Towards a Sustainable Knowledge Sharing Environment for Online Research Communities

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

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Declarations

Some parts of the work presented in this thesis have been published or submitted for publication in the following articles:

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Abstract

Sustainability of online knowledge-sharing communities is a major challenge at the present time. Many approaches to knowledge-sharing communities have suffered from the lack of active user participation. To explore this problem it is necessary to study both social and technical issues.

In this thesis, economic and social theories have been employed to investigate users' demand and behaviour in an online knowledge-sharing environment. An empirical study was carried out using the Virtual Knowledge Park (VKP) to analyse the relationship between the level of users' participation and their perceived cost and gain. The results show that [i] individual activity of participation was inversely proportional to his/her perceived cost over gain and [ii] the level of participation significantly correlated with the factor of mutual benefits among the users. The results suggest that the promotion of the mutual benefits may lead to increased active participation and thus a more sustainable online community. In addition, it was found from user feedback that the users were not satisfied with the flexibility and the lack of autonomy in the VKP.

To improve users' flexibility and autonomy, a decentralized approach was explored. A peer-to-peer Virtual Knowledge-sharing Environment (VKSE) was developed to support knowledge-sharing in an online journal club (OJC). The application of the OJC and another decentralized VKSE (Groove) were evaluated in a set of user scenarios. It was found that decentralized VKSEs can provide the users with more flexibility, sense of ownership and control over their shared knowledge resources. However, this approach was not as good in managing and coordinating the online community as the VKP.

Drawing from the studies above, a novel infrastructure was designed. It adopts a community based knowledge market paradigm with two main concepts: agreements and transactions. The infrastructure applies a hybrid-decentralized approach, where the agreements are handled by centralized servers, and transactions of knowledge resource are carried out in a peer-to-peer model. It is expected that the market paradigm would encourage the provision of mutual benefits to on-line community members thus enhancing active participation. This should improve the sustainability of online knowledge-sharing communities. Given the novelty of the technical platform and concepts required for this approach, this research has shown that it is significant to carry out further work to assess its effectiveness.

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Abbreviations

AI	Artificial Intelligence
API	Application Program Interface
CoP	Community of Practice
GUI	Graphical User Interface
HTML	HyperText Mark-up Language
ICT	Information and Communication Technology
ISO	International Standards Organisation
IT	Information Technology
KMP	Knowledge Market Paradigm
OJC	Online Journal Club
TCP/IP	Transmission Control Protocol / Internet Protocol
URI	Uniform Resource Identifier
URL	Uniform Resource Location
VKP	Virtual Knowledge Park
VKSE	Virtual Knowledge-sharing Environment
VSP	Virtual Science Park
XML	Extensible mark-up language
WWW	World Wide Web

Chapter 1 Introduction

It is well known that knowledge-sharing plays an important role in academic education and research. Books, journals and conferences have been the media for academic knowledge-sharing for more than two centuries. In the recent two decades, the advances in personal computer and computer networks has provided a powerful tool to acquire, store, process and exchange data and information across time and space barriers. This has led to radical changes in the operation of academic research communities (Gaines and Shaw 1995). As a result, interest in facilitating knowledge-sharing among academic research workers via the Internet has substantially increased (Swan, Newell et al. 2000).

1.1. Knowledge Sharing and Its IT Environments

Modern academic research is a social process that largely depends on collaboration and knowledge-sharing (Kraut, Egido et al. 1988). In general the purpose of knowledge-sharing is to make perceptual and/or rational knowledge available to the right people at the right time and in the right place (Alavi and Leidner 1999). Academic research workers create, capture and share knowledge in various ways. As advances in knowledge happen rapidly in the academic research, new approaches are needed to speed up the process of knowledge-sharing. One of them is the use of Internet-based online communities supported by a virtual knowledge-sharing environment (VKSE). The study reported here is concerned with improving the effectiveness of this type of environment.

A VKSE is a software environment that supports the online interactions of a networked group of people sharing knowledge: depositing, retrieving and exchanging of knowledge with each other. There are two main types of VKSEs: centralized and decentralized. In a centralized VKSE, the knowledge resources are held and maintained centrally on a server as illustrated in Figure 1.1A. Many VKSEs apply this approach, for example, the Leeds Virtual Science Park (Lau, 1999; Lau, 2003). As the knowledge resources are kept centrally, the stability and security of the exchanged knowledge resources are dependent on the server, and less dependent on the computational power on the client. However, it requires non-trivial effort to copy information onto the server, and the user has less control over the knowledge resources submitted. These may affect the knowledge acquisition and update.

A decentralized VKSE assumes that all participants in knowledge-sharing are equally able to exchange their knowledge resources. Each participant has direct control over when and with whom certain resources are shared, and where the resource is located (e.g. see Groove at http://www.groove.net). As illustrated in Figure 1.1B, each member can contribute resources to the community and establish direct connections with any other members to access communal resources or to carry out some communal activity (Whinston and Parameswaran 2001).

Compared with the centralized approach, a decentralized VKSE provides a more interactive environment for sharing knowledge: [i] files are stored and controlled locally, [ii] each member is able to connect directly to one another for exchanging information, and [iii] the members are responsible for managing their knowledge resources. Thus it is possible for each node to provide more accurate and up-to-date information (Parameswaran and Susarla 2001).

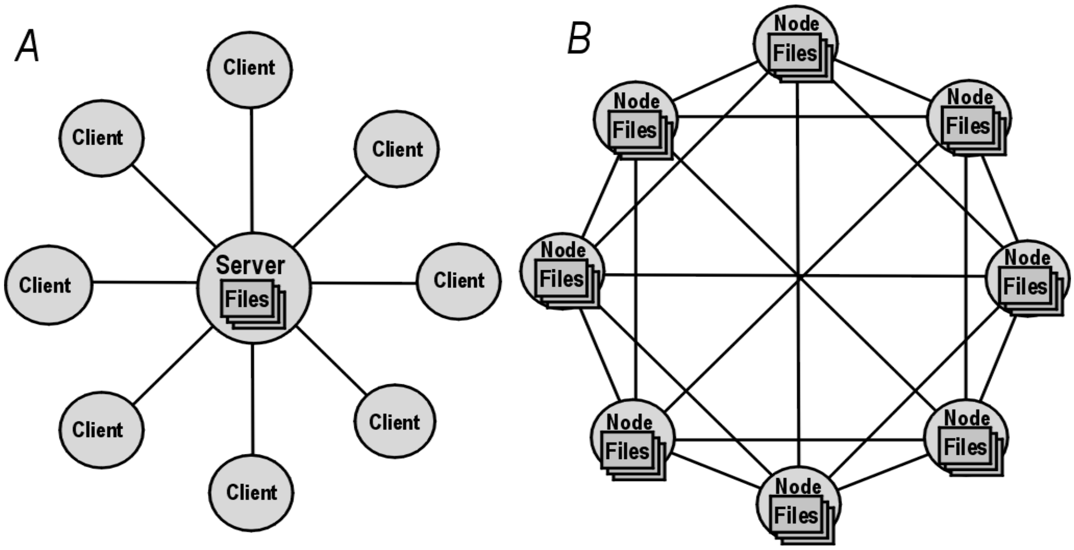


Figure 1.1 Centralized and Decentralized Approach

1.2. The Main Obstacles

Sustainability is a major issue faced by the designers of VKSEs (Kelly, Sung et al. 2002). Research has shown that many technical solutions to supporting online knowledge-sharing communities have suffered from the lack of active participation (Davies 2001; Snowdon and Grasso 2001; Brazelton and Gorry 2003). This has meant that sustainable knowledge-sharing could not be achieved (Vassileva 2002). Making and keeping users active and willing to contribute their knowledge resources is a top priority for online knowledge-sharing communities (Kelly, Sung et al. 2002).

Shortage of active participation and willingness to contribute resources were also identified in the study on the deployment of the University of Leeds Virtual Knowledge Park (VKP) (Lau et al. 2003). The VKP is a web based VKSE which supports research cooperation and knowledge management within the university and its external contacts. VKP has been available online at http://vkp.leeds.ac.uk from June, 2001 and there were over 1500 registered users in approximately 200 groups in the VKP in June, 2004. Unfortunately, many of these groups were only active for a short period and then became dormant (Adams 2004).

Major functions provided by the VKP include: [i] expertise matcher, [ii] document search for the resources, [iii] document management such as uploading/ downloading, viewing, deleting, version control and access control, [iv] contact management for processing and maintaining the relationship among individuals and/or groups, [v] collaborative tools such as discussion boards, emails and calendar, [vi] alerts, and [vii] real-time conferencing (Lau et al. 2003). The user interface of the VKP is designed as workspaces, as illustrated in Figure 1.2. The workspaces are provided at personal, group and public levels.

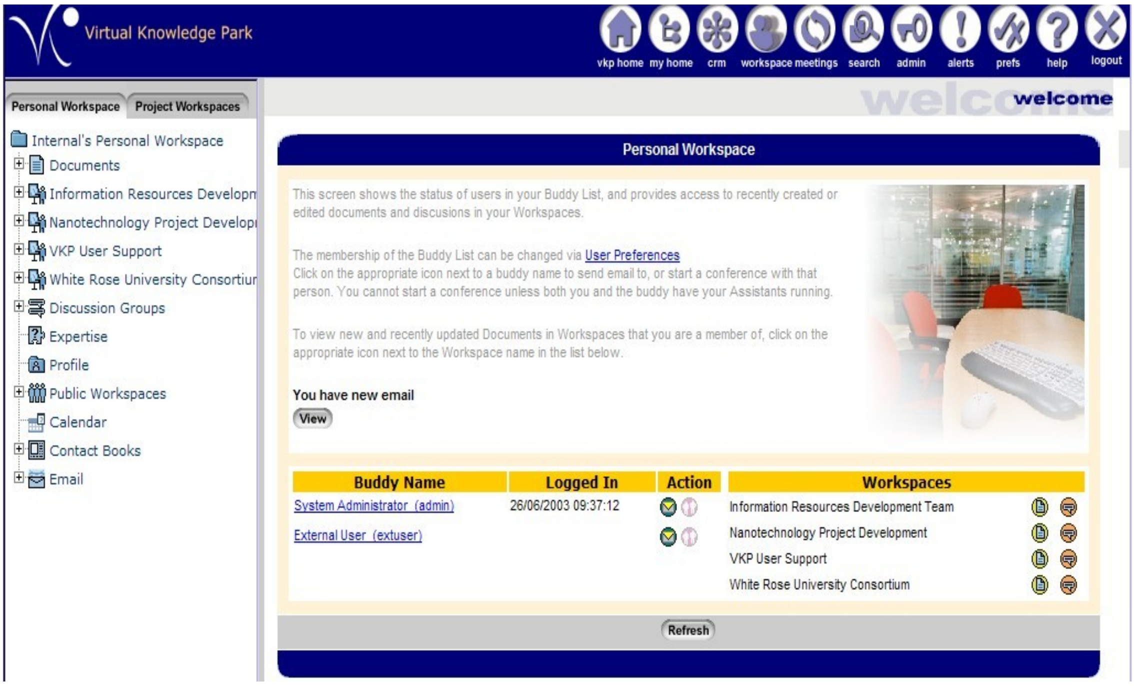


Figure 1.2 Screen Shot of the VKP

Experience of deployment of the VKP has shown that sustainability of these communities is a challenge, in particular for knowledge-sharing in research communities across the university and associated research institutes and committees. Despite the wide-ranging facilities provided by the VKP, it was found that there was a low level of user participation. According to the statistics of the data collected in the VKP log file, among the 1,500 users in total, only 200 of them logged into the system more than once in a month on average. Accordingly, the number of documents submitted and messages posted by the VKP users was limited, compared with what was expected. In the period from June 2001 to June 2004, about 6500 documents (including documents in personal folders) in total were shared in the VKP, which meant an average of 4 documents per person. In total, 825 messages were posted on the discussion boards.

The lessons learnt from the experience of the VKP indicated that it was not enough to just push out new technologies for VKSEs. A deeper understanding of the users, their motivations and barriers for participation was required. New mechanisms for keeping online research communities alive and active would be needed (Beenen, Ling et al. 2004). This provided the motivation for this study on the sustainability issue of VKSEs.

1.3. Research Objectives

The main question addressed in this research was how to improve the design of VKSEs so that they could support sustainable knowledge-sharing in online research communities. To achieve a sustainable knowledge-sharing environment, user participation and contribution need to be encouraged.

Objectives of the research were:

- To undertake a requirement analysis for a VKSE to support sustainable knowledge-sharing in online research communities;
- To undertake an empirical evaluation of the Leeds VKP to identify issues;
- To design and evaluate a decentralized VKSE using a real case study to better understand this approach; and
- To determine what mechanisms are needed to encourage user participation and contribution in online research communities, and thus achieve sustainability.

1.4. Research Methodology

1.4.1. An Overview of the Methodology

There were four main phases in the research methodology for this work (see figure 1.3).

Phase I of the research was to articulate and analyse requirements of VKSEs for sustainable knowledge-sharing in online research communities. The motivations for and barriers to knowledge-sharing were analysed based on a literature survey on the theory and practice of knowledge-sharing communities. Semi-structured interviews with selected VKP users were conducted to articulate the user requirements. In addition, an assessment of some representative VKSEs was carried out.

In Phase II of the research, the potential of decentralized features of VKSEs was explored. An Online Journal Club was chosen as a case study for testing peer-to-peer technology. Its development and implementation provided a proof-of-concept prototype for further evaluation. Another experiment using a commercial product ‘Groove Workspace’ was also conducted. Scenario-based evaluation was used in this experiment to test the decentralized features. The scenarios were created from the personal experiences of the VKP users. A questionnaire and semi-structured interviews were used to obtain feedback.

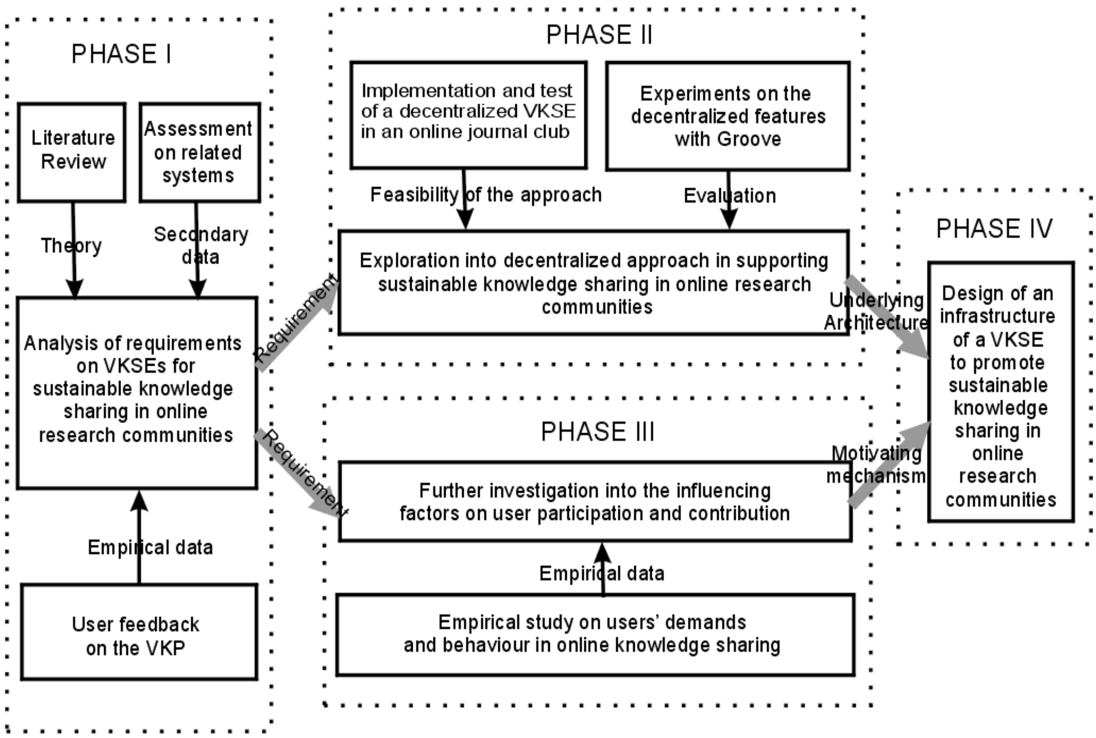


Figure 1.3 Research Methodology

After identifying the issues to be further investigated, Phase III of the research consisted of an empirical study with the VKP users. It involved the formulation of a hypothesis and proposal of variables to test the hypothesis. A questionnaire was constructed as a data collection instrument. Social and economic theories were employed to articulate the questions on the influencing factors, such as cost, gain and mutual benefit. These were identified as factors that were not properly understood by the designers of VKSEs. Semi-structured interviews were also held with the VKP users after the completion of the questionnaire. The data collected were analysed both quantitatively and qualitatively.

Phase IV of the research brought together the results from Phase II and III. An infrastructure was proposed for a VKSE that aims to achieve the goal of sustainable knowledge-sharing in research communities. Specifications of mechanisms to promote sustainability in online knowledge-sharing were proposed and discussed.

1.4.2. Research Methods Used

Qualitative methods (Bogdan and Taylor 1975) were used in Phase I for VKP user feedback and in Phase II in the evaluation of the decentralized VKSEs. Combined methods (Kaplan and Duchon 1988) were used in the empirical study using the VKP in Phase III. Details of the methods used in these studies can be found in section 3.4.2, 4.4.1, 4.5.1 and 5.3. The main techniques used for collecting data were: [i] semi-structure interviews, and [ii] questionnaires. The collected narrative and numerical data were analysed using content analysis (Krippendorff 1980) and statistics, respectively (see table 1.1).

	Qualitative Data	**Quantitative Data**
Collection	Semi-structured interviews	Questionnaire
Analysis	Content analysis	Statistics

Table 1.1 Techniques Used for Data Collection and Analysis

Semi-structured interviews were used for data collection in [i] the VKP user feedback (Phase I), [ii] the evaluation on the decentralized VKSEs (Phase II), and [iii] the empirical study on the VKP (Phase III). The rationale for this technique in these studies was to get an in-depth understanding of the identified issues from the users, as rich, detailed material could be elicited from semi-structured interviews (Lofland and Lofland 1995). All the interviews conducted were recorded on tape (with the permission of the participants) and summarized in notes. The qualitative data collected from the semi-structured interviews were analysed using content analysis (Krippendorff 1980). This technique was used to determine the presence of certain concepts (e.g. sense of control in online knowledge-sharing) within the data collected from the interviews. The presence, meanings and relationships of these concepts were analysed and developed into categories of issues.

A questionnaire was used for data collection in [i] the usability study of the OJC prototype (Phase II) and [ii] the empirical study using the VKP (Phase III). The rationale for using a questionnaire in these two studies was to provide statistical indications to the problems studied. For the VKP empirical study in particular, the data collected from the questionnaire were used to analyse relations among the variables to test the hypothesis. The data collected from the questionnaires were analysed using statistics, all statistical work in this research were conducted using Sigma Stats (SPSS).

1.5. Structure of the Thesis

The rest of the thesis is structured as follow:

[i] Chapters 2 and 3 discuss the main outcome of Phase I in the research. Concepts, approaches and issues in knowledge-sharing are reviewed. The problems with existing VKSEs and requirements within VKSEs for research communities are analysed.

[ii] Chapter 4 covers Phase II of the research. Development of a decentralized VKSE and experiments with two decentralized VKSEs are outlined and analysed.

[iii] Chapter 5 covers Phase III of the research where a more in-depth empirical study of the VKP with the issues of cost, gain and mutual benefit is discussed.

[iv] Chapter 6 proposes an infrastructure of a VKSE for sustainable knowledge-sharing in online research communities.

[v] Conclusions and future work are discussed in Chapter 7.

Chapter 2 Knowledge Sharing – Concepts, Approaches and Issues

2.1. Introduction

Issues on sustainability of online knowledge-sharing are related to both social science and computer science. This chapter reviews the related studies regarding knowledge-sharing in online communities. Four topics are involved in this review: nature of knowledge-sharing, conventional approaches for knowledge-sharing, emerging approaches for knowledge-sharing and factors affecting sustainability in knowledge-sharing.

2.2. Nature of Knowledge Sharing

2.2.1. Concept of Knowledge

It is widely accepted that knowledge is related to data and information, but is a distinct concept from either of them. The three terms are not interchangeable (Davenport and Prusak 1998). The difference among the three terms is a matter of degree, and knowledge is justified as a personal belief that increases an individual's capacity to take action (Alavi and Leidner 1999). According to the study (Alavi and Leidner 1999), there is a natural progression from data to information to knowledge. In general, data are signals, whereas information comprises and describes data. When an additional value is added, data become information that is determined by the receiver of the data. Knowledge is created from information. It is more valuable because it is closer to action as compared with data and information (Davenport and Prusak 1997).

There are a number of knowledge types that are suggested, for example, tacit and explicit knowledge (Polyani 1975), formal knowledge (Fleck and Tierney 1991) and domain knowledge (Monk, Nardi et al. 1993). Among these, tacit and explicit knowledge is the most common classification. Characteristics of explicit and tacit knowledge are listed in table 2.1 (Nonaka and Takeuchi 1995). Explicit knowledge is typically structured and retrievable. In contrast, tacit knowledge is partly or largely inexpressible, which may include the rich and complex expertise in individuals' heads. The current knowledge-sharing approaches tend to focus more on explicit than on tacit knowledge (Huysman and Wit 2003).

Tacit knowledge	Explicit knowledge
Not teachable	Teachable
Not articulated	Articulable
Not observable in use	Observable in use
Rich	Schematic
Complex	Simple
Undocumented	Documented

Table 2.1 Dimensions of Knowledge (Nonaka and Takeuchi 1995)

2.2.2. Concept of Knowledge Sharing

Sharing is a process whereby a resource is given by one party and received by another. For sharing to occur, there must be an exchange. A resource must be passed between a source (provider) and recipient (Sharratt and Usoro 2003). The term knowledge-sharing implies the giving and receiving of information within a context understood by both the provider and the recipient. As knowledge is directly related to understanding and is gained through the interpretation of information

(Alavi and Leidner 1999), knowledge-sharing is more than passing information from one person to the other. Moreover, there is no guarantee that the knowledge received will be identical to what is delivered by the provider, as the process of interpretation is subjective and is framed by the recipient's knowledge and identity (Miller 2002). Different from information sharing, knowledge-sharing fundamentally requires sense making and the generation of knowledge in the recipient. In other words, it involves knowledge creation.

