A social exchange architecture for distributed Web communities

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Abstract

Using the foundational lens of social exchange theory and communities of practice, proposes a three-layer Web-based architecture to facilitate knowledge integration in digital communities. Reviews the limitations of past collaborative filtering mechanisms and presents a prototype and the underlying mathematical model for the knowledge networking on the Web (KNOWeb) architecture. Further illustrates how real-time active feedback and valuation mechanisms reinforce social exchange in such communities.

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Introduction

In traditional organizations, members share knowledge through routines and cultural norms (Nelson and Winter, 1982). When organizations virtualize, they lose the binding glue of shared cultural norms, routines, and common frames of reference that would normally facilitate knowledge sharing and integration. As work is increasingly organized around such physically and temporally distributed communities of knowledge workers, the burden of compensating for the loss of social ties falls on the enabling technology. Moreover, members in such communities come from different backgrounds, organizational affiliations, and functional specializations that share little common knowledge (Dixon, 1997). Effective knowledge sharing is a precursor to the collaborative success of such project teams, task groups, and knowledge networks in the post-industrial digital economy (Drucker, 1999).

Although knowledge is created and held at the individual level, it must be elevated to high levels in collectives for it to be useful. This process of elevation to higher levels is described as the knowledge spiral (Nonaka and Takeuchi, 1995). Each ring of the spiral involves the continuous interplay between tacit and explicit knowledge at the group and individual levels, as illustrated in Figure 1. As the process of socialization, externalization, combination with other members' knowledge, and the assimilation of emergent knowledge occurs in groups, shared knowledge is created. Knowledge is applied in communities only when it is elevated to this collective level (Nonaka and Konno, 1998).

In Web-facilitated communities such as distributed teams, virtual task forces, and communities of practice, enabling technology can impede or facilitate knowledge sharing and integration. With the interest of understanding how information technology interplays with knowledge community spirals, we first review social exchange theory, apply it to previous research on distributed communities, identify the common limitations, and based on that, propose the KNOWeb architecture. We then formalize that architecture, and illustrate it with the case of a prominent Web community.

Theoretical foundations

Virtual communities are described as social groupings that exhibit shared spatial

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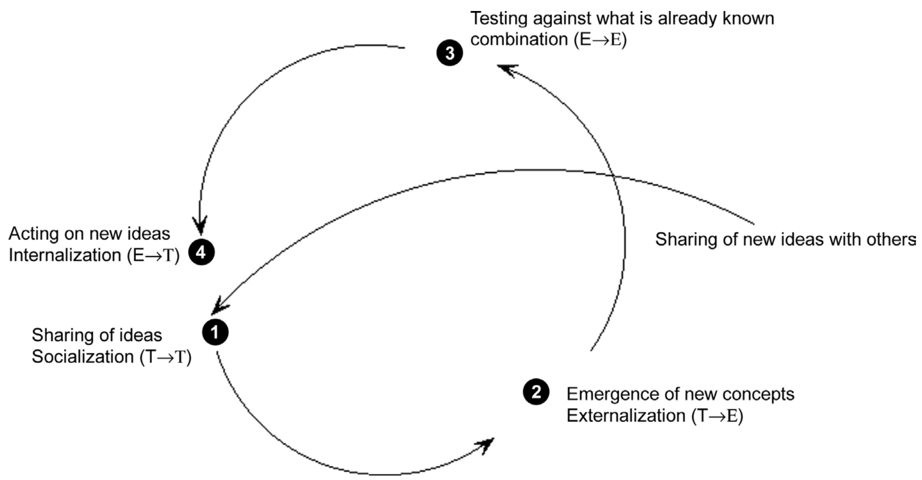
Figure 1 The spiral of knowledge moves knowledge to higher ontological levels



relationships (Rheingold, 1993), social conventions, a sense of membership and an ongoing rhythm of interaction (Hesselbein, 1998). Knowledge-sharing effectiveness in Web communities is influenced by three factors identified from collaborative filtering, organizational learning, and knowledge management research:

(1) level of participation;
(2) level of consensus and cooperation;
(3) satisfaction with group processes.

Social exchange theory (Thibaut and Kelley, 1959) further suggests that participants in such peer-to-peer community networks expect mutual reciprocity that justifies their expense in terms of time and energy spent sharing their knowledge. Group knowledge-sharing processes will result in poor outcomes if members are dissatisfied with them. Individual members reveal their competencies, interests and affiliations through their behavior in group activities (such as knowledge-sharing and problem-solving discussions) (Wenger, 1998). Knowing, Wenger contends, comes from active social engagement.

