were the following (even though participants were able to discuss any other issues also):

- Discuss the daily usage pattern of the application by explaining a typical session with the application.
- Give examples of use in which the interface leads to the discovery of (unexpected) interesting information from activities different from the ones you regularly do.

The analysis of the transcripts resulted in some recurring patterns for the use of the application, including: 1) interacting at concrete moments of the day, typically at the beginning of the work day, 2) combination of the discovery of potentially useful techniques or methods in the "ongoing" frame with searches in the Web and followed by requests for information to the person doing the activity, and 3) readjusting daily plans of collaborative work according to the kind of activity manifested in the "updates" frame. Pattern 3 is not related to the transfer of knowledge across domains under study here, even though it represents an interesting way of work organization as the one found in shared agendas. It is pattern 2 that was interesting from the viewpoint of step 3 (learning) in Hargadon's model. The analysis of the transcripts also revealed that only two of the participants had actually initiated the process of linking (step 4) according to the model, i.e., the process of re-applying know-how used in other activities to different problems.

The outcomes of the evaluation provide evidence about that simple social interface aspects are perceived as useful for the cross-domain transfer of knowledge and know-how, which is an essential step leading to innovation.

6 Conclusions and Outlook

Innovation is an element of organizational behaviour for which a number of specific models have been developed in the last years. Some of these models include as important elements the role of social networks and the value of people intermediating connected sub-networks as information brokers driving innovation. In consequence, the design of social network-aware interfaces can be modelled after these theoretical elements in an attempt to investigate how information system support can better foster innovation in organizations. This paper has described the integration of Hargadon's model of innovation as connected to a representation of the H&J ontology of KM as the base conceptual model of a social network user interface. The design has been driven by existing heuristics related to social software and has considered the underlying model in popular social systems as Facebook. The initial evaluation carried out reveals a fair coherence between automated social structure measures based on application activity with the a priori assessment of such structures. This points out a promising research direction on the use of social interfaces for the analysis of social structures of interest for exploratory capacities. Also, the semi-qualitative assessment has confirmed that user tactics fit well the reuse paradigm in Hargadon's model.

The social interfaces described can be used for a number of analysis and management tasks. These include the measurement and detection of structural features of the organizational social network, and eventually, support decision making related to the social structures. Further empirical analysis is required regarding the design of interfaces better supporting exploration, and these should follow future insights in our understanding of the underlying processes leading to innovation. Another interesting research avenue is considering the interaction in groupwares for concrete tasks as product innovation[55], which can be considered as a source of information for the social network models.

Future work should also deal with the integration of intellectual capital measurement models[56], thus integrating behaviour-based metrics with outcome-related ones. Other aspect that must be considered in the future is the inclusion of folksonomies[57] in social network-aware interfaces as a vehicle to share and increase knowledge acquisition, since they arise from data about how people associate terms with content that they generate, share, or consume.

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