Based on the discussions above, it has been defined in this research that: knowledge-sharing is a dynamic process of the transmission of knowledge resource (information) from a provider to a recipient in a given context. In most knowledge-sharing situations, reciprocal knowledge transmissions occur either naturally or as requested. Characteristics of the knowledge provider or the context influence the amount of knowledge that can be shared from the provider to the recipient.

2.2.3. Theories for Knowledge Sharing

Beginning with Roger's (Rogers 1983) investigation of early and late adopters of technological innovations, and more recently with Szulanski's (Szulanski 1996) study of sharing of best practices, many researchers have used communications theory (Shannon and Weaver 1949) to examine knowledge-sharing. More recently, organizational learning theories have become a focus in this field, as successful knowledge transfers are increasingly seen as an ongoing process of learning interactions, rather than just a series of communications (Szulanski 2000). The following sub-sections look at some of the relevant theories.

2.2.3.1. Knowledge Sharing in Organizational Learning

Within organizational learning theory, Nonaka (1994) explained the knowledge-sharing process as the conversion of knowledge between its tacit and explicit forms. Typical processes of knowledge-sharing include: [i] Socialization (tacit to tacit), e.g. dialogues and informal meetings. [ii] Externalisation (tacit to explicit), e.g. use of metaphor, analogy and model. [iii] Combination (explicit to explicit), e.g. document exchange and emails. [iv] Internalisation (explicit to tacit), e.g. study a number of documents and synthesize them into individual's tacit knowledge. According to Nonaka (Nonaka 1994), the key to knowledge creation lied in the conversion of tacit knowledge.

2.2.3.2. Social Construction of Knowledge

The "social construction of reality" theory had been used to explain the social construction of knowledge (Gaver and Martin 2000; Muller and Millen 2001). Knowledge-sharing was seen as knowledge "institutionalisation" on personal and public levels with three phases (Berger and Luckmann 1966): "externalisation", "objectification", and "internalisation".

In the phase of externalisation, personal knowledge is exchanged with others. This process involves maintenance, publication and exchange of the personal knowledge. During the phase of objectification, knowledge becomes an "objective reality" (Berger and Luckmann 1966). In this phase, new knowledge is created and individual knowledge is shared as public knowledge. In the phase of internalisation and in the course of knowledge socialization, objectified knowledge is widely accepted and used by individuals. This involves knowledge acquisition exchange and retrieval, which enable individuals to learn from either inside or outside of their organizations.

2.2.3.3. Implications

The organizational learning theory reveals the importance of facilitating the mobilization and conversion of tacit knowledge in knowledge-sharing.

Nevertheless, most IT solutions for knowledge-sharing focus on the sharing of explicit knowledge and apply a codification strategy (Hansen, Nohria et al. 1999). Codification strategy depends on sophisticated information technology (IT) to facilitate the acquisition, preservation, distribution, exchange and application of knowledge. Problems have been discovered in this strategy, as knowledge consists of information that is conceptualised and embedded in a "context" such as personal experiences, values and attitudes (Andriessen 2003). This "context" does not always get transmitted with the information for sense-making.

The personalization strategy (Hansen, Nohria et al. 1999), on the other hand, focuses more on the sharing of tacit knowledge, on people meeting each other, on interpersonal knowledge-sharing, on master-apprenticeship relationship and on communities of practice. People get knowledge through their interaction with other people and their environment, which provide the "context" for sense-making. Compared with the codified strategy, the personalized strategy acknowledges the importance of providing knowledge with its embeddings. However, it can be more complicated in practice as not only information and technological issues needs to be considered, but the issues about people and their behaviour as well. The social construction of knowledge theory reveals that knowledge-sharing is a social process, which involves interactions among people, knowledge and the sharing environment.

2.3. Conventional Approaches for Supporting Knowledge Sharing

This section reviews the conventional approaches for supporting knowledge-sharing. General technologies for knowledge-sharing are reviewed according to Nonaka's model of organizational learning (see 2.2.3.1).

2.3.1. Socialization Approaches

The most typical way in which tacit knowledge is built and shared is in face-to-face meetings and shared experiences (Nonaka 1994). In this context, information technology (IT) plays a minimal role. However, an increasing proportion of meetings and other interpersonal interactions use on-line facilities, such as chat rooms and e-meeting which can be classified under groupware.

2.3.1.1. Groupware

Groupware is a fairly broad category of application software that helps individuals to work together in groups (Kalwell, Beckhardt et al. 1988). Groupware can, to some extent, support all four facets of knowledge transformation in Nonaka's Model (Nonaka 1994). To examine the role of groupware in socialization, the review focuses on the important aspect of shared experiences.

Shared experiences are an important basis for the formation and sharing of tacit knowledge. Groupware provides a synthetic environment, known as a virtual space, within which participants can share certain kinds of experience, e.g. they can conduct meetings, have discussions and share documents. Groupware might be thought to mainly facilitate the combination process; however, the selection and discussion of the explicit knowledge to some degree constitutes a shared experience (Nunamaker, Dennis et al. 1991). Examples of groupware include Lotus Notes (Mohan 1999). Most groupware applications can be tailored for more specific purposes within groups. When a groupware application is used for knowledge-sharing, it becomes a VKSE. This will be described in 2.4.3.3.

2.3.1.2. Expertise Location

Another approach to tacit knowledge-sharing is for a system to find people with common interests. Expertise location systems have the goal of suggesting the names of persons who have knowledge in a particular area (McDonald and Ackerman 1998). The state of the art techniques include the use of: explicit profiles, evidence mined from existing resources, and evidence inferred from association of persons and documents for expertise matching in the expertise location systems. Applications of expertise location systems include: Lotus Discovery Server (Copeland 2001), Expertise locator (Kautz, Selman et al. 1996), Expert Finder (Mattox, Maybury et al. 1999) and Expertise Finder (Vivacque and Lieberman 2000).

2.3.2. Externalization Approaches

According to Nonaka (1994), the conversion of tacit to explicit knowledge (externalisation) involves the forming of a shared mental model, then articulating it through a dialogue. Online discussion and brainstorming applications can support this kind of interaction to some extent.

2.3.2.1. Online Discussion Knowledge Base

An on-line discussion knowledge base is a tool to capture tacit knowledge and to apply it to immediate problems. To be most effective for externalisation, the discussion should allow the formulation and sharing of metaphors and analogies, which probably requires a fairly informal and even freewheeling style. This style is more likely to be found in chat and other real-time interactions within groups. Newsgroups and discussion forums have been implemented in support of questions-and-answers in various kinds of online groups and communities for knowledge externalisation, examples include Indiana University’s Knowledge Base (Hewitt 1998).

2.3.2.2. Electronic Group Brainstorming

Brainstorming is a way of developing many creative solutions to a problem. It works by focusing on a problem, and then coming up with very many radical solutions to it (Hymes and Olson 1992). Ideas should deliberately be as broad and odd as possible, and should be developed as fast as possible. Group brainstorming applications form a class of computer software for electronic brainstorming in groups. Various creativity techniques are used in these applications include: visual outlining, textual outlining, idea mapping, mind mapping, concept mapping, storyboarding and diagrams (Aiken, Krosp et al. 1994). Electronic brainstorming has been used successfully in the context of knowledge-sharing in some previous studies (Gallupe and Cooper 1993; Neveitt 2000). Notable examples of brainstorming applications include ECCO (http://www.compusol.org/ecco/index.html) and MindMapper (Shneiderman 2000).

2.3.3. Combination Approaches

The phase of knowledge transformation best supported by IT is combination, because it deals only with explicit knowledge. Digital library technologies have been intensively implemented to support this process.

2.3.3.1. Metadata and Portals

Metadata is known as data about data. It is largely used for knowledge modelling, in order to bridge the gap between the acquisition of knowledge and its use. Metadata technologies involve [i] technologies for inferring metadata from content and [ii] technologies for translating metadata and processing metadata. A number of metadata standards were developed for interoperability in data exchange, including

[i] XML (Bray, Paoli et al. 2000),

[ii] MARC (Furrie 2003),

[iii] Dublin Core (Weibel, Kunze et al. 1999), and

[iv] Z39.50 (Lynch 1991).

On the Web, RDF (Resource Description Framework) provides interoperability for web resource exchange and processing (Lassila and Swick 1999).

Portals provide an environment or single interface that can facilitate users to access all the necessary information easily (Collins 2001). Portals maintain their own metadata about the information to which they give access. The metadata can be used to build selected views of the information space, such as a list of the documents in a given subject category, or mentioning a geographic location. This makes exploration of the information easier and more rewarding, which may in turn facilitate the internalisation process. Applications of portals include:

[i] Stanford InfoBus (Paepcke, Baldonado et al. 1999) and

[ii] ServiceWare Knowledge Portal (Hejazi 2004).

2.3.3.2. Search

The most important technology for the manipulation of explicit knowledge is that which helps people to find the information they need. Search technologies aim to solve the problems of information overload and the diversity of sources from which the explicit knowledge is available (Salton and McGill 1986). A central search index is used for most systems, while the recent developments in peer-to-peer applications, such as Gnutella (http://gnutella.wego.com) and Groove (http://www.groove), have promoted interests in distributed search.

Search recall and precision are the two most commonly used criteria for the effectiveness of search techniques (Salton and McGill 1986). Search recall is a measure of the completeness of the search result. To improve search recall, techniques such as controlled vocabulary (Lewis and Jones 1996) are used. Search precision is a measure of accuracy of the search result. Results from TREC (Text REtrieval Conference) (Voorhees and Harman 2000) indicated that the accuracy of natural language search engine technology has reached a plateau in recent years. Therefore, two areas of techniques were identified for improving search precision: [i] increased knowledge of the user and of the context of his or her information need, e.g. user profile and collaborative filtering, and [ii] improved knowledge of the domain being searched, e.g. use of ontology.

2.3.3.3. Taxonomies and Classification

Knowledge of a domain can also be encoded as a "knowledge map" or "taxonomy", i.e., a hierarchically organized set of categories (Roesler and Mclellan 1995). The value of a taxonomy includes: [i] it allows a user to navigate to documents of interest without doing a search, and [ii] it allows documents to be put in a context, which helps user assess their applicability to the task in hand. The most familiar example of use of a taxonomy is Yahoo.

Techniques of automatic classification, such as document clustering, are used in building taxonomies (Yang and Liu 1999). One of the challenges for automatic classification is the design of the taxonomy, which has to be comprehensible to the users and has to cover the domain of interest in enough detail to be useful. Currently, human input is needed in the design process. There is an increasing focus on the need to map from one taxonomy to another, in order to provide a bridge between the terms/categories used by different groups. Some of the current research on ontology language also is trying to address this issue.

2.3.3.4. Summarization

The value of a summary is that it allows users to avoid reading the whole document if it is found to be not relevant to their current tasks or interest. Commercially available summarizers use the sentence-selection method, originated by Luhn (Luhn 1958). This method constructs an indicative summary from what are judged to be the most salient sentences in a document. Construction of coherent summaries using natural language generation is limited to a specific subject domain; for example, basketball games (Robin and McKeown 1993). Summarization of long documents containing several topics is improved by topic segmentation (Boguraev and Neff 2000). Whereas summarization of multiple documents, either about the same event (Radev and McKeown 1998) or in an unconstrained set of domains (Ando, Boguraev et al. 2000) remains a challenge.

2.3.4. Internalization Approaches

Technology to help users form new tacit knowledge is a challenge and it is of particular importance in knowledge-sharing. Only one group of approaches can be identified to support internalisation, information visualization technologies.

2.3.4.1. Information Visualization

V   isualization of a large collection of documents has been used to make subject-based browsing and navigation easier. An example of such a technique is text-based category trees. The two approaches in information visualization include:

[i] the graphical approach, such as Themescape (Wise, Thomas et al. 1995) and VisualNet (http://www.map.net), and

[ii] the ontology approach, such as the "Cat-a-Cone" system (Hearst and Karadi 1997) that allows visualization of documents in a large taxonomy or ontology.

Other visualization experiments have attempted to provide a user with some insight into which query terms occur in the documents within a results list. Examples include TileBars (Hearst 1995). A later study (Sebrechts 1999), compared text, two-dimensional, and pseudo three-dimensional interfaces for information retrieval. It found that the richer interfaces provided no advantage in the search tasks that were studied. This result may explain why graphical visualization has not been widely adopted in search applications. A more promising application of visualization is to help a user understand the relationships between concepts quickly. For example, the Lexical Navigation system (Cooper and Byrd 1997) for visualizing concepts in a set of documents or the use of hyperlinks to present relationships between documents (Ben-Shaul, Herscovici et al. 1999).

2.3.5. Summary

Selected technologies that contribute to knowledge-sharing solutions have been reviewed using Nonaka's model (Nonaka 1994) of organizational learning as a framework. The extent to which knowledge transformation within and between tacit and explicit forms can be supported by these technologies has been discussed. The individual technologies are not in themselves knowledge-sharing solutions. Instead, they are typically embedded in a smaller number of “solutions packages”, each of which is designed to be adaptable to solve a range of problems.

The strongest contribution to current solutions is made by technologies that deal largely with explicit knowledge, such as search and classification. Contributions to the formation and communication of tacit knowledge remain weak.

2.4. Online Communities and VKSEs

This section reviews an emerging approach for knowledge-sharing – online communities and VKSEs. A framework will be used to analyse the key dimensions for online knowledge-sharing communities. A review of the different categories of VKSEs is also presented in this section.

2.4.1. Online Communities for Knowledge Sharing

There has been increasing interests in the practice of knowledge-sharing in communities (Davenport and Prusak 1998; Alavi and Leidner 1999; Hansen, Nohria et al. 1999; Zack 2000). A community can be seen as a group where individuals come together based on an obligation to one another or as a group where individuals come together for a shared purpose (Seely and Duguid 1991). Gusfield (Gusfield 1975) distinguished two kinds of communities: geographic communities and relational communities. Most of the online communities fall under the definition of relational community since their members are not physically bound together (Wellman and Gulia 1999). Preece (Preece 2000) noted that an online community consists of four components: people, a shared purpose, policies, and computer systems. Regarding an online community as a class of group, Jones (Jones 1997) suggested a minimum set of conditions for being an online community: interactivity, communicators, sustained membership and virtual space. Common keywords such as people, interaction, virtual environment and shared goals are found in these characterizations of online communities.

The idea that networks of computers might provide a medium within which individuals might come together to share knowledge dates back to at least 1960s (Ramo 1961). Although almost all online communities involve some knowledge-sharing among the members, sharing knowledge has been realized as the predominate interaction in an online knowledge-sharing community (Erickson and Laff 2001). Some of the examples of such online communities can be found in DesignCircle (O'Day, Bobrow et al. 1996), Educational professionals (Schlager, Fusco et al. 1998) and Dilto (Schlager, Fusco et al. 2002).

2.4.2. Key Dimensions for Online Knowledge Sharing Communities

To understand knowledge-sharing and its relationship with the social and human factors in online communities, a framework has been proposed (Figure 2.1). It has been adapted from the framework of cooperation work (Andriessen 2003) and the model for computer mediated interactions (Riva and Garlimberti 1998).

The framework developed by Andriessen (2003) described cooperation work and the influencing factors on virtual cooperation from the perspective of context, process and outcome of virtual cooperation. The model proposed by Riva and Garlimberti (1998) described motivation and outcome of computer mediated interactions at the levels of: individual, group and organizational. Since online knowledge-sharing shares many similar elements with virtual cooperation, and it also involves a lot of computer mediated interactions, the two frameworks described above were combined to form a framework of knowledge-sharing in online communities.

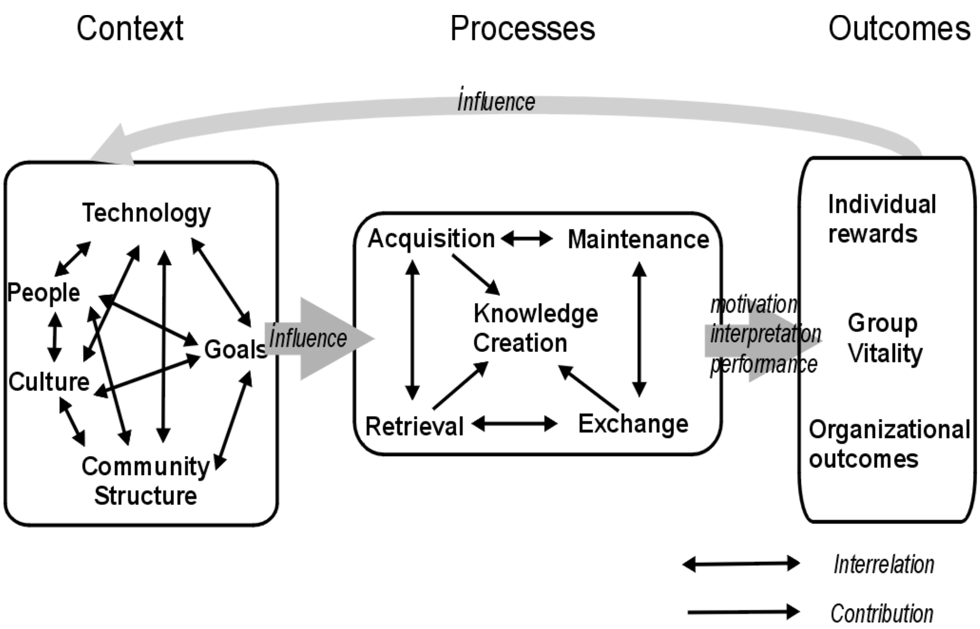


Figure 2.1 A Framework of Knowledge-sharing in Online Communities

As illustrated in figure 2.1, this framework describes knowledge-sharing in online communities in terms of context, processes and outcomes of knowledge-sharing. Elements of the context, which form the 'community background' (Andriessen 2003) for knowledge sharing, are related to each other (small black arrows). All the knowledge sharing processes taking place in a VKSE are inter-related (small black arrows). Characteristics of the elements in the context can influence the knowledge sharing processes (grey arrow) (Andriessen 2003). The outcomes of the knowledge-sharing are a result of interpretation, motivation and performance of the knowledge sharing processes (grey arrow), and they are in three levels (Riva and Garlimberti 1998). The outcomes of knowledge sharing can also influence back to the elements of the context (Andriessen). Details of the elements in the context, processes and outcomes of knowledge sharing in online communities are described below.

2.4.2.1. Context for Knowledge-sharing

In the literature, the following aspects have been mentioned as influencing factors on the success of online knowledge-sharing communities: the media and facilities for interaction (Kock and Davison 2003), the recipient's learning predisposition (Argote 1999), the provider's knowledge-sharing capability (Ahmadabadi, Asadpour et al. 2001), the relationship between the provider and the recipient (Sharratt and Usoro 2003), the culture (Skyrme 2002) in which the sharing occurs. These issues are all considered as related to the context for knowledge-sharing, e.g. tools and media, characteristics of people (knowledge providers and recipients) and their relationship and the cultural issues. Based on the above studies, together with the studies of online communities (Jones 1997; Preece 2000), five aspects of the context for knowledge-sharing in online communities are summarized below:

- IT facilities, which provide the basic tools and media for the online interactions.
- People in the online community and their characteristics. Members of a community may play various roles in the community and have different views on the knowledge-sharing activities.
- Goals of the online community. Knowledge-sharing is the main purpose for this kind of online community. Characteristics of the tasks and/or

subjects associated to the goal may influence the knowledge-sharing interactions.

- Community structure, which influences the relationships among the members and the way they interact with each other.
- Knowledge-sharing culture, which influences the norms of knowledge-sharing in the online community.

The "context-of use" can influence the processes that take place in the social system. Systems theory states that the "context-of-use" characteristics inter-relate with each other (Luhmann 1995).

2.4.2.2. Processes for Knowledge-sharing

According to the systems theory, the processes in a system are influenced by their input (i.e. elements in the "context-of-use") and also by the output of the processes as part of the feedback loop (Luhmann 1995). The processes of knowledge-sharing have been discussed in a number of studies (Nonaka and Takeuchi 1995; Andrews and Delahaye 2000; Huysman and Wit 2003; Shadbolt and O'Hara 2003). The processes are also referred to as "the dynamics of knowledge-sharing" (Nonaka and Takeuchi 1995), "phases for knowledge-sharing" (Andrews and Delahaye 2000) or "lifecycle of knowledge" (Huysman and Wit 2003).

Five knowledge-sharing processes are summarized below, based on the literature. These processes are: knowledge acquisition, knowledge maintenance, knowledge retrieval, knowledge exchange and knowledge creation. Viewing the processes within a social system, the social construction of knowledge theory (see 2.2.3.2) is used to explain these processes. All of these knowledge-sharing processes can take place in a VKSE.

2.4.2.2.1. Knowledge Acquisition

During the process of knowledge acquisition, knowledge resources are acquired from outside the community and published within the community. It may involve making tacit knowledge explicit, identifying gaps in the knowledge already held, and acquiring and integrating knowledge from multiple sources (Shadbolt and O'Hara 2003).

2.4.2.2.2. Knowledge Maintenance

Knowledge maintenance is the process of keeping the shared knowledge repository functional in an online community. Knowledge maintenance also involves the regular updating of content as content changes (Shadbolt and O'Hara 2003). In addition, knowledge maintenance may also involve a deeper analysis of the knowledge content, and verifying and validating the content. Knowledge maintenance cannot be viewed as an add-on to knowledge acquisition, it should be understood and planned together with other knowledge-sharing processes (Menzies 1998).

2.4.2.2.3. Knowledge Exchange

Knowledge exchange is the process of knowledge-sharing from one individual to other individuals in an online community (Berliant 2000). The knowledge can be either tacit or explicit. During this process, individual learns from other individuals. Knowledge exchange in online communities involves online person-to-person communications and interactions via ICT facilities, such as videoconferences, discussion forums and so on.