The standards on which relationships among virtual community members are evaluated are defined by two components:

(1) their comparison level (CL); and
(2) the comparison level of alternative relationships (CL_{alt}) (Rusbult and Farrell, 1983).

CL is defined as the standard by which a participant evaluates his or her satisfaction with, and attractiveness of, the present – in this case, knowledge sharing – relationship. CL_{alt} defines the minimum acceptable level of outcome reciprocity and satisfaction failing which the participant will choose other knowledge-sharing relationships (such as participating in other discussion groups and peer networks). A participant becomes increasingly committed to his peer group as the level of satisfaction with group processes exceeds CL_{alt}, typically through reciprocity and mutual help extended by peers. Rusbult and Farrell (1983) further suggest that investment of resources such as time, money, and energy that an individual has invested in a relationship will be lost if such a peer relationship ends.

The process of knowledge sharing in social communities involves four components: practice, community, meaning, and identity (Wenger, 1998). In Web-based communities, these components must be reinforced by the collaborative medium, so that a sense of belonging, shared experiences, reciprocity, and cultural identity of the group are strengthened, as illustrated in Figure 2.

Web-based collaboration

Information systems researchers have attempted to build technology-facilitated environments to enable effective knowledge sharing and integration in knowledge-based virtual groups and communities. Two aspects of past research are noteworthy in the context of our work:

(1) Most previous research attempts have focused on these communities in settings other than the Web. In such cases, the audience has typically been technically proficient and comfortable with incipient pre-Internet technologies. However, the Web has made these communities more

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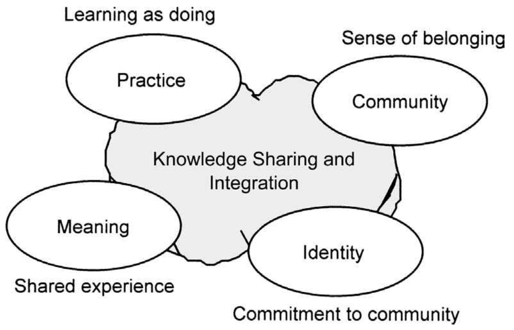
Figure 2 The four components of social communities



accessible to participants with limited technical proficiency.

(2) Most of these attempts utilize passive feedback mechanisms, if any at all. Table I summarizes some of these technical collaborative knowledge work architectures, and their common limitations.

The limitations of these systems can be insightfully interpreted through social exchange theory. Unwillingness of members to rate and value other members' contributions, lack of benefits that are consistent with personally incurred costs, and high levels of overhead can all be associated with the four dimensions of communities, as described in Figure 2. In Web-based communities, it is the enabling technology that must compensate for the inability of members to perceive actual costs and benefits of knowledge sharing and mutually supportive collaboration. In that context, we propose a system that overcomes some of the aforementioned impediments to knowledge sharing and integration in Web-based communities.

We propose an architecture for knowledge networking on the Web (KNOWeb) to enhance knowledge sharing among stakeholders and participants in a virtual task-oriented, virtual community of knowledge workers connected through the Web. Investments aimed at increasing future productivity cannot deliver results unless they are maintained at a stable level over substantial periods of time (Drucker, 1999). Through the systematic application of social exchange theory in the context of virtual communities, this architecture encourages the maintenance of such stable investments by team members *over time* through real-time, individualized, active feedback provided to each member.

A Web-based front end

Our system relies on a Web-based front end which was chosen primarily for its platform independence and low-cost connectivity afforded in a spatially-distributed collaborative environment. Because the knowledge-sharing system does not impose any specific platform, users can continue different types of systems to access it (e.g. Macs, Windows PCs, or Unix machines). This also lowers the initial adoption costs, both for organizations and for individual members.

This is in agreement with earlier proposals for repositories and navigational devices within which content can be arranged using applicable taxonomies (see Apostolou and Mentzas, 1998). Such a Web-based environment provides a familiar common space for discussions and deliberations that users might engage in. It further makes it

Table I Limitations of previous community-centric knowledge-sharing systems

Information system	Focus	Shared limitations
Tapestry (Goldberg et al., 1992)	UseNet and e-mail based recommendations	Perception of no benefit Unwillingness to rate contributions
Grapevine (Brookes, 1995)	Collaborative filtering	Cold start problems Users tend to abandon the system early on
GroupLens (Konstan et al., 1997)	Community centric collaborative filtering applicable only to news groups	Difficult to build a critical mass of users
Lotus Notes/Pointers (Lotus, 1997)	Collaborative work including e-mail and routing	Perception of an unfavorable cost/benefit balance High overhead that is often difficult to justify
REMAP	Decision tracing in project teams	
Delphi Web (Delphi, 1998)	Web-based discussion group	

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possible to retain currency of displayed content and devise an easy-to-use and familiar interface (Apostolou and Mentzas, 1998). Such shared space provides indirect feedback loops throughout the community and allows groups to "share knowledge through recommendations" (Malone *et al.*, 1987; Kautz, *et al.*, 1997). Users can also post pointers, documents, links, pictures, video clippings, and messages.

Active and individualized feedback

Active feedback overcomes the problem faced by previous attempts to create such environments, notably GroupLens, in which "many users abandoned the system before ever receiving rewards because they perceived effort without reward" (Konstan *et al.*, 1997). Users can see a cumulative indication of other members' contributions and receive immediate rewards for contributing, in the form of contribution ratings that they can use to base their own reading-time allocation.

In our proposed architecture, we propose that active feedback will encourage knowledge sharing and reinforce active learning in virtual knowledge-based communities by providing each member with feedback on her level of contribution to group processes in *relation* to those of the group as a whole. This increases the commitment of members to their group's processes, deliberations, problem-solving tasks and discussions by providing an objective measure that allows them to privately evaluate their relative contribution to the group. Recent research in group systems literature indicates that such satisfaction with group processes is correlated with findings of higher consensus, better decision quality, high confidence levels in peer decisions, trust and increased participation (see Steeb and Johnson, 1981; Nunamaker *et al.*, 1987; Kraemer and Pinsonneault, 1990).

Evaluating active feedback

To provide active feedback, KNOWeb uses two dynamically calculated variable values: α, the average contribution by each member and β, the average contribution by a typical member of the group. While the value of β remains constant for any member at any given instance, the value of α is calculated specifically for the individual user as uniquely identified through a user ID denoted by an integer value assigned to the variable η.

Average group contribution,

$$\alpha = \frac{\sum_{i=1}^{\eta} \sigma[i]}{v.\kappa} \forall \eta \neq 0K \tag{1}$$

Average member constribution,

$$\beta = \frac{\sigma[\eta]}{v} \forall \eta \geq 1K \tag{2}$$

$$\begin{aligned} \gamma &= \text{Rating} = \{1,\ 2,\ 3,\ 4,\ 5,\ \theta\} \\ v &= \text{View} = \{7,\ 30.584\} \\ \kappa &= \text{Number of members} \\ \eta &= \text{Member ID} \\ \forall\eta &\equiv \text{Integer} \\ \sigma[\eta] &= \text{Number of ratings} \end{aligned}$$

As illustrated in Figure 3, values of α and β for both contributions and responses are calculated separately based on beginning threads and responses posted by each member. Each contribution is associated with an average "worth rating", γ, which may have a discrete value between 1 and 5 or a null value if it is not yet rated. The member ID, η, is recorded each time a user logs in. The right browser frame graphically displays contributions and discussions much like a conventional Web forum with the exception that messages now have a value rating associated with them. The left frame in the user's Web browser indicates the average level of contribution measured on a relative scale of daily contributions per week or per month, depending on the view selected. The view is specified by the variable v, which can have a value of 7 or 30.584 days (for approximately seven 31-day months and five 30-day months in any given year other than a leap year).

These Web pages are generated on-the-fly by a Cold Fusion-based™ Web server that calculates the relative heights of the four bar graphs based on equations (1) and (2) described above. A radio button allows the user to select either a weekly view or a monthly view. For ease of interpretation, all contributions are scaled down to a day and no numerical count is displayed. This allows each member of the community to make an objective judgment of the relative contributions and benefits that he/she brings to the community as a whole. Further, each member's belief of their contribution to the efficacy of group processes through regular and perceptually high-quality contributions is reinforced through real-time contribution level data.