2.4.2.2.4. Knowledge Retrieval

Knowledge retrieval is the process of knowledge-sharing from the community to the individuals, e.g. to find a particular piece of knowledge resource in a knowledge repository. The knowledge retrieved in this process is mostly explicit knowledge. During knowledge retrieval the individual learns from the community. Knowledge retrieval in online communities involves: finding knowledge again once it has been shared, as well as understanding the structure of the archive in order to navigate through it efficiently (Shadbolt and O'Hara 2003).

2.4.2.2.5. Knowledge Creation

Knowledge creation is a process of internal learning by combining existing individual, or shared knowledge (Huysman and Wit 2003) to generate new knowledge, either individually or on the community level. It is heavily dependent on the other four knowledge-sharing processes. Knowledge creation has been seen as the most important process in online knowledge-sharing communities, as knowledge-sharing is characterized by creation of new knowledge and innovation.

2.4.2.2.6. Summary

The five knowledge-sharing processes in online communities reflect the three phases in the ‘social construction of knowledge’ (see 2.2.3.2): externalisation, objectification, and internalisation. Knowledge acquisition and exchange reflect the phase of externalisation, where knowledge is acquired by the individuals from outside the community or shared by the individuals in the community. Knowledge creation and maintenance reflect the phase of objectivity, as new knowledge is created, individual knowledge is shared as public knowledge and the knowledge resources are maintained for reuse in the community. In the process of knowledge retrieval and exchange, objectified knowledge is widely accepted and used by individuals.

2.4.2.3. Outcomes of Knowledge-sharing

The outcomes of knowledge-sharing in online communities are usually a result of interpretation, motivation and execution of the five knowledge-sharing processes described above. There are three types of the outcomes: individual rewards, group vitality and community outcome.

The first outcome is the individual rewards. Every individual in a knowledge-sharing community has his or her own goal(s) to be satisfied when participating in the knowledge-sharing activities. Previous research has revealed that the personal goals may include: personal knowledge management, publication, problem solving, and satisfaction of personal learning purposes (Polyani 1958; Harris 1996).

The second outcome of online knowledge-sharing communities is to establish relationships among the participants (Hendriks 1999). This can be realised through the networking of people and the sharing of knowledge resources in the community.

The third outcome of the knowledge-sharing processes is the community outcome. Much of a community's knowledge lies within its documents, discussions and conceptual models, and the context for the content, such as processes and the awareness by members of other members' expertise (Rice, Collins-Jarvis et al. 1999). Through the knowledge-sharing processes, a shared context for knowledge-sharing can be built by the community. Besides, community outcomes can also be in the form of organizational interventions.

2.4.2.4. Implications

Knowledge-sharing in online communities is a social system which involves the context, processes and outcomes of the system. The five aspects of the context for knowledge-sharing are inter-related with each other and form the community background for the VKSE. The five knowledge-sharing processes are also inter-related with each other. The effectiveness of knowledge-sharing depends on the quality of the five knowledge-sharing processes, which in turn depend on the extent to which the five aspects of the context support them.

2.4.3. VKSEs

This section describes five categories of VKSEs: Multi-user Object-oriented Domains (MOOs), mailing lists, shared spaces, collaborative recommender systems, collaborative learning systems and integrated systems. These are the representative technologies perused in the field of VKSEs.

2.4.3.1. Multi-user Object-oriented Domains

One kind of VKSEs is the Multi-user Object-oriented Domains (MOOs). MOOs were originally developed as multi-user text-based gaming environments in 1980s. They have been applied to educational and business knowledge-sharing context in later years. Representative knowledge-sharing communities supported by MOOs include MOOSE Crossing, an educationally oriented environment for children aged 8-13 (Bruckman 1997); Pueblo, a school-centred MOO in Phoenix, Arizona (O'Day, Bobrow et al. 1996); Tapped In, an environment supporting a distributed community of teachers (Schlager, Fusco et al. 1998; Schlager, Fusco et al. 2002); and a MUD (multi-user domain) used by employees at Argonne National Labs for work related discussion (Churchill 1999).

MOOs were one of the earliest forms of online knowledge-sharing communities. However, the text-based environment has its limitations in supporting the richness of various forms of digital knowledge resources. Therefore, MOOs are no more widely used as VKSEs.

2.4.3.2. Mailing Lists

Another kind of VKSEs is the electronic mailing lists, also known as email list management system. While mailing lists are used for a variety of purposes, the existence of mailing lists used to share knowledge via email among cohesive communities is well documented. In one case, a community of about a thousand professional journalists used a mailing list to help one another with technical problems and to find story-specific information sources (Millen and Dray 1999). Another example, the use of a mailing list to support discourse amongst a scholarly community, was described by Ekeblad (Ekeblad 1999). A similar example is Jiscmail which supports knowledge-sharing in research communities in the UK higher education and research (http://www.jiscmail.ac.uk). Mailing lists are widely used in online communities for their ease to use. However, these mailing lists can also cause information overload. Lack of synchronous communication has also identified as a limitation (Ekeblad 1999).

2.4.3.3. Shared Space Systems

Many groupware systems are under this category. Common functionalities include: [i] communication tools such as messaging, forums, and chat, [ii] content sharing tools, such as sharing of documents and contacts, and [iii] joint activity tools, such as joint web browsing, editing and group calendar tools. Notable examples of shared spaces include IBM Lotus Notes (Mohan 1999) and BSCW (Basic Support for Cooperative Work) (Richard, Bentley et al. 1997). A number of VKSEs have been implemented based on Lotus Notes, BSCW or other shared space systems within various organizational contexts, examples include: (Herzberg 1999; Brown 2000; Vincent 2000). IBM Lotus Notes and Groove workspace are described below as representative shared space systems.

IBM Lotus Notes

The IBM Lotus Notes (http://www.lotus.com/) is one of the most widely used shared space systems. Tools provided by Lotus Notes include: e-mail, instant messaging, discussion forums, and document and Web content management. Lotus Notes is built on an integrated document database management system. One of the techniques used in the Lotus Notes is called "replication", which let the users make reciprocal copies of the document databases in a peer-to-peer manner.

Groove

Groove (http://www.groove.net), is a leading peer-to-peer collaboration and knowledge-sharing application (Stanhope 2002). The basic online activities available in Groove are: chat, bulletin-board style discussion forums, file sharing, calendar, and sketching. Groove includes synchronization technology that stores data for intended recipients who are offline and later forwards that data when the recipients eventually re-connect. Groove users meet in virtual rooms called "spaces," and within these spaces all parties are free to work concurrently.

Groove is also an extensible system that some people called it a platform. It includes the Groove Development Kit – a separately downloadable package that includes documentation and examples for writing code that tie into existing Groove using XML for data exchange. To support near real-time communications, Groove transmits a package (called a delta) representing very low-level user actions such as keystrokes or brush strokes. Groove can also function inside corporate firewalls or other environments that use Network Address Translation (NAT). To do this, the platform relies on dedicated relay servers that act as an intermediary or proxy devices.

2.4.3.4. Collaborative Recommender Systems

Collaborative recommender systems, also known as collaborative filters (Glance, Arregui et al. 1997), have emerged recently. These systems filter information based on community members' rating or comments, and recommend the information to users with similar interests. Examples of collaborative recommender systems include Knowledge Pump, which is a web-based shared bookmark and recommender system (Glance, Arregui et al. 1997); Jasper II, which is an agent based recommender system (Davies 2001); NewKnow (http://www.newknow.com), which classifies knowledge in categories and is able to create relationships between documents by analyzing users' consultations of these documents; and Coins (http://orgwis.gmd.of/projects/Coins), which recommends relevant web pages that have been rated by other users who read them recently. Knowledge Pump and JASPER II are introduced below as representative recommender systems.

Knowledge Pump

Knowledge Pump (Glance, Arregui et al. 1997) is a web-based shared bookmark and recommender system developed in the XRCE lab. It aims to help communities to share knowledge more effectively and more efficiently by using community-centred collaborative filtering (Glance, Arregui et al. 1997). The Knowledge Pump is a web-based system. It allows users to submit recommendations of URLs, local files (via upload), or text. A recommendation consists of a rating and a comment, along with the user's classification of the item into one or more communities, which presented in the Knowledge Pump as folder-based document repositories. Each recommended item consists of a link to the item, the predicted score for the user, a list of the names of the users who reviewed it and links to their comments.

JASPER II

Jasper II, developed by British Telecommunications (http://www.labs.bt.com/projects/), is an agent-based recommender system which aims to encourage the interchange of tacit and explicit knowledge through communities of interest (Davies 2001). Main features of Jasper II include: community construction, document sharing, recommendation, and expertise matching.

2.4.3.5. Collaborative Learning Systems

This category of VKSEs enables students to learn in a process of knowledge-sharing. The units of knowledge shared in these systems include exercises, studies, tutorials and questions-and-answer. Examples of collaborative learning systems are: WISE (www.wise.berkeley.edu), which is a system for web based knowledge acquisition for grade 5-12 students. In addition to offering a space for the community of learners, it also supports to other types of user communities such as teachers interested in creating a common area for sharing ideas and references. Oxymoron is a Web-based knowledge “capitalization” and sharing tool (Haan, Chabre et al. 1999). There are other systems which focus on the support for students exchanging ideas. An example is the DEGREE system (Distance education Environment for Group Experiences). It allows users to swap ideas and contributions with a view to reaching agreements and thus jointly drafting a document. Oxymoron and WISE are introduced below as representative of collaborative learning systems.

Oxymoron

Oxymoron (http://sgwww.epfl.ch/uf/oxymoron) is a Web-based knowledge capitalization and sharing tool (Haan, Chabre et al. 1999). Oxymoron aimed to facilitate the work of students and researchers in social science by providing them with a system where they can contribute and obtain knowledge about the relevant reading in their fields of interests. The concept of reading card is central to the design of Oxymoron, it serves as the unit of knowledge resources shared in the community. The reading cards are mainly used to conceptualise knowledge and to exchange it between the users. Main features of the Oxymoron include: [i] a search engine, [ii] an annotation tool, and [iii] discussion forum and chat.

WISE

The Web-based Inquiry Science Environment (WISE: http://wise.berkely.edu), developed at the University of California, Berkeley, is a system for web based knowledge acquisition. Main features provided by WISE include: [i] WISE Resource Repository, which consists of a set of documents uploaded by an administrator for members the community to browse; and [ii] WISE Discussions, which provide the community members a means for learning from each other.

2.4.3.6. Integrated Systems

This category of VKSEs integrated tools and features that belong to more than one of the categories above. Examples of integrated systems include: the social web cockpit (Grather and Prinz 2001), Microsoft SharePoint Portal (http://office.microsoft.com/en-gb/FX010909721033.aspx) and other portal systems. Below is a more detailed description of the social web cockpit.

Social Web Cockpit

The Social Web project (Grather and Prinz 2001) is a VKSE developed by the Basic Support for Cooperative Work (BSCW) (Bentley, Appelt et al. 1997) at GMD (http://bscw.gmd.de/). It aims to support knowledge-sharing in online communities by providing a combination of a shared workspace system, an awareness service, a collaborative recommendation service, a community vocabulary and a web browse front-end. BSCW shared workspace is used in the Social Web Cockpit. The awareness services provided by NESSIE in Social Web Cockpit can keep track of presence of other people in the community and the status of the shared web pages. The Concept Index service enables members to create their own vocabulary. Users can select a word or a phrase from a web page and link to the vocabulary adopted by their community.

2.5. Factors Affecting Sustainability

One of the critical factors determining an online community's sustainability is its members' motivation to actively participate in knowledge generation and sharing activities (Wenger 1998). There are two aspects of participation: supply and demand of knowledge. On the supply side, members of an online community can post knowledge resources, such as documents, location of expertise. On the demand side, members would be visiting the community, using online search tools, posting questions or requesting for information (Cross, Bogatti et al. 2001).

Earlier studies have found that [i] people often resist sharing their knowledge in a community of practice (Ciborra and Patriota 1998), [ii] many technical solutions for knowledge-sharing have suffered from a lack of participants (Snowdon and Grasso 2001; Brazelton and Gorry 2003), and [iii] the success of knowledge-sharing depends on the social and technological attributes of the community (Davies 2001). This section reviews issues related to the motivation for and barriers to members' participation in online knowledge-sharing communities.

2.5.1. Motivation for Participation

Motivation for knowledge-sharing in online communities can be affected by economic and non-economic reasons, self-interest or organizational interest

(Wasko and Faraj 2000). According to Wasko and Faraj (Wasko and Faraj 2000), the motivation for participation is non-economic. In online community knowledge-sharing, people do not act largely out of self-interest, but also out of a sense of fairness, public duty and concern for their community (Wasko and Faraj 2000). However, other studies (Hall 2001) have found that "free-ride" in communities (a phenomenon that users use the community resources without contributing to the community) can deter participation and would stop the growth of the sharing content in the community. Community members' loyalty to the community and trust to other members are of paramount importance to ensure the sustainability of the community. However, as the loyalty and trust are developed simultaneously with the evolution of the online community, if a free-ride strategy is adopted by most members at an early stage, it can be very difficult for knowledge-sharing to take place effectively (Hall 2001). Besides, the online community would never have the chance to build up a reasonable amount of content for sharing.

Other researchers (Constant, Kiesler et al. 1994; Jarvenpaa and Staples 2000) studied knowledge-sharing based on the social exchange theory (Kelley and Thibaut 1978). In this approach, motivation for participation is considered as economic and out of personal interests. It is based on the notion that people review and weigh their benefits for participation in terms of costs and rewards (West and Turner 2001). Costs are those elements in the knowledge-sharing that have negative value to a person and rewards are those that have positive value to a person. People will strive to minimize costs and maximize rewards. Some recent empirical studies contribute towards theorizing the approach (Chan, Bhandar et al. 2004). This study indicates that social recognition in online communities would promote participation in knowledge-sharing activities. Table 2.2 listed a summary of the studies on motivation in online knowledge-sharing communities.

Study	**Type of Community**	**Motivating factors leading to sustainable community**
Hall and Graham (Hall 2001)	Online community with the purpose of sharing information relating to a code-breaking competition.	Initial motivation was to discover information for personal benefit. Later on the network took on a more collaborative nature with members more willing to help one another.
Feng, Lazar and Preece (Feng, Lazar et al. 2003)	Network of practice based upon instant messaging between participants.	Communication between participants was partly determined by the degree to which discussions were empathetic and supportive. Responses that accurately inferred the content of participant's thoughts and feelings led to higher level of on-line trust.
Chan, Bhandar et al. (Chan, Bhandar et al. 2004)	Online community with the purpose of sharing information relating to textile development research.	Social recognition in the online community promoted participation in knowledge-sharing activities.
Breu and Hemingway (Bentley, Appelt et al. 1997)	Small online groups situated in a commercial company in the utility sector. Mostly involved face- to- face interaction with some communication via email.	Online community acted as a way of bringing members together partly due to a feeling that the company was failing to satisfy their needs for affiliation and interaction in general. Members felt motivated to take part in the CoP in order to provide better social cohesion in the organization.

Wasko and Faraj (Wasko and Faraj 2000)	Three Usenet Groups set up to discuss topics related to computer programming and databases.	Opportunity to engage in the exchange of ideas and problem solutions were the main reasons for taking part. Participation was seen as fun and providing an opportunity for dialogue and help for others. Members saw the community as a way of gaining respect and visibility.

Table 2.2 Summary of the Empirical Studies Examining Motivation in Online Knowledge-sharing Communities

2.5.2. Barriers for Knowledge Sharing

In the literature, barriers for participation or sharing have been discussed under two situations: public good dilemma and cooperation dilemma. These situations are further examined within the context of online communities.

In a "public good dilemma", a public good is a shared resource (e.g. a public park) from which each member of the community may benefit, regardless of whether he/she contributes to its provision (Olson 1965). Since access to a public good is not restricted to its contributors only, there is a temptation for individuals to adopt a "free-ride" strategy: to enjoy the resource without contributing to it (Sweeney 1973). This 'free-ride' strategy is considered as a dominant strategy (Dawes 1980) that yields immediate positive return at any time within the community, regardless of which actions other participants may take. The current use of the World-Wide-Web is an example of this dominant strategy. However, the 'free-ride' strategy at an aggregate level can cause a situation called 'social fence' (Messick and Brewer 1983), which means that for each individual is worse off if all individuals avoid contribution than if they had managed to 'scale the fence' (Messick and Grewer 1983). In the special case of a 'closed' knowledge-sharing community, this social fence might be reached quicker than an open environment like the Web. This is a barrier for knowledge-sharing as the contribution of knowledge-sharing resources would be very limited.

Knowledge-sharing may also be conceptualised as a special example of a 'co-operation dilemma' (Connolly and Thorn 1990). In this case, individuals' rational actions for maximizing their pay-off lead to 'collective irrationality' (Kollock 1998). As every individual is expected to maximize his/her pay-off in knowledge-sharing, this 'co-operation dilemma' in knowledge-sharing can result in [i] participants expecting to be rewarded for their contribution (of knowledge, time, efforts and so on) in the knowledge-sharing interactions; and [ii] participants tending to be reluctant to share with other community members knowledge which they consider would/will not get enough in return for sharing it (Cabrera and Cabrera 2002). To take part in knowledge-sharing, each member would consider his/her expectations, and the potential benefits before deciding whether to participate or not.

2.6. Summary

This chapter has reviewed the concepts, approaches and issues in knowledge-sharing. From the literature review, four issues have been identified that are relevant to the design and development of VKSEs for sustainable knowledge-sharing in online research communities:

[i] knowledge-sharing in online communities is not just an information problem. It is also a social problem that involves people, their relationships, and the social context. This view raises a considerable challenge for the design of VKSEs;

[ii] Various technologies have been applied in supporting knowledge-sharing, though most of these technologies only address the sharing of explicit knowledge;

[iii] As an emerging approach to online knowledge-sharing, online communities and supporting VKSEs have been developed which focused on people meeting each other online and sharing of tacit knowledge; and

[iv] Further understanding of the factors affecting knowledge-sharing is needed. Sustainability of knowledge-sharing is an interdisciplinary issue that needs integration with cross-disciplinary research.

Chapter 3 Problems and Requirements Analysis

3.1. Introduction

Drawing from the literature on the issues relating to online knowledge-sharing, this chapter investigates further issues and special requirements for online research communities and the VKSEs which support them. This is achieved by [i] articulating the characteristics of research communities from related literature, [ii] identifying useful features of VKSEs and any outstanding problems by an assessment of some representative VKSEs, and [iii] an in-depth analysis of user feedback on their experience in using an in-house VKSE - the Virtual Knowledge Park (VKP). Based on these studies, requirements on VKSEs to support sustainable knowledge-sharing in online research communities are summarized.

3.2. Research Communities

The purpose of this section is to provide further understanding of knowledge-sharing in research communities. Research communities have been characterized as invisible colleges formed to monitor and manage the changing structure of knowledge in their domain (Crane 1972). In an increasingly networked world it is advantageous for researchers to be able to share their knowledge at a distance (Landow and Delany 1993).

3.2.1. Driving Forces for Knowledge Sharing

As modern academic research continues its exponential growth in complexity and scope, the need for knowledge-sharing among researchers at different institutions and across disciplines is becoming increasingly important (Kraut, Egido et al. 1988). Researchers working at one level of analysis may need to find and explore results from another level, from another part of the field, or from a completely different research field. There is a whole range of reasons that have driven researchers to knowledge-sharing and to the recognition of a need for knowledge-sharing support. Grouped together, these reasons are summarized as follows: [i] An enormous "information explosion" has resulted in a greater need for specialization and cooperation to put the pieces of knowledge and partial results back together (Kraut, Galegher et al. 1986); [ii] The need for knowledge-sharing between formerly non-related research domains to address more complex problem settings (Kraut, Egido et al. 1988); [iii] Self-interest to profit from others' experience, which also introduces the problems of hidden agendas and conflict of interests (Nylund 1989).

A common approach today is looking for information on the Web. However, researchers looking for results in sites developed for different research communities are often at a lost (Hendler 2003). For example, a scientist searching for a technique to analyse some image-based data may not know that Laplacean invariants (found under the symplectic geometry category in many math sites) is the technique that is needed. A general search on image analysis will find thousands of possibilities but will provide little or no guidance as to which sites can explain how to use the techniques, sites for instructors teaching the topics, or reports describing a case where the technique was used.

One of the solutions to the problem of information overload and the limitations of the current web search in research work are to build online research communities for knowledge-sharing. These online research communities are characterized by groups, with varied levels and types of expertise, interacting through technology mediated networks. In some cases, face-to-face communication can be involved as well (Garrett and Caldwell 2002). Research communities have their own characteristics that may influence the researchers' behaviour in knowledge-sharing.

3.2.2. Community Structure

Most researches on knowledge-sharing have focused on well-structured, and often hierarchical, organisations (Schmidt and Rodden 1994). However, current academic research environments reflect a much less organized and well-behaved situation, as pointed out by Schrage: "*Real scientific research… is an elaborate and inherently collaborative process through which the members of scientific subcultures alternately share information; exchange papers, tools, insights, and gossip; mingle at bars and airports; visit one another's laboratories; forge alliances; schmooze with their patrons; go to conferences; and publish their findings.* " (Schrage 1990). This observation is also supported by the findings of a number of researchers examining scientific research cooperation in the CSCW context (Kraut, Galegher et al. 1986; Kraut, Egido et al. 1990). It has been indicated that the organizational structure of research communities is by no means strictly hierarchical and involves "extensive social interaction" (Kraut, Egido et al. 1990).

In a research community, the participating groups and/or individuals often work autonomously in loosely coupled social networks. Knowledge-sharing in this context is often initiated through informal contacts. However, the dynamics and mechanisms of these informal exchanges were not investigated. One of the reasons may be due to the difficulties in modelling informal interactions.

Studies of the organizational structure of research communities indicate that: [i] online knowledge-sharing in research communities requires loosely connected knowledge-sharing networks; and [ii] the ability to extend the knowledge network is an important requirement (Kraut, Egido et al. 1988).

3.2.3. Co-opetition

The phenomenon that cooperation and competition may occur simultaneously is defined as co-opetition (Brandenburger and Nalebuff 1996). The way, in which researchers share knowledge, is influenced by this co-opetition situation. Modern research work is highly competitive despite the importance of cooperation (Pollard and Linger 2003). On one hand, examinations of patterns of authorship revealed that collaboration is increasing in many disciplines in academic research (Kraut, Egido et al. 1988). On the other hand, as the development of the professionlization of academic research increases and the mechanisms for competing for research funding develops, competition for academic research has increased (Pollard and Linger 2003).

Knowledge-sharing is a form of cooperation. However, the knowledge obtained via the cooperation may be used to compete with the knowledge suppliers. As a result, it has been discovered that most researchers assume that knowledge-sharing involves researchers of equal or comparable ranking (Schrage 1990). This peer-to-peer relationship allows disagreements to be solved through discussion, in which the social ranking of the participants does not have a large influence, as every participant can accept being proven wrong without facing the loss of reputation. In this context of equality, researchers are less likely to fall into the traps of egoism or pure competition.

In addition, Kraut's discovery from his empirical study on patterns and relationships in research cooperation indicated another dimension in a co-opetition situation: *"Despite that collaborators could frequently identify ownership of the initial idea, they also acknowledged that initial ideas usually underwent major transformations before work was done."* (Kraut 1990)

The co-opetition situation indicates that [i] academic researchers must cooperate with their computer science colleagues to find out appropriate mechanisms to prevent the problems of intellectual property policies and runaway patent madness that make dissemination of the knowledge resources impossible (Hendler 2003); [ii] the peer-to-peer relationship between participants in knowledge-sharing should be better supported; and

[iii] sense of control and ownership over the share knowledge resources needs to be considered in the design of VKSEs.

3.3. Assessment on Representative VKSEs

Eight representative VKSEs are assessed in this section. These systems are either widely recognized as knowledge-sharing solutions or have been pilot tested to facilitate knowledge-sharing in online research communities. Seven of these systems has been introduced in 2.4.3, the other one, the Virtual Knowledge Park, has been introduced in 1.2. The purposes of this assessment are: [i] to deduce generic functional requirements of VKSEs; and [ii] to identify problems and challenges in the evaluation and deployment of the VKSEs for further improvements. The representative VKSEs are assessed in two ways: [i] generic functionality requirements are analysed based on a comparison of the functionalities of the systems in supporting the knowledge-sharing processes identified in 2.4.2.2; and [ii] documented deployment of the systems are analysed against the characteristics of research communities to identify the problems and challenges facing the designer of VKSEs for research communities.

3.3.1. Functionalities of the VKSEs

Functionalities of eight representative VKSEs are analysed and compared in their support for five knowledge-sharing processes: knowledge acquisition, knowledge maintenance, knowledge exchange, knowledge retrieval and knowledge creation (as described in 2.4.2.2).

3.3.1.1. Knowledge Acquisition

The first aspect to analyse is the functions supporting knowledge acquisition. As described in 2.4.2.2.1, this is the process of acquiring the external knowledge for the online community. Most of the VKSEs allow users to share knowledge by acquiring external knowledge resources and publishing them in the community. There are two issues to be considered in knowledge acquisition:

[i] Restriction on knowledge publisher: some systems enable the publication of knowledge resources by any user in the community, while some systems only support knowledge publication by an organizer or an administrator.

[ii] Degree of sharing: some systems support different degrees of sharing, such as sharing a document within a specific group or person in the community. This is usually achieved by allowing users to set permission on the documents.

Features of the eight VKSEs for knowledge acquisition are compared in table 3.1.

	LN	**GRV**	**KP**	**JASP**	**OXY**	**WISE**	**SW**	**VKP**
Restriction on publisher	No	No	No	No	No	Yes, only by an administrator	No	No
Access Control	Yes,	Yes	No	No	No	No	Yes	Yes

Table 3.1 Comparison of Features for Knowledge Acquisition

Note:

LN: Lotus Notes
GRV: Groove
KP: Knowledge Pump
JASP: Jasper II
VKP: Virtual Knowledge Park
OXY: Oxymoron
WISE: Wise
SW: Social Web

(Same abbreviation used in the later tables in this section)

3.3.1.2. Knowledge Maintenance

The second aspect to analyse is the functions supporting knowledge maintenance. As described in 2.4.2.2.2, this is the process of keeping the shared knowledge repository accessible and up-to-date in the online community. The Knowledge repositories in VKSEs handle different types of knowledge units, such as web pages, emails, or documents in a specific format. These knowledge units are structured in the systems for easy location. Two approaches are used in the systems to structure the knowledge units: [i] reflecting the inherent structure of the topic, and [ii] hierarchical networks of nodes interconnected by relationships, which is according to the user groups. In addition, some VKSEs also provide document management functions such as awareness and version control. Table 3.2 compares the features for knowledge maintenance.

	LN	**GRV**	**KP**	**JASP**	**OXY**	**WISE**	**SW**	**VKP**
Can handle different knowledge unit	Documents in any format	Documents in any format	Documents in any format	Web pages	"Reading cards"	Documents in any format	Web pages	Documents in any format

Means to organize the content	Directories defined by the users	No basic structure	Folders defined by the users	No basic structure	No basic structure	Folders according to the course	Ontology defined in the concept index	Directories defined by the users
Awareness of update	Yes, monitoring the updates of the documents	No	No	No	No	No	Yes, monitoring changes of the WebPages	No
Version control	Yes	Yes	No	No	No	No	Yes	Yes

Table 3.2 Comparison of Functional Features for Knowledge Maintenance

3.3.1.3. Knowledge Exchange

The third aspect to analyse is the functionalities supporting knowledge exchange. As described in 2.4.2.2.3, this is the process of passing knowledge from one individual to another, and vice versa, in the online community. The functions supporting knowledge exchange include [i] Asynchronous communication, such as discussion forums and email, [ii] Synchronous communication, such as instant messaging and real time chat, and [iii] Awareness of the presence of other users. Table 3.3 compares the features for knowledge exchange.

	LN	**GRV**	**KP**	**JASP**	**OXY**	**WISE**	**SW**	**VKP**
Allow users to give opinions on the content	No	Yes, notes for the documents	Yes, ratings and comments	Yes, comments in the annotations	Yes, comments in the reading cards	No	Yes, ratings	Yes, comments in annotations

Discussion forum	Yes	No	Yes	No	Yes	Yes	No	Yes
Instant messaging	Yes	Yes	Yes	No	No	No	No	No
Email	Yes	No	Yes	No	No	No	No	Yes
Presence awareness	Yes	Yes	No	No	No	No	Yes	Yes

Table 3.3 Comparison of Functional Features for Knowledge Exchange

3.3.1.4. Knowledge Retrieval

The fourth aspect to analyse is the functions supporting knowledge retrieval. As described in 2.4.2.2.4, this is the process of retrieving the existing community knowledge. Support for knowledge retrieval is mainly needed to enable the knowledge transfer between the community and the individual. It is closely related to the knowledge maintenance process. All VKSEs enable users to localize the knowledge they require, knowledge retrieval can be accomplished by: [i] providing users with categorized knowledge units for browsing, [ii] responding to users' search request, or [iii] making recommendations according to some pre-defined recommendation mechanisms. Table 3.4 compares the features for knowledge retrieval.

	LN	**GRV**	**KP**	**JASP**	**OXY**	**WISE**	**SW**	**VKP**
Browsing under categories	Yes, under directories defined by the users	No	Yes, under the folders built by the users	No	No	Yes, under the folders according to the courses	Yes, using the concept index	Yes, under categories defined in the REPIS database

Search	Yes, using the Lotus Domino server	Yes, keyword search in the knowledge repository	Yes, keyword search in the knowledge repository	Yes, searching the metadata in the annotations	Yes, keyword search in an Informix database	No	Yes, keyword search on the Internet and in the local knowledge repository	Yes, keyword search in the knowledge repository
System recommend	No	No	Yes, via collaborative filtering	Yes, based on user profile matching	No	No	Yes, using NESSIE	No

Table 3.4 Comparison of Functional Features for Knowledge Retrieval

3.3.1.5. Knowledge Creation

The fifth aspect to analyse is the functionalities supporting knowledge creation. As described in 2.4.2.2.5, this is the process of internal learning by combining existing individual or shared knowledge. Facilitating knowledge creation requires the support of networks resembling the communities of practices described by researchers like Brown and Guguid (Brown, Guguid et al. 1989).

VKSEs have different kinds of users: the consumers of knowledge, the suppliers of knowledge, the administrator, whose role is to supervise contributions, and, finally, the experts. All these kinds of the users compose the knowledge-sharing community in the VKSE. Most systems support construction of knowledge-sharing communities, and different means are used, such as by making recommendations, during the process of creating a documents, or by using discussion forums. Some VKSEs support use of personal space, for users to complete different personal learning tasks, such as for editing and evaluating. Some systems consider the support for expertise identification as part of the community's knowledge, and they allow experts to be located within certain topics. Table 3.5 compares the features for knowledge creation.

	LN	GRV	KP	Jasp	OXY	WISE	SW	VKP
Personal space	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Formation of user communities	Formed around the projects in the workspaces	Formed around the projects in the workspaces	Community might be formed by people choosing 'advisors'	Formed through the formation of groups and recommen-dation in the groups	Formed under the interesting groups	Formed under the courses delivered	Formed through the recommen-dation of Webpage	Formed around the projects in the workspaces
Existence of expert figures	No	No	Yes, by matching user profile	No	Yes, by matching user profile	Yes, the adminis-trator is considered as the expert	Yes, expertise matching services	Yes, by expertise matching services

Table 3.5 Comparison of Functional Features for Knowledge Creation

3.3.1.6. Summary

The eight representative VKSEs reviewed in this section support the five knowledge-sharing processes to some extent, although some are better than the others. As discussed in 2.4.2.2, the five knowledge-sharing processes are inter-related. In particular, knowledge creation is heavily dependent on the other four processes. Therefore, the five aspects of functionalities should be viewed as related to each other as well. In summary, a VKSE needs to support the five knowledge-sharing processes in an online community.

3.3.2. Problems and Requirements

This section reviews the documented deployment of six representative VKSEs in the context of supporting knowledge-sharing in research communities. Problems identified from this review are discussed against [i] the characteristics of online knowledge-sharing research communities (described in 3.2), and [ii] the factors affecting sustainability of online communities (discussed in 2.5). Besides, further requirements on VKSEs for sustainable online research communities are discussed.

Issues relating to the remaining two VKSEs (i.e. VKP and Groove) will be discussed in greater detail in later chapters as these two were chosen as a representative of centralized and decentralized approaches respectively.

3.3.2.1. Issues Raised From the Deployment of Six VKSEs

The review of the deployment of the representative VKSEs from the literature reveals that low user participation in online communities is a key problem facing the designers of VKSEs. Sustainability of these online communities has been identified as a major challenge. These studies concluded with either an analysis of the reasons for the low user participation in the online knowledge-sharing or a discussion on how to improve the design to encourage user participation. These are summarized in table 3.6.

VKSE and the Community	**Problems and Reasons**
Lotus Notes Two research communities, one consisted of postgraduate students, one consisted of academic researchers and financial professionals (Geib 2002)	The level of use of the Lotus Notes for knowledge-sharing was not as high as expected. Two reasons have been identified for the ‘failure’: Existing power base was threatened: possession of information was seen by some community members as possession of power, so they did not want to share them with the others Disparity in Benefit: Individuals got no benefit from sharing information, only risks if information was misinterpreted.

Knowledge Pump A community of researchers in the XRCE laboratory (Snowdon and Grasso 2001)	The majority of Knowledge Pump users do not use it. Two reasons were found from the empirical study: Easy to abandon use: The effort required to prevent people from using the system is very low, i.e. little things can stop people from using the system. Lack of motivation for investment of effort: Users did not feel that they would get anything in return for their effort.
Jasper II A community of researchers in the University of Greenwich and the BT Laboratory (Davies 2001)	Lacking of participation was noticed, the cause of it was concluded as: Non-technical issues: The main barrier to sharing more knowledge was the need to be selective: most respondents indicated they were concerned about adding too many items or overloading others. Functional deficiencies: Lack of functions for online interaction among the community members, such as chat or discussion.
Oxymoron A community of researchers at two institutes of health care. (Haan, Chabre et al. 1999)	Oxymoron was not systematically used by the users. Possible reasons include: Psychological berries: Users were used to the traditional face-to-face interactions, and were reluctant to use the system. Functional deficiencies: It lacked the means to manage and organize the shared reading cards, so they were not searchable by other community members.
WISE A community of lecturers in the biological science department in UC Berkeley (Cuthbert, Clark et al. 2002)	The real use of the system was very low. Restriction: The resource repository in WISE could only be uploaded and updated by the administrators. The central control largely restricted the activity of contribution from the community members. Functional deficiencies: The discussion facility was the main means for knowledge-sharing in the communities.

Social Web Cockpit A small community of researchers in the GMD lab (Grather and Prinz 2001)	User participation in knowledge-sharing using the system was identified as crucial to realize the attraction of the combination of the services provided by the cockpit.

Table 3.6 Summary of the Documented Deployment of Six VKSEs

3.3.2.2. Requirements Emerged from the Studies

Four requirements for a VKSE for sustainable online knowledge-sharing in research communities have been articulated based on the analysis summarized above. They are discussed below.

The first requirement is that suitable motivating mechanisms to help the users to realize the benefit for their participation and contribution are needed. Fear of disparity in benefit (Geib 2002) and unwillingness for investing time and effort (Snowdon and Grasso 2001) have been identified as barriers for user participation and contribution. Underneath these problems is the "cooperation dilemma" in knowledge-sharing (as described in 2.5) that people expect to maximum the pay-offs for their investment in knowledge-sharing, such as time and effort.

The second requirement is to provide the users with better control in their knowledge-sharing interactions. It has been identified that the fear of losing power (Geib, 2002) and the uneasiness on the restrictions on when and with whom to share their documents (Cuthbert, Clark et al. 2002) were hindering participation. The "co-opetition" situation in research communities (as described in 3.2) can explain these behaviours. On one hand researchers know they ought to share knowledge with others. But on the other hand they have concerns of losing their control and ownership of the knowledge they share, and hence losing competitiveness.

The third requirement is providing means to overcome the "psychological and social barriers" of using the technologies. These were indicated in almost all of the above studies as a reason for low participation. The "change of people's behaviour" was identified as very difficult (Haan, Chabre et al. 1999). A limitation must be stated at this point that in many respects, the state of the art is such that many of the social aspects of work important in knowledge-sharing cannot currently be addressed by technology. This situation is referred to as a "social technical gap" (Ackerman 1998). This thesis is not going to address this situation. The emphasis will be on those requirements that are possible to be addressed by technology.

Finally, it is required that a VKSE needs to satisfy the functional requirements described in 3.3.1. It has been identified that the functional deficiencies in a system also can discourage the users of the system and consequently (Davies 2001; Haan, Chabre et al. 1999; Cuthbert, Clark et al. 2002), this affects their participation in online knowledge-sharing.

3.4. An Empirical Study – User Feedback on the VKP

This section presents an empirical study on the Leeds Virtual Knowledge Park (VKP). Users' feedback on the problems they experienced and their requirements on the system for sustainable knowledge-sharing are articulated and discussed in this section.

3.4.1. History of the VKP

As illustrated in Figure 3.1, the VKP was an integration and re-development from two knowledge-sharing/management systems previously used in the University of Leeds: the Virtual Science Park (VSP) and the Research Expertise and Publication Information System (REPIS). Key features of the two systems were integrated into a pilot system: KiMERA. After the trial, the VKP was rolled out within the university.

An initial evaluation of the functional feasibility of VKP was conducted in a study in 2002 (Lau, Adams et al. 2003). The VKP pilot software – KiMERA was tested by 34 MSc students for four months using a scenario-based approach. The outcomes of the study were used to refine the functionalities of the VKP and to identify training/user support required when the system went into production usage.

This empirical study was conducted about one year after the deployment of the VKP in the University of Leeds. At this stage, some online research communities were being formed. Hence, suitable users who had used the system for a relatively long time could be involved in the study to provide their insights and experience with the system. The focus of this study was issues related to sustainability of their online knowledge-sharing communities.

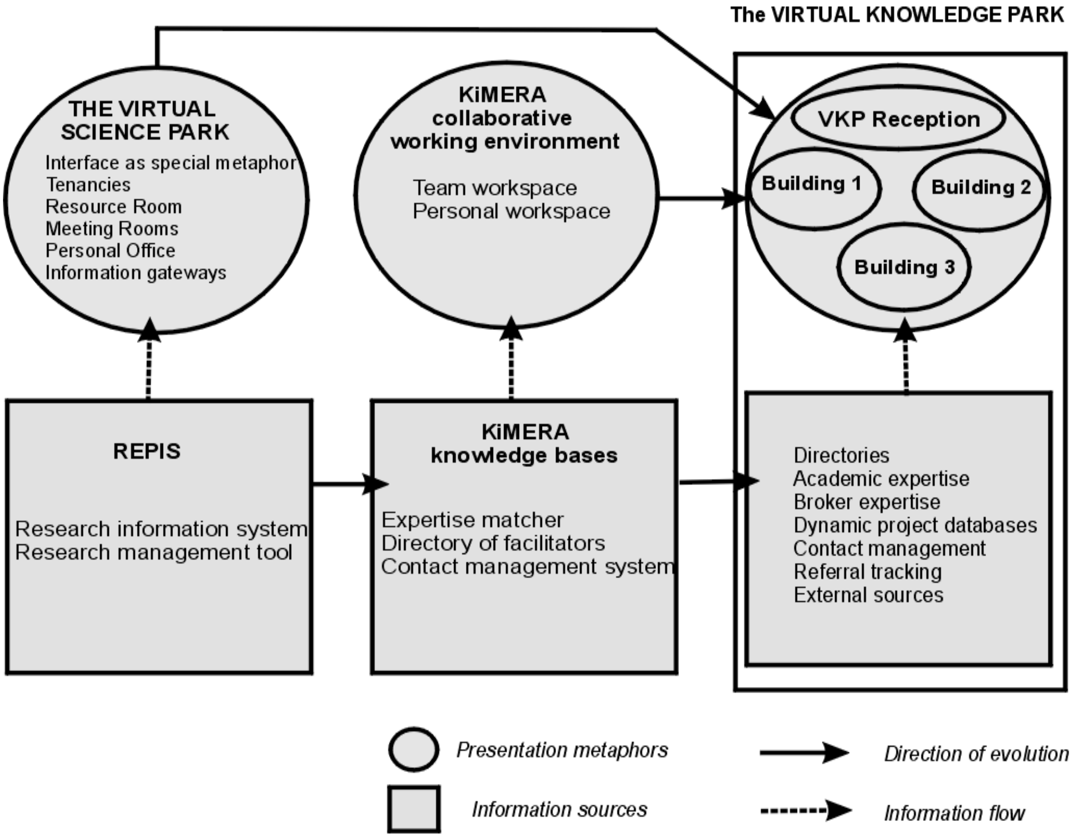


Figure 3.1 Integration and Development of the VKP

3.4.2. Method

Seventeen of the VKP users, who had played different roles in their groups/communities within the VKP (e.g. leader, expert, administrative manager or group member), were chosen as subjects for the study. The study was conducted via semi-structured interviews. It was designed in accordance with the principles of qualitative methodology for survey studies (Babbie 1990). The users of the VKP were asked to tell their stories of the difficulties or problems on using the VKP in their experience. The instruments of the survey were developed based on relevant literature, the results of prior interviews and discussions with the VKP support team members. The narrative data taped from the interviews were analysed using content analysis (Krippendorff 1980).

The first step in this content analysis was to determine the key words/phrases within the transcript of the taped interviews. Taking into consideration the context of the discussion, the author jotted down the important words and phrases that captured the essence of the issues. This initial list of key words/phrases was then categorised into higher level themes (Krippendorff 1980). This process of coding was basically one of selective reduction, by reducing the text to categories consisting of a word, set of words or phrases (Krippendorff 1980). After the list of keywords was established, the author went through the transcript again to count the number of occurrence (i.e. frequency) of these words' presence in the interviews.

3.4.3. User Feedback

A total of 44 stories were collected from the 17 interviewees. Nineteen issues were identified and seven of them were reported by 50% of the users or more (see Appendix A for the details). These seven issues were then further grouped into three categories: flexibility, user autonomy and culture issues to form the framework for investigation. 76% of the users raised flexibility and user autonomy as important issues in their experience with the VKP. 53% of the users raised the cultural issues. The rest of this sub-section describes the results of the study.

3.4.3.1. Flexibility

Flexibility could exist in different forms in an online community. At the most basic level it means online interactions at different levels and in different types; at a higher level it means the social networking in the community in various ways. The flexibility issue was identified from the user feedback as an important requirement to encourage their participation in the online knowledge-sharing activities. The issue was reported in connection with: [i] supporting knowledge-sharing interaction at different organizational levels, [ii] supporting knowledge-sharing in various situations, both formal and informal, and [iii] promoting opportunities for knowledge-sharing in the knowledge network.

Users of the VKP expected to interact at different organizational levels, such as one-to-one interactions, research group level interactions or community level interactions, as commented:

"One of the main reasons for us to choose the VKP rather than Yahoo Group to build our research community was its multi-level workspace – we expected to involve some external contacts, such as funding bodies, into our community…Obviously, we needed means to separate the documents shared within our research group and with the public…"

In addition, many VKP users also reported expectations on using the VKP in formal situations, such as online meetings or exchange of research documents, as well as information knowledge sharing interactions, such as chat or organized social event. In these informal situations, people could meet each other online and exchange some ideas. This requirement is related to the loosely coupled social networks structure of research communities, as described in 3.2.2. Example comments include:

"I would expect VKP to provide more tools for community events to take place so that it really serves as a platform for our community, not only as a document management system…"

Finally, the third aspect of flexibility in online knowledge sharing reported by the VKP users is the requirement for extending their knowledge network in the community and getting more opportunities for sharing knowledge. This requirement is an extension of the above two aspects of flexibility.

3.4.3.2. User Autonomy

User autonomy was discovered as another area of requirement. Autonomy refers to the capability to act on the basis of one's own decisions and to be guided by one's own reasons, desires and goals (Friedman and Issenbaum 1996). In the context of online knowledge-sharing in the VKP, the requirement for user autonomy was reported in connection with: sense of control and sense of ownership over the shared knowledge resources.