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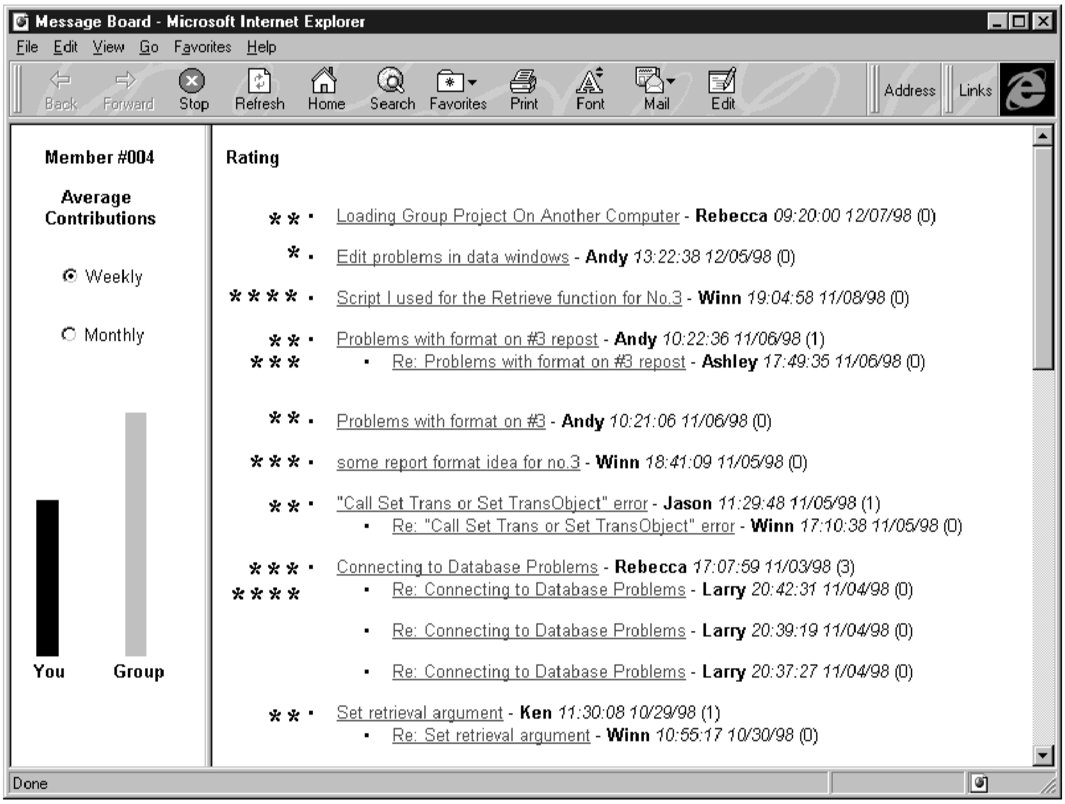
Figure 3 A typical dynamically generated HTML page in the prototype system



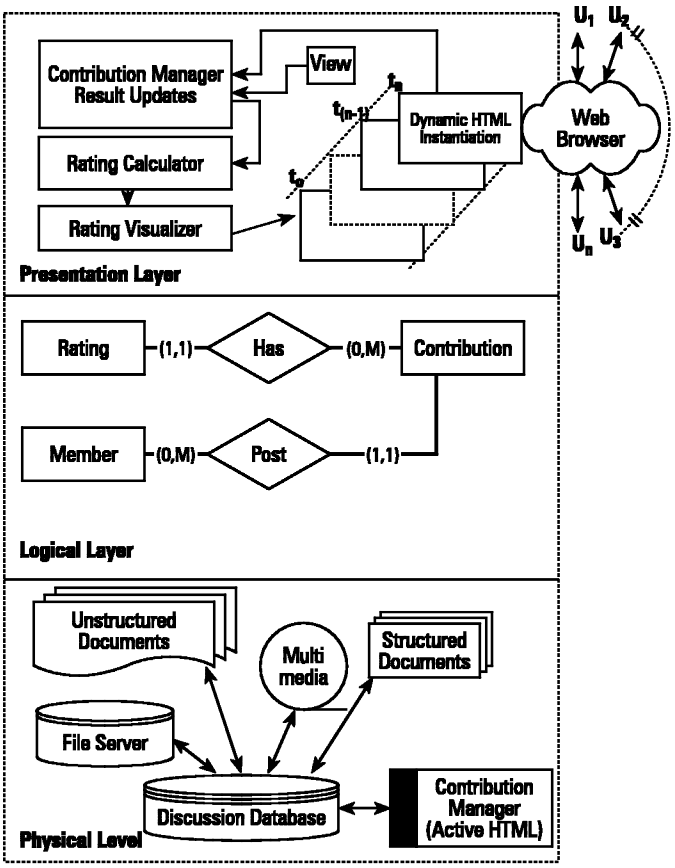
The KNOWeb architecture

The technical architecture underlying this system can be divided into three levels: physical, logical and presentation, as described in Figure 4. The physical (storage) level shows how information is stored in terms of the types of applications, databases, file types, and logical directory structures. The logical level describes the database schema used to implement the architecture. The presentation level describes how this information is delivered to individual users U_1 through U_n. The following sections describe the three layers in further detail.