3.4.3.2.1. Sense of Control

Sense of control includes the control of the knowledge resources, such as control of when and with whom to share a document, and the ability to trace the use of a document by other members in the community. The importance of this sense of control over the knowledge resources is shown in this comment on the VKP's document permission and awareness facilities:

"Yes, these functions definitely improved the security to share these data. However, my concern is that once these data have been uploaded for sharing, I have no control of other group members' use of them…the membership is controlled by our administrator. When I have the fear that there is any opportunity of misinterpreting or misuse of the data, I am not going to share them in the VKP… I would rather send the data on demand by email. "

The problem described here is that when a user feels a lack of control in the environment, s/he would rather use another means such as email than uploading the resources to the VKP.

Another aspect of sense of control is the control of the knowledge-sharing interactions. This issue is related to the capability and complexity of the VKSE. Sense of control can be undermined when the system does not provide the user with the necessary technological capability to realize his or her goals. In some instances, systems may provide the necessary capability, but the realization of the goals in effect becomes impossible because of its complexity. As revealed from the user feedback, functional deficiencies such as the limitations in the VKP search facilities and video conferencing, and the poor user interface influenced users in their decisions about which functionalities to use for knowledge sharing.

3.4.3.2.2. Sense of Ownership over the Share Resources

Sense of ownership over the shared resources is another issue of user autonomy identified from the user feedback. As defined by Ballantyne (2002), ownership is the "process where a local stakeholder takes responsibility for the design, implementation, and monitoring of an activity". The 'sense of ownership' is especially crucial to the sustainability of development activities (Ballantyne 2002). Although the concepts of ownership and control are quite similar, there is a subtle difference: the sense of control emphasises the sharing process of a piece of knowledge resource, whereas the sense of ownership emphasises the maintenance and management of the knowledge resources.

The importance of sense of ownership is reflecting in the comment below on VKP's personal space:

"I like the personal space in the VKP, and I suspect that I would find it more useful if I had a real personal space on my PC and connected to the VKP. The current problem is that the updating of my documents can sometimes be problematic."

3.4.3.3. Knowledge Sharing Culture

Knowledge sharing culture is another issue that was identified from the VKP users' feedback. This issue involves two aspects: [i] knowledge sharing customs and [ii] established practices in the research community/group.

The first aspect concerns the influence of the knowledge sharing custom or tradition in a research community or group. It was identified that the knowledge sharing cultures were different according to the difference in research subject, as well as the knowledge sharing practices and efforts in the "off-line" research groups and departments. Comments on this issue include:

"We do not use the VKP often. It's not because we are not happy with the VKP, but that we are not used to share our documents ourselves. I have to say that in culture research, researchers are doing research on an individual basis, not much cooperation is involved… "

The second aspect of knowledge sharing culture concerns the affect of the established practices for knowledge sharing in a research group/community, either IT or non-IT. Users reported that the established practices, such as mailing lists or face-to-face meetings, could make the VKP redundant for the same purposes.

3.4.3.4. Other Issues

Other issues reported by the VKP users include: [i] evolution of the research project: some users reported that once a project has finished, their use of the VKP reduced a lot, as they only share project-related documents and knowledge in the VKP; and [ii] difficulties in learning and using the system.

3.4.4. Discussion

From this empirical study, three main issues have been identified from the VKP users' feedback on the problems they have had and their requirements on sustainable online knowledge sharing: flexibility, user autonomy and knowledge sharing culture.

These results reinforce and extend the issues and requirements identified from the previous studies on related systems, as reviewed in 3.3.2, although the sample size of the empirical study is small and the result is preliminary.

Within the requirements identified from this study, some are possible to be addressed by technical solutions, while the others are more to do with changing people's behavior and are not able to be addressed technically. These issues have been defined as forming the 'social-technical-gap' (Ackerman 1998). The knowledge sharing culture issue (see 3.4.3.3) belongs to the 'social-technical-gap', and this research is not going to further study this requirement as more input would be needed from social and cognitive science research.

For the requirements on flexibility and user autonomy, a decentralized approach is considered as a potential solution. However, further studies are needed to test the feasibility of applying the approach, to evaluate its effectiveness. The studies on the decentralized approach will be described in chapter 4.

3.4.5. Concluding Remarks

Three areas of requirements have been highlighted in the user feedback from the empirical study on the VKP. Among them, two requirements will be further studied in this research: [i] flexibility in knowledge-sharing interactions, and [ii] user autonomy in knowledge-sharing interactions, as illustrated in table 3.7.

Requirements	**Details**
Flexibility	Scale of levels of interactions Scale of types of interactions Ability for the extension of the knowledge network

User autonomy	Sense of control: Control of the knowledge resources Control of the knowledge-sharing interactions
	Sense of Ownership: Storage of the resources Display and view of the resources

Table 3.7 Requirements Emerged from the VKP Study

3.5. Summary of Requirements

Based on the secondary research on six VKSEs and the empirical study on the VKP, four areas of requirements for sustainable online knowledge-sharing for research communities have been articulated. These requirements are summarized below.

3.5.1. Comprehensive Functionalities for Knowledge Sharing Processes

A VKSE needs to provide the features to support the five knowledge-sharing processes described in 3.3.1. As revealed in the secondary analysis of related systems, deficiencies in the functionalities for knowledge sharing processes can bring difficulties into the use of system and thus users' participation in online activities, e.g. WISE's lack of communication facilities. In addition, it also has been identified from the empirical study that functionalities also can influence the flexibility and users' sense of control in the online knowledge sharing activities.

3.5.2. Flexibility

The second area of requirements is the provision of flexibility in knowledge-sharing, in particular, in the research communities. As discussed in 3.2.2, the organizational structure of research communities is in the format of loosely structured social network and knowledge-sharing in the communities takes place in an informal network rather than a strict hierarchical model. There is an obvious need for supporting researchers through more open and informal ways for knowledge-sharing in VKSEs in order to preserve the social context of the sharing. Both the secondary and empirical evidence have revealed the importance of this issue.

3.5.3. User Autonomy

The third area of requirements is user autonomy. As discussed in 3.4.3, co-opetition exists in modern research communities. This situation causes an emphasis on user control and sense of ownership in online knowledge sharing in research communities. The user autonomy issue can affect researchers' contribution of content in their community. Both the secondary research and the empirical research revealed that the users' sense of control and sense of ownership over the knowledge resources they shared are important to the researchers.

3.5.4. Realization of the Benefits in Online Knowledge-sharing

Benefits of taking part in online knowledge-sharing have been identified as an important concern from the users on whether they use the system, e.g. Lotus Notes, Social Web Cockpit, and Knowledge Pump. Users' participation can be affected by their assessment on the benefits of participation in online knowledge-sharing. In other words, maximising the benefits for most, if not all, participants is another requirement for a sustainable VKSE.

3.6. Summary

This chapter has analysed the problems experienced by VKSEs in terms of their sustainability. Areas for improvement were identified as a result of secondary analysis of some representative VKSEs and from interviewing some users of the VKP. After discounting the 'social' requirements, which are beyond the scope of this research, four main requirements emerged for systems designers to consider: [i] comprehensive functionalities for knowledge sharing processes, [ii] flexibility, [iii] user autonomy and [iv] realization of the benefits in online knowledge-sharing.

Chapter 4 Decentralized VKSEs

4.1. Introduction

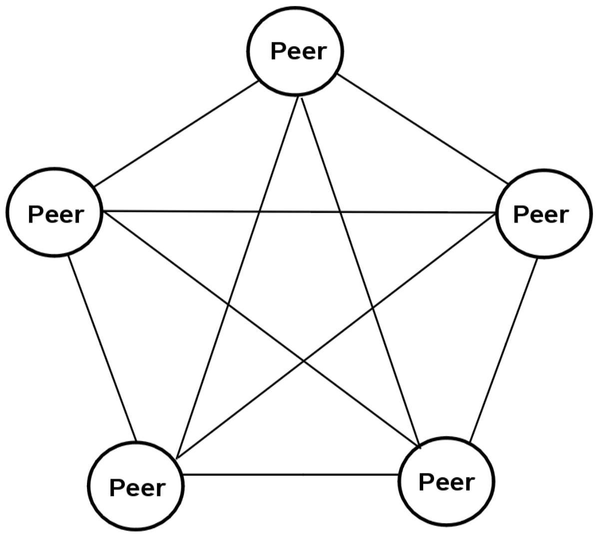
This chapter explores the potential of peer-to-peer technologies and presents the findings of two experiments with decentralized VKSEs. Features provided by decentralized VKSEs to encourage members' participation and contribution in a research community were investigated and evaluated. The first experiment involved the development of a prototype, based on JXTA technology, for a specific research community application. The second experiment was based on a commercial product Groove (using a limited free-trial version). More important than the results for a particular environment is the analysis of the underlying causes. Based on semi-structured interviews with the users in the studies, this analysis has been achieved.

The chapter starts with an introduction to the peer-to-peer paradigm that technically underpins the experimental VKSEs. It is then followed by an outline of the design and implementation of the JXTA-based prototype, the online journal club (OJC). The first experiment will then be reported in terms of its objectives, methods, results and analysis. As a comparison, a more polished peer-to-peer product for knowledge-sharing, Groove, was evaluated and lessons were drawn from these two experiments.

4.2. The Peer-to-Peer Paradigm

A peer-to-peer network distributes information directly among its member nodes (i.e. peers) instead of using central servers. The discussion in this section is based on the work of Manski (2001), Whinston and Parameswaran (2001) and Barkai (2000). Peer-to-peer networks differ markedly from the client-server architecture that typifies applications in the TCP/IP world. A client-server application, such as the Web, depends on central servers for the storage and distribution of information. The information repository remains essentially static and changes occur when updates are sent by the providers (Whinston and Parameswaran 2001). A peer-to-peer network, on the other hand, considers all peers equal in their capacity for sharing information with other network members. Each node in the network can make an information repository available for distribution and it can establish direct connections with any other member nodes (Whinston and Parameswaran 2001). Combining this feature with the member nodes' ability to join the network, it can lead to a flexible expansion of a network composed of distributed information repositories (Whinston and Parameswaran 2001).

Currently there are two predominant types of peer-to-peer network to support information sharing: pure peer-to-peer network (Figure 4.1) and hybrid peer-to-peer network (Figure 4.2).



Connection for data exchange

Figure 4.1 Pure Peer-to-Peer Network

For the pure peer-to-peer model, the network operates without a central node (server). Each node can have a partial index of the member nodes that join the network (Barkai, 2002). A lookup for content can start with this index and propagate to directories found at other nodes. Such a system is less vulnerable to a central node's failure. It also has the potential to spread the load across the nodes (Manski 2000). However, the inherent challenge is in the discovery of information required, as there will not be 'central' directory for lookup. Therefore a hybrid peer-to-peer model has emerged as a more effective topology.

In a hybrid peer-to-peer model, there is a notion of a super peer which provides central services, such as directory (Whinston and Parameswaran 2001). Individual nodes (peers) connecting to the network can access a real-time index of other active nodes and of the resources they share held in the super peer. As soon as a new node is connected, it becomes part of the index, with the resources they choose to share automatically added to the index. Because the index provides addresses for resources available at any given time, a member node can simply initiate a direct connection with any connected member node that currently holds the requested information (Whinston and Parameswaran 2001). This hybrid model combines the features of flexibility and scalability of a pure peer-to-peer network and augments it with more efficient content discovery provided by the super peer.

4.2.1. Potentials as a Knowledge-sharing Platform

The peer-to-peer paradigm offers exciting advantages in information and knowledge-sharing, but it also presents challenges (Whinston and Parameswaran 2001). There is a potential for: [i] a flexible information sharing environment (Manski 2000) that matches the research communities' loosely coupled structure; [ii] support for user autonomy as the members have more control over both the shared content and the knowledge-sharing interactions within the network; and [iii] more up to date information to be made available instantly without waiting for uploading to a central server (Whinston and Parameswaran 2001).

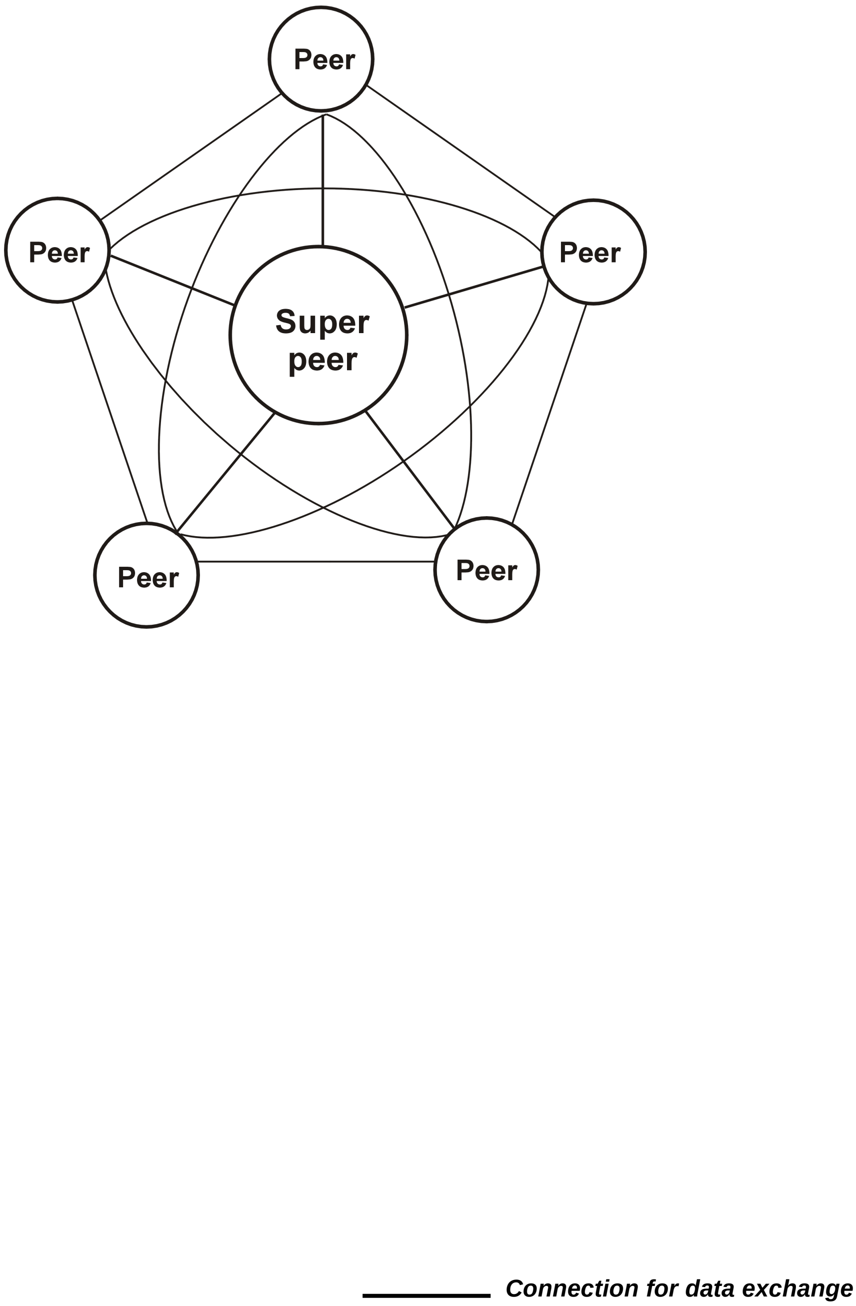


Figure 4.2 Hybrid Peer-to-Peer Network

4.3. Development of a Decentralized VKSE

In order to evaluate the feasibility of a decentralized VKSE, a prototype was implemented as an experimental platform for the study as no suitable ready-made solution was available at the time. The development work also gave the author deeper insights into the user requirements of VKSEs for research communities and the technical challenges in peer-to-peer technology. A case study, the Journal Club, was chosen to provide the context for gathering specific requirements. The following sub-sections discuss the development process.

4.3.1. Online Journal Club

Within the Informatics Institute at the University of Leeds, there was an organised Journal Club for members to meet every Wednesday. The purpose was to encourage researchers to exchange ideas on the research papers they had read. This involved a typical set of knowledge-sharing activities within a research community (e.g. recommend, exchange papers, etc.).

However, the Journal Club needed all members to be co-located. To extend this to a 'distributed' environment, the idea of an Online Journal Club (OJC) was born. With the members of the physical Journal Club within easy access, realistic requirements could be gathered and extrapolated for the online version.

4.3.2. User Requirements

This section describes the functional requirements of the OJC prototype based on the discussion with the existing Journal Club members on their current practices. Their additional expectations for an online community were also gathered. Table 4.1 lists the summary of the activities/requirements. A scenario was also formulated for better understanding of these functional requirements (see Appendix B). This scenario was used in the usability study of the OJC system.

4.3.3. Functional Requirements of an OJC Prototype

Based on the user requirements discussed above, three categories of functionalities were identified for the OJC prototype application:

- Setting up of an OJC: let OJC members [i] build groups under the OJC as the basic structure of the online community according to projects and/or research topics, and [ii] join and leave groups/sub groups in the community.
- Sharing and recommending research papers in digital format: let OJC members [i] share and recommend research papers to other OJC members, [ii] maintain their shared papers, such as editing bibliographic information for them, and [iii] retrieve and view the shared papers by other members in the OJC.
- Exchanging ideas based on the shared papers: let members set up connections, communicate and interact with other members, such as text-based discussion and chat.

	Activities/ Requirements	**Description**
Current practices in the physical Journal Club	Recommend and exchange of research papers.	Each week, one member recommends a research paper to other members in the club prior to the meeting. During the Wednesday meeting, the paper is presented by the member and for follow-up discussion.
	Discussion on research papers	Discussion and exchange ideas by all members on the shared research paper. The interaction can be at multiple levels, discussion within the whole community and at individual level.
	Community administration	A PhD student was taking care of the JC management work, which involves organizing meetings, scheduling presenters and maintaining a web page for the JC.

Additional expectations for an online journal club	Records of the shared papers	Storage of the shared research papers, which can be searched by the members of the JC.
	Interaction outside meetings	In addition to the Wednesday activity, more online activities at various times, such as discussion and sharing related information outside the meeting period.
	Extension of the community	Extension of the online journal club to internal and external partners, as well as other similar communities.

Table 4.1 Findings from Journal Club Members

Above functionalities identified for the prototype also satisfy the functional requirements of VKSEs as described in 3.3.1. The community construction functionalities echo the functions supporting the knowledge creation. The research paper sharing facilities echo the functions supporting knowledge acquisition, retrieval and maintenance. The communication facilities echo the functions supporting knowledge exchange. As the OJC prototype was developed as a decentralized VKSE, the online activities in the OJC was supported in a peer-to-peer manner and the shared research papers were kept locally on individual's PC. A peer-to-peer developing platform, JXTA, was used in the development.

4.3.4. JXTA Platform

JXTA was chosen as the developing platform for the OJC prototype application as it was an open source project (http://www.jxta.org). Help and support was available from the JXTA developers' online community. Besides, JXTA claimed the following features: [i] it brings a common infrastructure that reduces duplicate efforts in building system primitives commonly used in a peer-to-peer system; [ii] it is independent of programming languages, transport protocols and deployment platforms; and [iii] it is implementable on every digital device (Gong 2001).

JXTA comprises a set of protocols for interoperating, language and network technology for peer-to-peer computing. It was originally conceived by Sun Microsystems. Figure 4.3 (Gong 2001) illustrates the software architecture of JXTA, which is divided into three layers: [i] The core layer encapsulates minimal and essential primitives that are common to peer-to-peer networking, [ii] The services layer includes network services that may not be absolutely necessary for a peer-to-peer network to operate, but are common or desirable in the peer-to-peer environment, and [iii] The applications layer consists of programs specific to the implementation (Gong 2001).

The OJC prototype is a JXTA application, which applies the JXTA services and protocols. More detailed explanation is provided in the next sub-section.

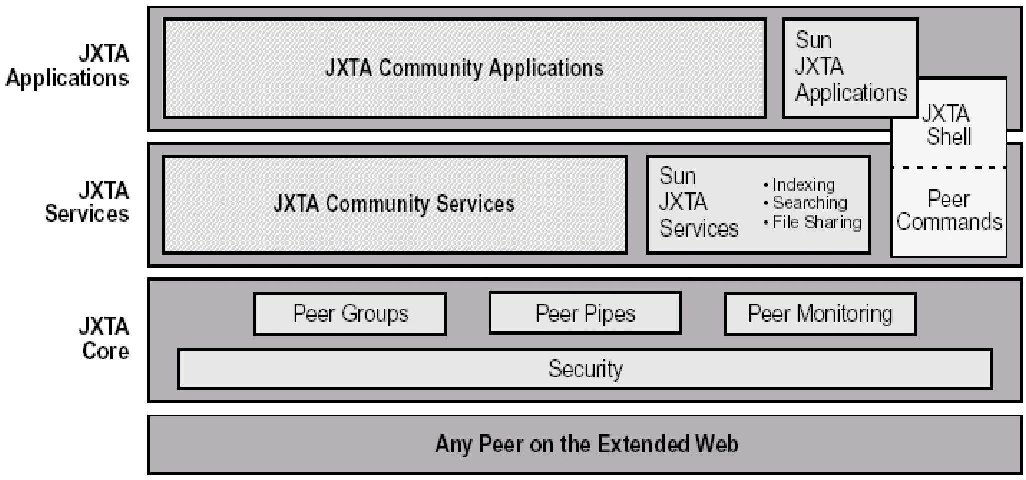


Figure 4.3 JXTA Architecture (Gong 2001)

JXTA also defines a number of concepts, which will be frequently referred to in the description of the design and implementation of the OJC prototype: Identifier, Advertisement, Peer, Message, Peer group and Pipes. Details of these JXTA concepts can be found in the JXTA White Paper (Gong 2001).

4.3.5. System Architecture of the OJC Prototype

Figure 4.4 illustrates the overall architecture of the OJC. The OJC prototype applies the pure peer-to-peer model. Each peer (solid circle) is directly connected (solid lines) with each other. These peers can form groups (Gi, dashed circle) and sub-groups (Sgi, dashed circle) in the OJC.

Each peer holds a three-layered OJC application. The OJC core layer contains the JXTA protocols and services – a stable build of the jxta.jar packages, together with the availability of a full Javadoc API reference for the J2SE implementation. The OJC services layer is an interface between JXTA protocols and services and the OJC applications. The JXTA services, such as discovery service and pipe service, are specified in the OJC services layer components in order to transform the JXTA services into commonly known and adaptable forms for the OJC applications. On the OJC applications layer, five application components as well as user interface were implemented to meet the functional requirements. Each peer also holds a local storage, which includes JXTA caches and an OJC local storage. The JXTA caches contain the JXTA advertisements. The OJC local storage stores basic bibliographic information, as well as the information of the location of the shared research papers on the peer. The design of the OJC services and applications layer components are described in the section 4.3.6 and 4.3.7.

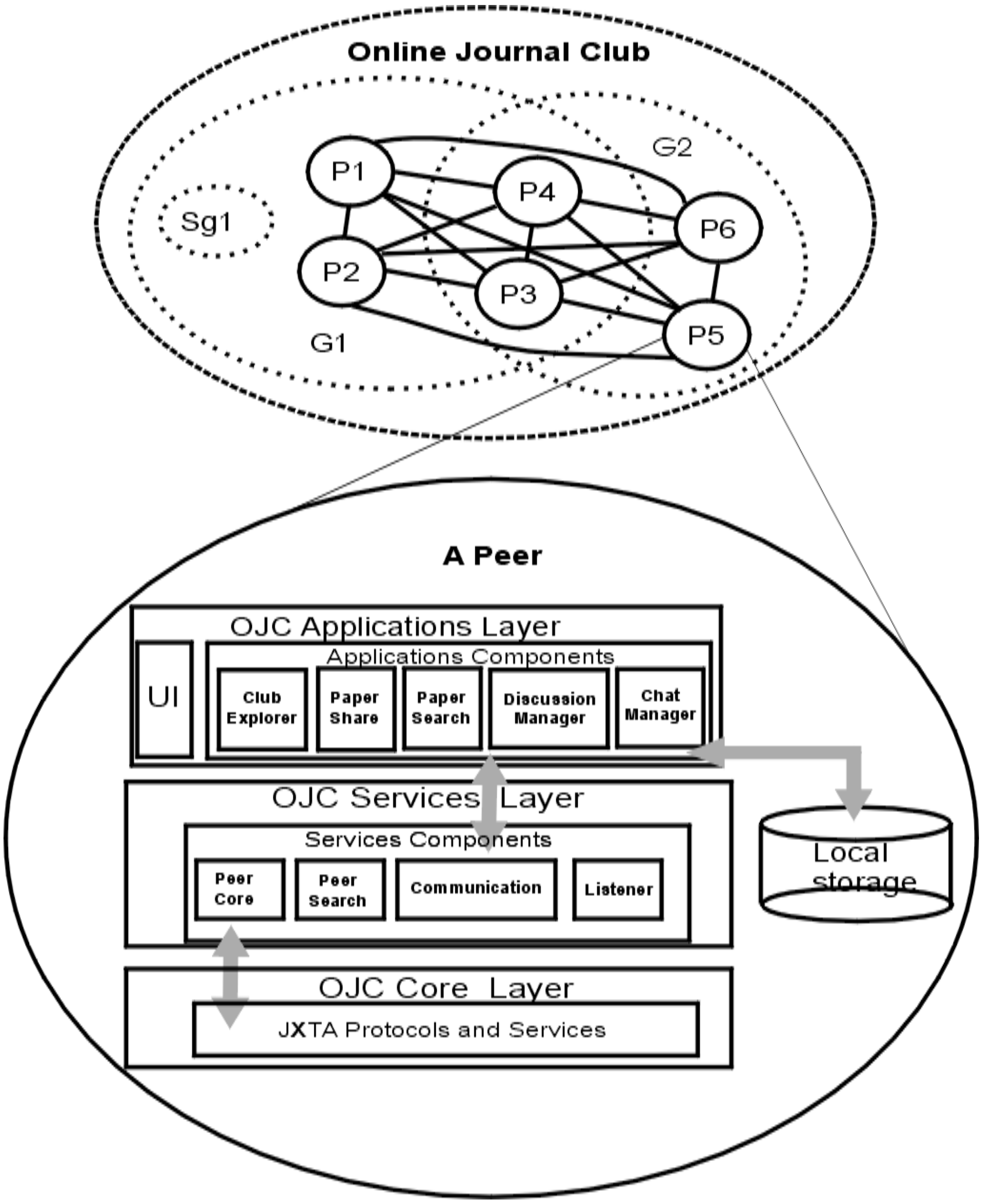

Online Journal Club
G2
P1
P4
P6
Sg1
P2
P3
P5
G1
A Peer
OJC Applications Layer
Applications Components
UI
Club Explorer
Paper Share
Paper Search
Discussion Manager
Chat Manager
OJC Services Layer
Services Components
Peer Core
Peer Search
Communication
Listener
Local storage
OJC Core Layer
JXTA Protocols and Services

Figure 4.4 Overall Architecture of the Journal Club Prototype

4.3.5.1. Communications between Peers

The inter-peer message communication between any two peers (a message sender and a message receiver) in the OJC prototype is illustrated in Figure 4.5. Every message generated on the sender's peer has to go through the three layers on the message sender's side, through the network, and go through the three layers on the receivers' side to be received by the message receiver.

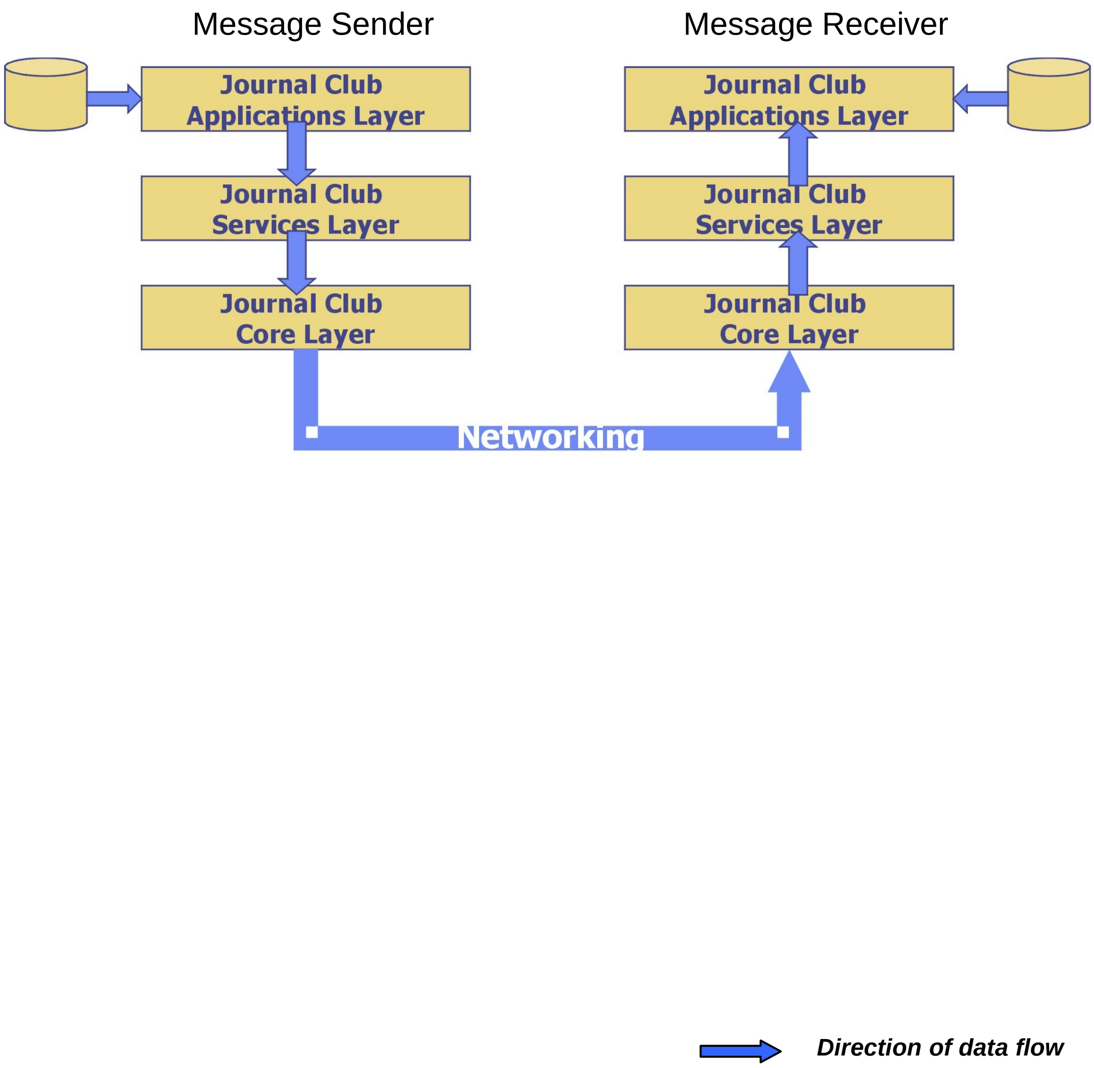


Figure 4.5 Inter-peer Communications in the OJC Prototype

4.3.6. OJC Services Layer Components

The group construction and awareness functions are supported by the components on this services layer: ‘peercore’, ‘peersearch,’ ‘communication’ and ‘listener’. These components specify JXTA peer and peer group services into the OJC and set up peer-to-peer communication. Specifications of these components are provided in section two of Appendix B.

4.3.6.1. Peer Core

Component PeerCore provides the following services: [i] loading JXTA configurator for users to configure networking settings of the peer at start-up. [ii] registering the peer in the default JXTA NetPeerGroup and get an assigned ID. [iii] advertising this peer for discovery. [iv] getting and processing the advertisements distributed by other peers. JXTA *peer group* is used as a template for the OJC and the groups in the OJC in the PeerCore in order to enable the peer to [i] create a group and publish advertisement for the group in the NetPeerGroup; [ii] join a group and register to the group services of the group; and [iii] resign from a group.

4.3.6.2. Peer Search

Peer Search component provides the following services: **[i]** searching and discovering JXTA peers/peer groups in the NetPeerGroup using JXTA’s discovery service. [ii] handling the request for the discovery of sub groups or peers in a group by distributing request to the network and cache the response for the discovery from other peers.

4.3.6.3. Communication

Communication component provides the following services: [i] building channels for communications between the local peer and other peers in the network using JXTA input and output pipes. [ii] publishing the pipes’ details in JXTA pipe advertisements. [iii] binding the input pipes to a Listener.

4.3.6.4. Listener

Listener component provides the following services: [i] listening to all incoming requests from other peers through the input pipe. [ii] forwarding the incoming messages to subordinate listeners for appropriate response based on the type of the messages indicated in the message headers.

4.3.7. OJC Application Layer Components

Application components on the OJC application layer aims to meet the functional requirements specified in 4.3.3. Specifications of the implemented components are provided in section two of Appendix B.

4.3.7.1. Club Explorer

ClubExplorer allows a peer to monitor the status of all members (peers) and groups/sub groups in the OJC. This component is based on the PeerSearch service. ClubExplorer works by calling the peer/group discovery services in the PeerSearch component, and then saving the structure of the peers/groups discovered to a buffer which could be displayed in the user interface.

4.3.7.2. Paper Share

PaperShare is designed to let members in the OJC manage their locally stored research papers by: [i] granting access to specific members or groups in the OJC; [ii] withdrawing access that have been granted before; and [iii] editing and managing the bibliographic information of the shared papers.

4.3.7.3. Paper Search

PaperSearch allows a member to search for shared papers within the OJC. Distributed and dynamic search mechanism is designed for this component, in which the search is performed by disseminating query request to the entire peer-to-peer network for other peers' responses. The queries for the journal search are based on the bibliographic information of the papers. The distribution of the queries is in a propagate way. This component uses the Communication service.

4.3.7.4. Discussion Manager

DiscussionManager is designed for a discussion board application in the OJC. It is built on the Communication service. JXTA rendezvous service is also implemented in the component to set a peer as a rendezvous peer (super peer) to hold and distribute the discussion board messages to other peers in the group/sub group.

4.3.7.5. Chat Manager

Members of the OJC can use online chat for real-time communication, either in private or public style. ChatManager is designed for this purpose. It is based on the Communication and Listener services on the OJC services layer.

Figure 4.6 demonstrates the inter-relationships of all the component that have been implemented at the OJC service and application layers.

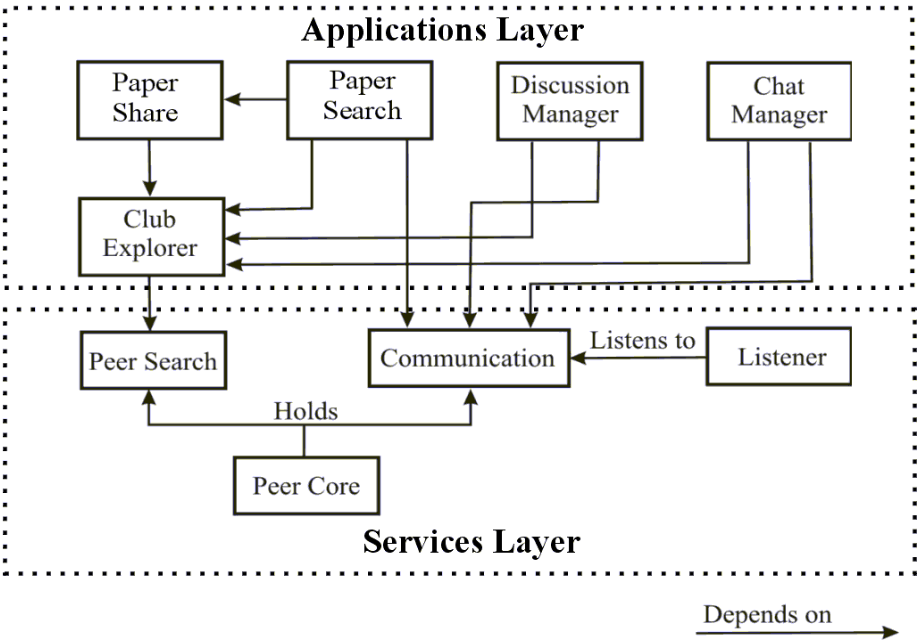
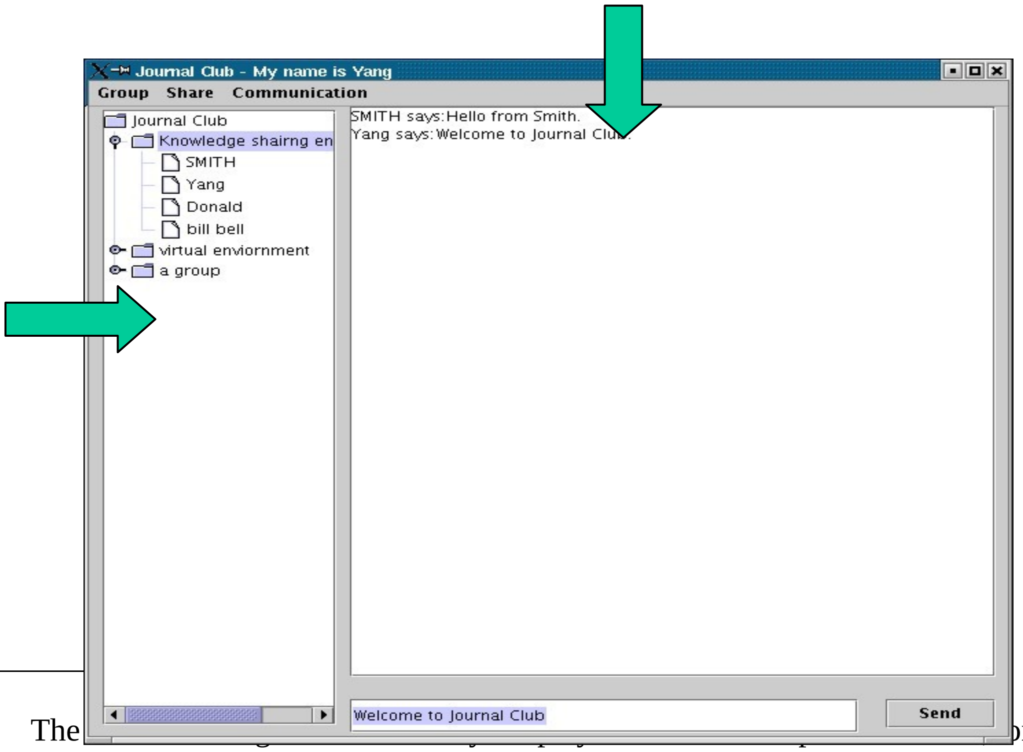


Figure 4.6 Inter-Relationship of the Components

4.3.8. The User Interface Design

Upon starting the OJC application prototype for the first time, a JXTA Configurator form is displayed to the user for the network settings, such as the port, selection of relay peers, as well as the registration information, such as preferred user name and password[1], which will be required for future logins.

The main user interface of the OJC application is designed to provide the users with a view of whole OJC community, and to navigate through the facilities. The main window contains two main areas: on the left is a club-explorer area, which allows users to view the available groups and members under each group; The area on the right contains a common area, which allows users to send text-based chat messages to all other members currently in the OJC. The three categories of function, i.e. group construction, paper sharing and communication, are listed under the menu Group, Share and Communication across the top of the window. Figure 4.7 illustrates the user interface.



1 The … only a window asking for user name and password will be displayed to identified the user.

Figure 4.7 OJC User Interface

The Group facilities let the users build groups and subgroups in the OJC according to projects and/or tasks, and join or leave the groups/sub groups in the OJC. The Share facilities allow the users to transfer a file (paper in electronic format) to another user in the OJC; make a file accessible to another user or a group in the OJC by setting permissions; browse/download the files shared in a group or on a peer; and search/download for a file in a sub/group by bibliographic items of the paper, such as title, author or keywords. Communication facilities let the users chat on group and individual's level; and receive and send discussion messages. Figure 4.8 demonstrates share and browse papers on two peers in the OJC.

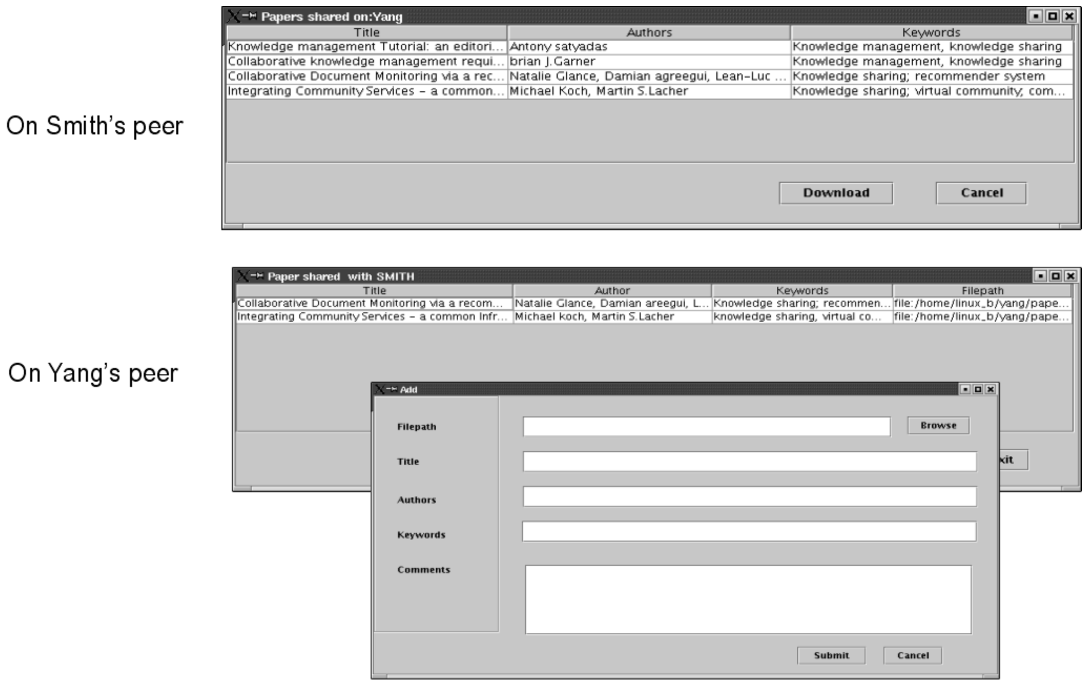


Figure 4.8 Share and Browse Papers Between Two Peers

4.3.9. Local Storage Design

In addition to the files of the shared papers on the peer, the OJC local storage includes two files containing special information: [i] a 'journal file' which stores the bibliographic information of the locally shared papers for remote search and browse, i.e. title, author, keywords and the file location of the paper; and [ii] a 'share file' which stores the authenticating information of the shared papers on the peer. Details of the data structure of the two files can be found in section three of Appendix B.

4.3.10. Implementation Issues

This section summarises the main problems faced during the implementation of the OJC prototype, and the solutions adopted. The trade-offs and design decisions are also discussed.

4.3.10.1. Efficiency of Request and Response in a Peer-to-Peer Network

In a peer-to-peer environment, when a peer broadcasts a query to the network, it cannot predict when exactly the responses can be back. The messages are propagated through the network for others to discover and respond to. The turnaround time can be very long. This can affect the efficiency of peer/peer group discovery, as well as searching for papers in the OJC.

The solution adopted to this issue involves two steps. The first one is to specify a time out for each query. By doing this, the responses are collected in a given amount of time, and the sender will not wait forever for the responses. However, as a time has been specified to wait, there is a delay in the execution of the queries. Therefore the second step to build a listener for each type of queries adopted to improve the efficiency of the process, e.g. specific listeners for file transfer query, search query and so on.

4.3.10.2. JXTA Messages used in the OJC

JXTA message is the only means to carry content from one peer to another through JXTA pipes. In the OJC prototype, a electronic file transferred between two peers is read in as a stream of bytes. , and then is attached to a JXTA message. At the receiver's side, the stream will be removed from the message and output to a file. JXTA "structure document" (XML based) is used in transferring the bibliographic information of the shared papers. On response to view or search for a specific paper, the bibliographic details of a paper are appended to a JXTA "structured document". The document then is converted to a stream of bytes and sent to the request end. On receiving the message, the receiver will convert the stream in to a "structured document" and extract bibliographic details. Because the "structured document" is based on XML, more than one paper's details can be sent using one JXTA message.