Physical level

At the physical level, a discussion database stores past discussions, issues and deliberations. It also stores multimedia content, structured and unstructured documents linked to discussions and files that are hosted on a file server. The discussion database also stores ratings for each contribution. In some cases the boundaries between the physical level and presentation level are blurred, since information delivered at the presentation level feeds back to the

Figure 4 Three levels of the KNOWeb architecture



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logical level for calculation of averages which are then stored at the physical level. The contribution manager, for example, takes inputs through the final interface, which is a Web browser. These ratings are then aggregated and averaged according to equations (1) and (2) to respectively calculate the relative contribution of the group as a whole in comparison to that by the individual user.

Logical level

At the logical level, the structure for the discussion database, which serves as a central repository for messages (contributions) and ratings, is described. Within the database, *member* contains information to uniquely identify the members of the group. Only members with valid user IDs and passwords are allowed to participate in the discussion. This allows the contribution manager to track each individual's contributions to the community. Members are allowed to post messages under a pseudo-name for privacy reasons, but their presentation level display will always display their current relative contribution. *Contribution* contains information on all messages including date, time, member ID and a unique message ID. *Rating* tracks the ratings assigned to each message by members of the community. Each member is allowed to rate each message on a scale of one to five (representing useless to very useful) only one time. Message IDs and member IDs together combine to uniquely identify such ratings.

Presentation level

The presentation layer dynamically generates a HTML page each time any member reads or posts a contribution, as shown in Figure 1. This layer is built using Cold Fusion™ to actively generate a dynamic instantiation of a "mass-customized" Web page in the user's Web browser using contribution graphs generated by the contribution manager.

Application case exemplar: Amazon.com

Active feedback mechanisms, facilitated by the technology through which members of a community interact, improve the commitment of members to knowledge sharing and integration within the community. Amazon.com is a leading Internet retailer with Web-based stores in the USA, the UK (www.amazon.co.uk), France (www.amazon.fr), and Germany (www.amazon.de). Customers can rate and comment on books, music, and other products that the company sells. Feedback mechanisms kick in after customers comment on and rank products that the company sells. Other members can add value ratings on a simple two-level feedback scale that identifies whether specific customers who read those comments found them to be of value. This feedback accumulates in the electronic records of individual customers. Based on the value that other members of Amazon.com's customer base attach to these rankings, the original contributors' profiles are populated with an increasing count of useful/useless votes. Individual contributors are then assigned a rank, and the highest ranking customers are given additional recognition as being the "Top 10", "Top 100", or "Top 1,000" reviewers. Although Amazon.com's contribution feedback mechanism exemplifies a simplified version of this system's concept, there is a 24-hour lag between feedback and its public display. It also exemplifies how active feedback can actually make electronic commerce sites "sticky" over time. The use of wider scale, and real-time feedback are expected to improve this ranking system further.

Conclusions, implications, and future work

The contribution of our work lies in the actualization of social exchange theory in virtual communities of knowledge workers as enabled by the Web. We have described an architecture for a system to enhance knowledge sharing in knowledge-based communities through active feedback mechanisms provided through the Web. Based on its theoretical roots in social exchange theory, we have demonstrated how participants can be encouraged to contribute to group processes and task through real-time evaluation of what knowledge they both give and take from their peer group (i.e. costs and benefits). We have also mathematically demonstrated how such measures can be calculated cumulatively over a sustained period of time and scaled to a common denominator of one day. Further, each user can remain anonymous to the system if he/she so chooses, thereby overcoming both concerns about privacy and the contradictory requirement for identification for community building. Our prototype focuses on the community not the individual.

We have demonstrated how the proposed architecture can encourage knowledge sharing and active involvement of members within a peer community. We are currently in the process of implementing a scaled-up version of a prototype based on this architecture. This will then be followed by empirical validation of the effectiveness of this system in comparison with other Web-based discussion systems lacking active feedback. We plan to incorporate multimedia in the form of real-time audio and video to enable richer communication.

The implications of our study are as meaningful in work-centric Web communities as they might be in electronic commerce customer communities. Despite the potential for KM in electronic commerce communities, its current application is limited (Tiwana, 2000a, b). Understanding the behavior of individual members through the theoretical lens of social exchange, holds promise for extension to electronic commerce *site-specific* communities, especially those associated with business-to-consumer electronic commerce sites (Tiwana, 1998). This will, in effect, address the issue of customer retention and loyalty by providing insights into mechanisms that make Web sites sticky.

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