4.3.10.3. The Use of Discussion Boards

Content of discussion boards on every peer member of the same discussion group must be the same so that the same discussion board is displayed to every member. As not all peer members are always online, therefore, when a peer gets offline and then online again, it expects to receive all copies of discussion messages sent out by other peers during its offline period. The peer member can ask one of the currently online peers to get copies of those messages. A problem will occur if at a certain point of time all members of a discussion group are offline, and then some members get online. At this stage, no peer has the latest updated version of the discussion board messages. The solution adopted to this problem in the OJC is to make sure that at any given time, there is at least one peer online.

4.4. First Experiment

This experiment was set up to evaluate [i] the usability of the basic functions of the OJC prototype, and [ii] the feasibility of implementing a decentralized VKSE using the novel peer-to-peer platform. The OJC case study (section 4.3.1.) provided the context for the usability study. The task list used in the experiment was formulated based on the knowledge-sharing activities identified in the case study. The feasibility of applying the decentralized architecture into VKSE was assessed based on the result of the usability study, as well as on the experience gained from the development process.

4.4.1. Method

The usability test attempted to find out from the users how easy or difficult it was to perform the knowledge-sharing tasks during the evaluation sessions. Five postgraduate students in the University of Leeds participated in the usability evaluation[2]. The participants were selected based on two criteria: [i] having community-based knowledge-sharing experience (either online or physical interactions), and [ii] having academic research experience.

Two evaluation sessions were carried out. One with a group of two participants and the other a group of three. During each evaluation session, the users were asked to form a temporary OJC and perform the tasks on the list (Section two, Appendix B). The participants were provided with a brief training on the use of the OJC prototype, and an introduction to the background of the OJC. Instructions and help were also provided on demand during the session.

Throughout the evaluation session, participants were encouraged to speak out their opinions and feelings about the interface and usability of the system as they were performing the tasks. The process was also observed and notes were taken. After

2 Two of them are members of the physical Journal Club.

completing the tasks, each participant was asked to rate the following facilities in the OJC prototype, in terms of their ease of use.

a) Create/join/leave groups

b) Navigation of groups/members

c) Browse the papers shared by other members

d) Search for papers

e) Share paper with members/groups

f) Chat

g) Discussion

h) User interface

Participants were also encouraged to feedback their thoughts on the OJC prototype, in particular, issues related to the underlying decentralized architecture of the system, and wider issues via follow up semi-structured interviews. This feedback was used to assess the feasibility of implementing a decentralized VKSE.

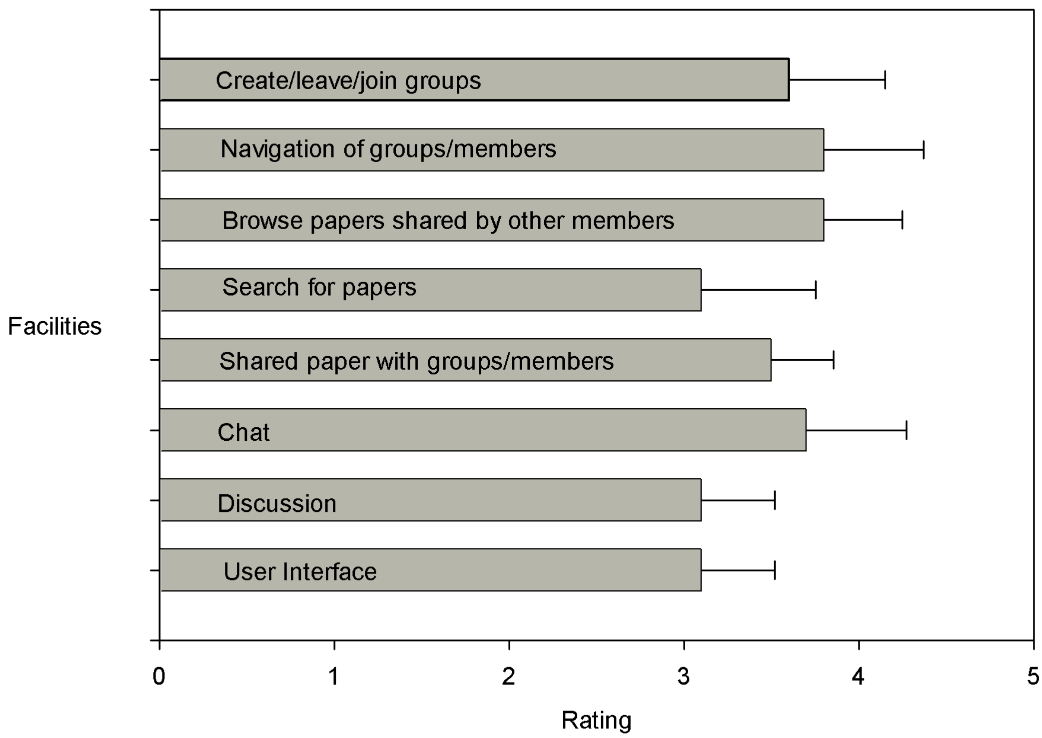
The narrative data collected from the user feedback during their task performing process and in the post-task interviews were taken down in notes. The following areas in particular: [i] functionality of the prototype, [ii] issues and problems of the prototype, [iii] advantages of the decentralized features and [iv] challenges of the decentralized features were further analysed.

4.4.2. Usability of the OJC Prototype

Figure 4.9 shows the average of participants' rating for the usability of the eight OJC facilities used while completing the tasks.

Overall, all the participants completed the tasks, and all the functionalities designed were used to facilitate performing the tasks. However, deficiencies were identified. Of the facilities rated, search for papers in a group received the worst scores.

Users expected more comprehensive search facilities, such as Boolean search, rather than string matching. The facility could be improved by indexing paper details, and implementation of algorithms to support more comprehensive search. Besides, in some cases, returned results for a search query were incomplete. This was caused be the nature of the pure peer-to-peer search mechanism: in the OJC, only the discovered results would be returned, those which were not discovered, or discovered out of the timeout of the discovery query were not displayed to the users. This was also the reason why in some cases the search query took some time to get a response.



Scale: 1 (very difficult to use) to 5 (very easy to use)

Figure 4.9 Usability of OJC Facilities

Another facility which received rather low rating was the discussion facility. As described in 4.3.10.3, the discussion message was to support asynchronous communication within the OJC, and it demanded at least a peer to be online at all times to ensure that the discussion messages were kept updated. Some users reported problems in receiving discussion messages, as the member peer who held the discussion messages got offline unexpectedly without delivering his discussion message holder position to another member in the group. The problem was caused by the conflict of the synchronous nature of peer-to-peer communication and the asynchronous communication required by the online discussion. A solution to this problem would be by setting a peer as a discussion message server what is always online, and will automatically synchronize the discussion messages for all members in the OJC when they login.

Common comments on system usability included the need to provide training to use the system, although a brief demonstration of the system provided most of the users with enough clues to proceed. A noticeable problem with the listed groups in the club explorer area was highlighted in two of the cases: all discovered groups and members in the OJC were displayed in the area, whereas it was expected as only the groups they joined would be displayed. It was suggested that the system should either display only the joined groups or highlight the joined groups.

From the user feedback during their performing of the tasks and in the post task interviews, some other issues were also raised. They are as follows:

- Speed: This issue was raised by all the participants that running the OJC application slow downed the performance of all the applications running on the machine. This problem was due to JXTA and the overheads inherent in a peer-to-peer network, as intensive message flow for request and response could take up memory resources.

- Security: Some users raised the security issue. As security was a big issue beyond the scope of this study, it was intentionally left out in this prototype. The user feedback reflected that in a decentralized environment, as their knowledge resources were kept locally on their own machine, they had some concerns about the security risk of connecting with other peers, and if there might be any chance that their local resources would be attacked by others in the network.
- Collaborative facilities: some users suggested that more collaborative facilities should be provided, such as co-editing and browsing the web together.
- Integration with bibliographic management system, such Endnote or Reference Manager, was thought to be desirable by some users.

4.4.3. Feasibility of Applying the Peer-to-Peer Architecture

This part assesses the feasibility of applying the peer-to-peer architecture to a VKSE. This assessment involves further discussion on the result from the usability study, together with a reflection on the development of the prototype. Potentials and challenges of implementing a decentralized VKSE are analysed and discussed.

4.4.3.1. JXTA as a Developing Platform

Features of JXTA largely influenced the performance of the OJC prototype. Using JXTA as the developing platform significantly simplified the design and implementation of the OJC prototype, as described in 4.3.4. The JXTA protocols and services implemented the basic peer-to-peer communication on more specific applications can be built.

However, as the JXTA platform was under continuous upgrading and development during the implementation process of the OJC prototype, it was found that the elegance of the JXTA platform was not matched by the actual implementations, documentation and tutorials. The poor quality of JXTA documentation and software was identified as responsible for major difficulties in the development work. A large amount of time was spent on coping with the various changes in different versions of the JXTA. As the new versions of the JXTA released continuously, it intended to improve the features of the platform, on the other hand, the lack of consistency of the JXTA platform made the development work very difficult. It is worth noticing that the OJC prototype was built based on JXTA version 1.1. It has been declared that the problems concerning documentation, tutorials and functionality has been largely improved in the version 2 of JXTA.

4.4.3.2. Advantages and Challenges of the Decentralized Features in VKSE

The advantages and challenges of the decentralized features in VKSE analysed in this part are based on the user feedback in the post-task interviews (see section three in Appendix C). Some issues raised in the user feedback are further discussed with findings of peer-to-peer features from related studies and issues raised during the development of the system. The purpose of this extension of the discussion is to further reveal the potential and challenge of the peer-to-peer approach for VKSEs.

The two most mentioned decentralized features of the OJC in the user feedback were user control and dynamic information repositories. In the decentralized environment, the shared content was kept locally on each peer and each user had full control of when and to whom to share their knowledge resources. It has been revealed from the user feedback that users found a clear sense of self-control in the knowledge-sharing activities in the OJC.

Besides, the local control of the content made the sharing process in the OJC resemble what users do in a physical Journal Club. The OJC member could scan the active nodes for desired information, and then downloaded it directly from the node with permissions. Users who downloaded information could make it available for sharing from their own nodes to others. Thus, in the knowledge-sharing community, any knowledge resources in high demand could rapidly spread to many nodes. As the community grows, the amount and scope of content available for sharing will grow as well.

As to the problems and challenges of applying the peer-to-peer architecture to VKSEs, two issues have been identified from the experiment and the development work. First, as the network admits individual nodes without restriction, the quality of their links and the capacity of their servers can vary widely. Various situations were raised by the users on what if a member were connected to the community through a low-speed dial-up connection and what if a member had a low-end PC that could not support a high traffic volume.

Second, security in a peer-to-peer network can be problematic. Adventures in PC operating systems and many peer-to-peer protocols, crackers could exploit this vulnerability. As in the OJC case, security features were compromised to reduce overhead. Using such architecture in communities that share critical information could lead to serious security vulnerabilities.

4.4.3.3 Limitations of the study

From the usability study of the OJC prototype and the further assessment on the feasibility of applying the peer-to-peer architecture to VKSE, it has shown that online knowledge sharing activities in an Online Journal Club can be supported in a decentralized way. It is feasible to apply the peer-to-peer architecture of VKSEs, although problems and challenges still exist, such as security.

The result of the usability study is very encouraging, although the sample size is limited. Deficiencies in the prototype have also been identified, some of these limitations can be addressed by refinement and extension of the functionalities, such as support for more complex search; others, such as the problems of the speed of application, are due to the peer-to-peer communication, and needs refineness of the protocols in the network. This usability study has provided indications for issues of implementing a decentralized VKSE that need further investigation, such as security and scalability.

4.4.4. Conclusion

This experiment assessed the usability of the implemented OJC prototype, and the feasibility of applying the peer-to-peer architecture in VKSE. It has been identified that it is feasible to build a VKSE based on the peer-to-peer architecture. Features such as user control and the dynamic knowledge repository were well received by the users, but issues such as traffic in the network and security were identified as potential problems.

4.5. Second Experiment

As described in chapter 3, flexibility and user autonomy has been identified as two important requirements on VKSEs for supporting sustainable knowledge-sharing communities. This experiment examined these two issues in another decentralized VKSE and the influence of these two issues on user participation and contribution. Scenarios based on the VKP user feedback (see 3.4) have been devised for the evaluation. User feedback were collected and analyzed. Finally, comparisons between the centralized and decentralized VKSEs were made.

4.5.1. Method

Three academic researchers participated in the study, they were selected from the 17 VKP users who participate the requirement study (see 3.4) according to these criteria: [i] having academic research experience, [ii] having practical knowledge about one or more VKSEs (e.g. the VKP), and [iii] having some experience with knowledge-sharing within online communities.

A commercial off-the shelf product, Groove (see 2.4.3.3), was used in this study for the following reasons: [i] Groove satisfied the definition of a decentralized VKSE. [ii] At the time of this study, free trials of Groove were available. Compared with the OJC prototype, Groove provided more sophisticated functionalities for knowledge-sharing and collaboration. This helped the users to concentrate on the features to be investigated in the evaluation. [iii] The functionalities provided by Groove were comparable with the VKP, so a better comparison between a centralized and a decentralized VKSE could be made.

For the evaluation, three user scenarios derived from the early empirical study (described in 3.4) were used. These scenarios highlighted the issues of flexibility, sense of control and sense of ownership over the shared resources in online knowledge-sharing.

The evaluation took place in the HCI Lab in the School of Computing. Three participants were grouped to perform the tasks within each scenario. They were provided with a brief training session on the use of Groove before starting to evaluate the system. Instructions and help on using the systems were also provided during the procedure of the evaluation. The participants were given the description of the scenarios and suggested tasks within each scenario. All participants were free to choose any facilities provided by Groove to perform the tasks.

Each test session started and ended with an interview with each participant. The pre-task interview focused on the user's knowledge about VKSEs and online communities for knowledge-sharing. The post-task interview focused on their opinion on the Groove's provision of flexibility and user autonomy in online knowledge-sharing and the possible influence on their willingness to contribute and participate in knowledge-sharing. The participants were also invited to make comparisons with their previous experience with online knowledge-sharing in the VKP. Other issues discussed during the evaluation and/or brought up by the user were also followed up in the interview. Questions, scenario description and other supporting material for this experiment can be found in section one and two of Appendix D.

The conversations in the interview were taped and summarized. Content analysis (Krippendorff 1980) was used to analyze the qualitative data. The list of issues identified from the VKP user study (see 3.4), was initially used as a framework for analysis and developed into the categories as: [i] flexibility, [ii] user autonomy and [iii] influence on participation. The key words/phrases determined in the VKP user study, as assembled in Appendix A, were then expanded based on the user feedback on Groove. Therefore, the issues for analysis under each category in this experiment were slightly different from the issues identified in the VKP user study. Presence, meaning and relationships of the key words/phrases within the summaries of user feedback were analysed and inferences were made about users' feedback on Groove in terms of its support for flexibility and user autonomy in online knowledge sharing, and the possible influence of these features on user participation. Details of the analysis can be found in section three of Appendix D.

4.5.2. Scenarios

Three user scenarios used for this experiment are described below. These scenarios were used so that a comparison of VKP and Groove's would be possible.

User Scenario 1 – Sharing documents in a large community

Virk was a member of a research community formulated around a European research project. The community involved more than 300 members from 16 institutes *across Europe. As Virk was the leading researcher and one of the main contactor in the project, he had to interact with a lot of people in the project. In addition, a lot of documents were flowing via him. He expected that the knowledge-sharing could take place in various means online, such as video conferencing and document sharing. He also expected the knowledge-sharing interactions could take place in different depth and at different levels. Besides, he also expected that as the project grew, the community could be extended and developed.*

This scenario highlighted the need of flexibility in knowledge-sharing: different means for knowledge-sharing, different levels of knowledge-sharing and extension of the knowledge network.

User Scenario 2 – Sharing sensitive data

John was a researcher in the Leeds Future project, which aimed to suggest further development of the area based on assessment of the current development of the region. A virtual community was formulated around the project; members included policy makers in the City Council, researchers from social science, geography and urban management in the university of Leeds and Leeds Metropolitan University, as well as related organizations in Yorkshire. John would like to share some statistical data as a reference to one of his project reports within the community. However, he had some concerns about who would get access to the data. These data could only be shared with people who were authorized. John needed to set permissions for these data. He also expected to trace all the viewing of the data once it was shared.

This scenario highlighted the issue of sense of control over the shared resources. This issue is especially important when sharing 'sensitive' knowledge resources within the online community. Users expect full control on their end of the shared resources, to prevent any misuse of the resources.

User Scenario 3 - Sharing unpublished documents

Joanne was a member of a cultural studies research community. She maintained a storage of the materials for a project proposal and had been working on the proposal fro a long period of time. During a group discussion, she found it would be helpful to use some information in this proposal to support some points she made. However, as some members in the community were also the competitors in the funding application, Joanne wanted to handle the situation carefully. She expected that her ownership of the information would be acknowledged within the whole community.

This scenario highlighted the issue of sense of ownership over the shared knowledge resources. This issue is important especially in maintaining and sharing unpublished information, as well as some initial ideas in the online community.

4.5.3. Evaluation Results

Analysis of the user feedback on the decentralized features evaluated in the experiment is presented below.

4.5.3.1. Flexibility

As discussed in 3.4.3.1, the flexibility issue involves three aspects: [i] supporting knowledge-sharing interaction at different organizational levels, [ii] supporting knowledge-sharing by various means, both formal and informal, and [iii] promoting opportunities for knowledge-sharing in the knowledge network so that the network can be extended. Accordingly, participants were asked to comment on the levels of interactions, types of interactions and its ability for the network extension based on their use of Groove.

It was identified from the user feedback that Groove was considered as a very flexible VKSE. Groove provided the users with various facilities to interact with each other to share knowledge online. Besides, the decentralized features such as the one-to-one communication and search for knowledge resources also provided the users with a flexible environment. The user feedback on the feature of flexibility could be classified as: [i] Groove supported multiple levels of knowledge-sharing interactions: individual, group and community; [ii] Various types of interactions were supported by Groove for knowledge-sharing, such as file sharing, co-editing and meeting; [iii] Extending the knowledge network in the community was easy. However, while providing the flexibility for each community member, Groove was not very good at community management from a group leader's perspective. Table 4.2 lists the features identified and some sample user comments.

Features	**Sample Comments**
Multiple levels of knowledge-sharing interactions	*"The one to one interaction is supported very well."* *"At first I thought it's only an extension of messenger, seems I was wrong, it supported group work as well."*
Various types of interactions	*" It's just so great to have so many functions in Groove, actually there were so many of them… at first it was quite confusing, but once you understand the workspace and the tools, you will find communication can be done in so many ways."*
Extensible knowledge network in the community	*"My feeling of this peer-to-peer network is that it's very similar to the social network in life. It lets you approach 'friends of a friend' to get more and more contacts. "*
Difficulties in community management	*"…but as a group leader, I think it is more difficult to manage the group and group documents compared with the VKP. I believe a place to store all the group documents is needed, so that every one of our group member can access…*

Table 4.2 User Feedback on Flexibility

4.5.3.2. User Autonomy

User Autonomy was another issue that was investigated in the study. As analysed in 3.4.3.2, this issue was separated into two sub-issues: [i] sense of control in the online knowledge-sharing interactions, and [ii] sense of ownership over the shared resources.

As analysed in 3.4.3.2.1, sense of control involves control over the shared knowledge resources, as well as control in the knowledge-sharing interactions. These two aspects were investigated in the experiment. The user feedback indicated that in the decentralized network of Groove, every user acted as an 'administrator' of his/her own knowledge resources to share in the community. They had full control over when and with whom to share these knowledge resources. Besides, the 'personal work space' look-and-feel of Groove gave users a better sense of control as it provided a personal view on all the knowledge-sharing activities. However, it was also identified that in case that the users found the 'personal space' presentation new and unfamiliar compared with the VKSEs they had used before, it could cause the users feel of not in control of the interactions. More training on the use of the system could avoid such problem. Table 4.3 lists the features and some sample comments from the users.

Features	**Sample Comments**
Local control of the knowledge resources	*"That's good, I was able to ask for more information about the person who requested these 'sensitive data' from me before releasing them out."*
Local control of the knowledge-sharing interactions	*"I found I got more privilege in this system, as every interaction was started from my workspace and my own view."*

Table 4.3 User Feedback on Sense of Control

Regarding the storage and display of the shared knowledge resources, the participants felt better sense of ownership over these resources he/she supplied. One interesting issue that came through was that the sense of ownership could also relate to the possible expectation on something in return for the knowledge resource a user supply in the community. Some negative feedback was also received on the Groove's storage and display of the shared knowledge resources. Some users were confused and saw Groove more as a personal document management system than as a knowledge-sharing system. A sense of the community was lost in the Groove. Table 4.4 lists the features identified and some sample comments.

Features	**Sample Comments**

Fully local storage of the shared knowledge resources	*"I like the idea that all the documents are stored on my own PC, and there is no need to upload them."*
The 'work space' display of the resources	*"I felt comfortable in this one-to-one workspace, I assumed it was to provide the feel of a real workspace."*
Lack of sense of community	*"Where is the community? I just see so many workspaces I created here."*
Lack of a community storage	*"I would prefer somewhere to store our documents for the whole community, in addition to the workspace based sharing."*

Table 4.4 User Feedback on Sense of Ownership

4.5.3.3. Influence on Participation and Contribution

Participants were invited to comment on how the features of the Groove might influence their participation and contribution in online knowledge-sharing. Overall, there was a very positive response from the participants. Table 4.5 lists their feedback. The users also commented on the features that related to some specific situations of knowledge-sharing in academic research communities.

Features	**Influence**		
	P1	*P2*	*P3*
Multiple levels of knowledge-sharing interactions	Y	Y	Y
Various types of interactions	Y	N	Y
Extensible knowledge network in the community	Y	Y	P
Fully local storage of the shared knowledge resources	P	Y	Y
Fully ownership over the resources	Y	P	Y
The 'work space' display of the resources	P	Y	Y
Local control of the knowledge resources	Y	Y	P
Permissions	Y	Y	Y
Trace of the resources	Y	P	Y

Y: positive influence

N: negative influence

P: partially positive, and partially negative, some where in between

Table 4.5 Influence on Participation and Contribution

4.5.4. Comparison with the VKP

This section discusses the strengths and weaknesses of the VKP versus the Groove in the three scenarios outlined in 4.5.2. Key features are compared.

4.5.4.1. Using the Scenarios

User Scenario 1 – Sharing documents in a large community

Current VKP facilities would provide Virk with a number of tools for knowledge-sharing, e.g. videoconferences and document management. However, in the VKP, the relations between groups could not be set, the group workspace only supports one level groups, which meant that no sub group could be built under a group. Virk had to arrange the documents according to the documents provided by him to the others, and provided by others to him. This was not a convenient way.

In Groove, various tools were provided for knowledge-sharing interactions, such as sharing of documents and online chat. Besides, relations between different groups could be defined, such as group and sub group. In Groove, the documents provided by Virk could be put under the folders in Virk's personal workspace, and those documents provided by others to Virk could be presented in the shared workspaces.

User Scenario 2 – Sharing sensitive data

VKP's permission setting facilities provide some level of security of the shared documents; also VKP let members trace the viewing information of the shared documents in the project workspace. However, as the data still needed to be uploaded to the project workspace for sharing, full control over the data could not be achieved in the

VKP. In Groove, the data were stored locally, and John would have full control over the data, when and with whom it was shared.

User Scenario 3 - Sharing unpublished documents

VKP's separation of a personal workspace from the project space provided the users with some sort of sense of ownership over the shared resources. However, as the VKP applied a centralized architecture, even the documents in the personal workspace were kept on a central server. Users still needed to upload and download documents from their own personal workspace. In the Groove, all the document in the personal workspace was kept locally. Full ownership of the shared resources was supported by Groove.

4.5.4.2. Comparison of the Key Features

The features and shortfalls of the centralized and decentralized VKSEs, using VKP and Groove as representatives, in terms of supporting the three scenarios are listed in table 4.6. This comparison was based on the user feedbacks on the two systems' provision of the features. The feedback was interpreted by the author as a three-stage rating (Y: satisfied, P: partly satisfied, N: not satisfied) was given to each required feature to show the extent of support. Y – when all users agreed, No – when no user agreed and P- when some users agreed.

	Required Features	**V**	**G**

Scenario I	Multiple means for knowledge-sharing interactions.	Y	Y
	Multiple levels of knowledge-sharing interactions	P	Y
	Extension of the knowledge-sharing networks	N	Y
	Place for Storage of the community documents which can be accessed at any time	Y	N
	Knowledge-sharing activities according to personal schedule	N	Y
	Efficiency of searching for documents in the large community	P	P
	Efficiency of the exchange of knowledge	Y	Y
	Different policies for sharing in different groups	N	Y
	Management of the community	Y	P
Scenario II	Permission control of the shared resources	Y	Y
	Trace of the shared resources	P	Y
	Direct knowledge-sharing interactions	N	Y
	Security	Y	P
Scenario III	Local Storage of the resources	N	Y
	Display of the resources	Y	Y
	Realization and claim of ownership	N	Y

V: VKP G: Groove

Table 4.6 Satisfaction of the Key Features by the Two Approaches

4.5.5. Discussion

As seen in the results, in a centralized VKSE (e.g. VKP), the central control restricted flexibility and autonomy. Decentralized solution (e.g. Groove) complemented the centralised model by making better provision for these two features. However, while providing the users with flexibility and autonomy, the decentralized approach was not as good as the centralized approach in community management and support for a sense of community in the community members.

It is worth noting that in the study, much of the sense of control and ownership also came from the ‘look and feel’ of the personal space in the system. This indicated that although the users had no idea of what the underlying architecture was, they felt that the content was stored locally on their PC from the user interface. Thus, they considered that they had the full control over the content that they shared in the community. Therefore, the peer-to-peer architecture might not be the only way for improving sense of control and ownership. More studies in HCI on the influencing issues of sense of ownership and control in knowledge sharing are needed.

4.5.6. Conclusion

From the experiment with Groove, it was found that Groove provided better features in flexibility and user autonomy when compared with the VKP. These features could have a positive effect on user participation and contribution in their online knowledge-sharing communities. However, deficiencies of the decentralized approach were also found. Management of the online community was not easy in the pure peer-to-peer VKSE. For improved sense of community and collaboration work in peer-to-peer, central services (such as a central storage) would be needed in some cases. Therefore, a hybrid decentralized VKSE was suggested as it can retain the decentralized features while overcome the shortcomings to some extent.

4.6. Summary

This chapter has described two studies on the decentralized VKSEs. The first experiment involved the implementation of an OJC prototype and a usability study on it. Despite the shortcomings identified, the usability study demonstrated the feasibility of such a decentralized concept. In the second experiment, Groove was used to evaluate the features of flexibility and user autonomy in a decentralized environment. The result of the experiment showed that Groove provided good features for flexibility and user autonomy which could encourage participation and contribution in the online knowledge-sharing community. However, it was identified from this experiment that the pure peer-to-peer approach was not good in managing the community and in supporting a sense of community. Therefore, a hybrid architecture combining the centralized and decentralized features is concluded as the way forward.

Chapter 5 Cost and Gain – An Empirical Study

5.1. Introduction

The factors affecting sustainability as described in chapter 2 (see 2.5) have been further investigated in an empirical study. This chapter uses economic principles of a ‘market’ as the basis to analyse the exchange of knowledge in a virtual place. A hypothesis, using cost and gain, was proposed as an underlying force driving sustainable online knowledge-sharing communities. An empirical study was carried out to obtain some primary data to test the hypothesis. Users of the VKP were chosen as the participants in this study. The results are discussed in the final section of this chapter.

5.2. Cost and Gain

If ‘knowledge resources’ could be treated as a commodity, it would be helpful to examine the ingredients of a sustainable economic market and extrapolate them to knowledge sharing communities. These are: (i) supply and demand supported by a pricing system, (ii) reliable interaction surrounding the exchange of ‘product’ (Berliant et al.), and (iii) the notion of the cost and benefit (Sloman 2003).

During the process of knowledge sharing, knowledge resources are given by one party (supplier) and received by another (consumer), and an exchange occurs via the network in a community (market). The idea of trading knowledge in the market has recently emerged, and the characteristics of knowledge assets and the pricing system have also been preliminarily investigated (Muller, Spiliopoulou et al. 2002).

However, unlike an economic market, in an online community knowledge market there is no agreed method of quality or quantity evaluation of a ‘knowledge resource’ (compared to a ‘product’) and hence difficult to establish a sensible pricing system related to supply and demand. The notion of cost and benefit (or gain) may also be vague, and worth further investigation.

According to the law of supply and demand in an economic market (Sloman 2003), the pricing system influences the behavior of suppliers and buyers, and vice versa. As there is no usable pricing system in the online community knowledge market, an alternative ‘regulation’ of participants’ behaviour would be the benefits based on each individual participant’s assessment on the balance of cost and gain at a given time and/or accumulatively over a period.

The cost and gain in a knowledge exchange can be the ‘value’ of the knowledge resources contributed or received. However, as the knowledge market is different from the economic market, it is not obvious how to value a piece of knowledge. Moreover, the cost to the knowledge supplier is paid immediately without any guarantee of a returned gain. Even when there is a potential gain, it might take a while to develop by appropriate ‘value-added’ actions (Cabrera and Cabrera 2002).

This empirical study attempts to articulate the participants’ perceived cost and gain in an online community knowledge market.

5.3. Motivation and Expectation

Motivation for participating in a knowledge-sharing community is well rehearsed in computing literature (see 2.5.1). The common ones, which are focusing on the ‘sharing’ aspect, include the ability to tap into expert knowledge held somewhere else, connecting people who are located in different places, or the accumulation of knowledge resources which can also serve as an organisational memory (Goodman and

Darr 1998; Dickinson 2002). There are other motivations based on the benefits from individual productivity tools that come with the ‘sharing environment’ (e.g. use of the environment for accessing personal email from anywhere in the world).

In addition, participants’ motivation and behaviour in knowledge-sharing may also be affected by economic and non-economic factors (Wasko and Faraj 2000). Based on the social exchange theory (Kelley and Thibaut 1978), participants’ motivation and activities reflect their expectation on the benefits from their participation in terms of costs and gains (Constant, Kiesler et al. 1994; Jarvenpaa and Staples 2000; West and Turner 2001). This may cause some problems/dilemmas in sustainable knowledge-sharing within an online community, as discussed in 2.5.2. In the empirical study, an attempt was made to find out the participants’ motivation and expectation. These were analysed to establish their relationship with the participants’ level of participation.

5.4. Hypothesis

The economic and social theories indicate that there should be a correlation between individual’s ‘cost and gain’ and the knowledge-sharing activities in the online environment. In other words, if every individual’s ‘expected gain’ can outweigh ‘expected cost’, the online community knowledge market should be sustainable. Hence this study aimed to test the following hypothesis:

“Mutual benefits have a positive effect on participation and contribution in online knowledge-sharing communities.” In this context, mutual benefits exist when there is a feeling amongst the critical mass of participants that their overall gain exceeds the cost, and each participant takes on the role of a supplier and a consumer of knowledge.

To ‘measure’ the amount of mutual benefit, a concept of ‘beneficial factor’ is introduced and its application is shown in section 5.7.5.

5.5. Method

The 17 users who participated in the user requirement study (see 3.4) were invited as informants for this study. The empirical study was conducted via a survey that consisted of a questionnaire and semi-structured interviews. It was designed in accordance with the principle of combined methodology for survey studies (Babbie 1990). The instruments of the survey were developed based on relevant literature and the results of prior interviews and discussions with the VKP support team members. It was pilot-tested with the VKP support team.

A questionnaire was used as the basis of the semi-structured interviews, during which emergent issues could be followed-up. The narrative data taped from the interviews were analysed using content analysis (Krippendorff 1980). Based on the analysis of cost, gain, participants' motivation, as described in 5.2 and 5.3, three areas for analysis was identified: [i] participators' motivation for online knowledge-sharing, [ii] their perceived costs and gains in online knowledge-sharing, and [iii] their expectations on the costs and gains and their participation. Key words and/or phrases were determined for each category. Presence, meaning and relationships of the key words/phrases within the summaries of user feedback were analysed and inferences were made about issues identified under motivations, perceived costs, perceived gains and expectations on the costs and gains. Details of the content analysis are provided in section four of Appendix E.

All statistic work was carried out using Sigma Stat (SPSS) (Hilbe 2003).

5.6. Questionnaire Design

The questionnaire included four sections: [i] informants' participation in online knowledge-sharing via the VKP; [ii] their expectation on the cost and gain; [iii] their assessment of current costs and gains as knowledge suppliers and users in online knowledge-sharing; and [iv] related activities of knowledge-sharing outside the VKP. There were 5 to10 questions in each section and the variables of cost, gain and participation were measured on a scale of 1 to 5, with 0 for not applicable. The main items in units of analysis for the three variables: cost, gain and level of participation are listed below in table 5.1.

Variables	**Items in units of analysis**
Cost (amount of effort/time or amount/value)	Providing content
	Replying to help-seekers' questions
	Commenting on the shared content
	Looking for/view content
	Looking for/view comments on the shared content
	Contents provided
	Replies provided to help-seekers
	Comments provided on the shared documents
Gain (amount /value or value)	Content received
	Replies to questions received
	Comments on the shared content received
	Chances in sharing and discussing ideas with other users
	Social network in the KSE relating to research work.
Participation (activity)	Providing/updating content
	Replying to help-seekers' questions
	Commenting/raising topics for discussion on the content shared
	Viewing content posted by other people
	Asking questions
	Viewing comments posted by other people on the shared content
	Discussions

Table 5.1 Units for Analysis in the Questionnaire

5.7. Results

Data collected from the survey were analysed under five headings. They are: [i] informants' motivations for participation in knowledge-sharing with the VKP; [ii] informants' perceived costs in knowledge-sharing; [iii] perceived gains; [iv] informants' expectations on the balance between costs and gains and if these had influenced their participation; and [v] the relationship between participation and mutual benefits.

5.7.1. Motivations

The main motivations are listed in Table 5.2 below.

No.	**Motivations and % of informants**	**Sample comments**
I	Geographically distributed knowledge-sharing and 88% of the informants gave this as motivation.	"One of the investigators in our project is an off campus contact; the VKP provides us a place to access to the project documents and resources."
II	Knowledge transfer from academia to industry or practice (50%)	"the VKP is mainly used for sharing knowledge between the practitioners and policy makers in local Council and the researchers in two universities. The academic researches hopefully can improve policy making for the practitioners."
III	Multi-disciplinary knowledge-sharing (35%)	"the VKP provides a place for the researchers in the art faculty to meet those in engineering and science."
IV	Miscellaneous (12%)	"I used it (the VKP) to manage my personal documents."

Table 5.2 Motivations for Knowledge-sharing in the VKP

5.7.2. Perceived Costs

According to informants' views on the notable costs, the main costs are listed in Table 5.3. Cost I was indicated by all informants. Most of them reported that the high pressure of their research work did not allow them to make more contributions in the VKP. Cost II was high during the early stage of their participation in order to get familiar with the VKP. Cost III was reported by the informants as significant in terms of privacy, permissions, and ownership of the knowledge resources they provided, as well as the high competition for funding and publications in academic research.

No.	**Costs and % of informants**	**Sample comments**
I	Cost of efforts/time in knowledge-sharing interactions: 100% of informants had considered the cost.	"[For the efforts put into commenting on shared resources], in terms of the effort to use the VKP to upload my comments, the efforts are low, but the efforts to make those comments are very high."
II	Cost of efforts/time to learn to use the technologies (70%)	"I found the cost at that time was very high… as learning how to use the system takes some efforts…"
III	Cost of knowledge resources (52%)	"The group permission setting in the VKP is very "flat"… I need more hierarchical settings to share some data…"
IV	Miscellaneous (18%)	"I also provided support on using the VKP in our group."

Table 5.3 Costs in Knowledge-sharing in the VKP

5.7.3. Perceived Gains

The main gains reported by the informants' are listed in Table 5.4. Gain I was valuable to all informants who were looking for solutions to their research problems and /or generation of new knowledge. Gain II was reported in terms of social recognition and influence in the e-communities. Gain III was the organizational benefits and was always tangible, for example, publication or acceptance of funding applications.

No	**Gains and % of informants**	**Sample comments**
I	Gain of knowledge resources obtained by 100% of informants	"The most significant gain for me is definitely the documents and support I got from others."
	Social gains were considered	"…some gains for me are outside the VKP and

II	by 47% of informants	beyond the knowledge exchange. It is the recognition within our community, both in the virtual and the physical world…”
III	Positive organizational outcomes (30%)	“[the gain] is that our project can get off the ground…”
IV	Miscellaneous (12%)	“…the avoidance of large documents in email flows.”

Table 5.4 Gains from Knowledge-sharing in the VKP

5.7.4. Expectations on the Costs and Gains

In general, all informants expected at least a balance of costs and gains. The balance could be either in short term or in long term, which was associated with informants’ roles in their groups/communities. Informants’ expectations on costs and gains during three periods of their participation are listed in Table 5.5.

At the beginning of the informants’ participation (during the Initiation), most of them could accept high costs of time and effort (the Cost II) to learn the technologies, since the cost was treated as an investment. However, some informants might give up if the costs went beyond their limits. The length of this period varied depending on informants’ IT experience.

During the Period II (Interaction), the informants’ considerations for the costs and gains were knowledge-oriented as well as community-oriented. Out of all the informants, 35% of them reported that they would participate actively only if the gain is high and can cover the cost. 30% of the informants’ participation and contribution could be affected by the costs of time and effort (Cost I) due to high pressure of work. 47% of the informants realized that the social gains (Gain II) had improved their sense of community and recognition in their groups/communities, which could encourage their participation. In terms of exchange of knowledge, there was a difference between different groups of informants. Most ordinary group members (63%) expected at least a balance between their contribution and receipt of knowledge. Most group leaders (about 80%) could accept contributing more than receiving knowledge resources.

During Period III (Harvest), tangible gains (Gain III) were expected mainly by the informants who were research administrators and group leaders. Their expectations of the balance between costs and gains were low in the Period I and II. However, their expectations of gains (Gain III) increased remarkably during this period. In other words, they looked for a balance of their costs and gains in long-term participation. It also has been found in the study that an extended achievement of the organizational outcome gains could significantly affect their decision on continuing participation in the online knowledge-sharing.

	Initiation (Period I)	**Interaction (Period II)**	**Harvest (Period III)**
Costs	Cost II	Cost I, Cost III	Cost I & III
Gains	Gain I	Gain I, Gain II	Gain III
Group members' expectation	Cost II > Gain I; High Cost II acceptable, considerations for the quality of Gain I.	Cost III <= Gain I; Gain I positive to participation; Gain II (expertise recognition) positive to participation; Cost I negative to contribution; Cost I was judged within the community context.	Not applicable

Group leaders' expectation	Cost II > Gain I; High Cost II acceptable, Gain I not considered.	Cost III >= Gain I; Gain I positive to participation; Considerations for the security of 'sensitive' information for Cost I; Gain II (social network and status) positive to participation; Cost I and III were judged from a community perspective.	Cost I + Cost III < Gain III

Table 5.5 Expectations on Costs and Gains

5.7.5. Relationship between participation and mutual benefits

Figure 5.1 shows the relationship among cost, gain, mutual benefits and activity of informants' participation. The data of costs (see 5.10 in section 2 of Appendix E) and gains (see 5.11 in section 2 of Appendix E) collected from the questionnaire were taken in terms of the exchange of knowledge resources (Cost I and III and Gain I and III). The activity of participation was estimated based on the data from the questionnaire (see part 3 in section 2 of Appendix E) and the VKP log files as a secondary source to double check the data. The data of each of the 17 informant's total costs, gains and his/her activity at a given time (when this study was conducted) in a range of 0 ~ 5 (see section 2 of Appendix E) were recoded into a range from 0 to 1, and were fitted with a linear regression and an exponential function, in Figure 5.1A and 5.1B, respectively.

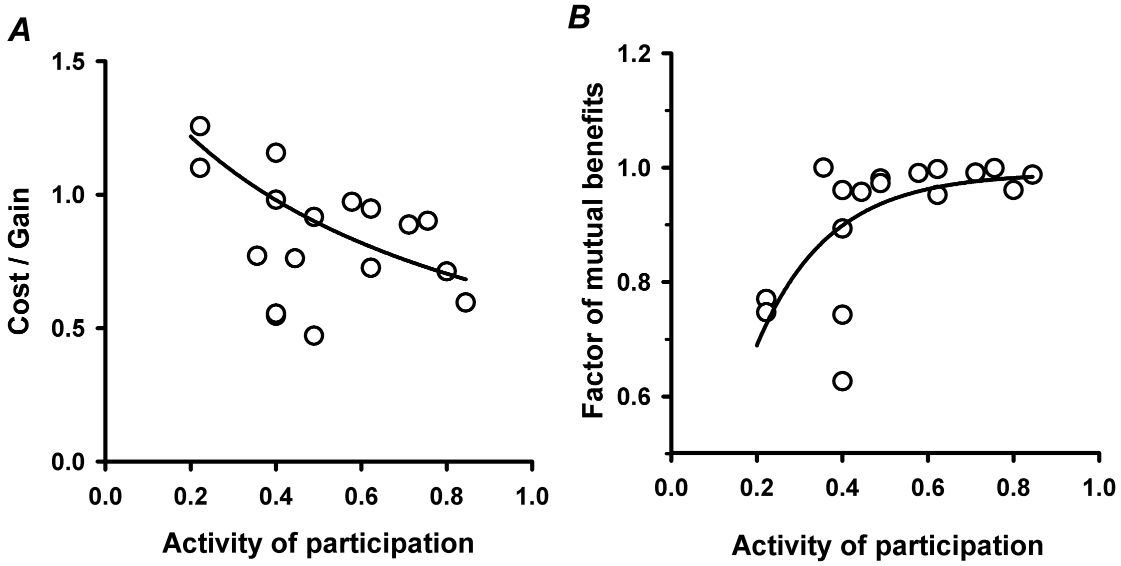


Figure 5.1 Relationships Among Informants' Costs, Gains, Mutual Benefits and Their Activity

Figure 5.1A indicates that: [i] the trend of the informants' activity at a given time is inversely proportional to their cost/gain ($r^2 = 0.43$); and [ii] the mean cost/gain ($n = 17$) is 0.91 ± 0.35 (S.D.M). From [i], we conclude that the level of participation is higher when the ratio of cost to gain decreases (i.e. the gain is increasingly exceeding the cost). From [ii], we conclude that 0.91 can be considered as a reasonable ratio of cost and gain for the VKP users.

Figure 5.1B shows the relationship between the informants' activity and their factors of mutual benefits. The factor of mutual benefits is a number aimed at indicating the effect of a combination of the benefit an individual participant could gain as a knowledge resource consumer and the risk s/he could take as a knowledge resource supplier in the online knowledge sharing activities. Based on the indications from the cost and benefit analysis, as well as credit risk analysis in economics and finance (Cossin 2000), the factor for mutual benefits (F) is expressed as:

$$F = 1/\exp(S+D)$$

where

the beneficial factor of demand = $D = (\Sigma G-\Sigma C)*\Sigma G/\Sigma C$;

the risk factor of supply = $S = (\Sigma C-\Sigma G)*\Sigma C/\Sigma G$;

ΣC and ΣG are each informant's current total costs and gains respectively.

During the knowledge-sharing process in the VKP, each informant might take on both a demand and a supply role. Both knowledge consumers and suppliers would aim to decrease their costs and increase their gains, and their benefits might affect their activity. During a knowledge exchange the consumers' gains could be the suppliers' costs, and in contrast the suppliers' gains could be the consumers' costs. Therefore, the benefits among the informants could conflict with each other. The resulting graph indicates that: [i] the informants' activity correlates with the factor of mutual benefits (r^2

= 0.37); [ii] the mean mutual benefits factor (n = 17) is 0.89 ± 0.15 (S.D.M) and [iii] the mean activity (n = 17) is 0.52 ± 0.19 (S.D.M).

5.8. Discussion of Results

From the empirical study, the participants' knowledge-sharing activities were shown to be influenced by their assessment on the fulfilment of their expected costs and gains. This was echoed in both the qualitative comments and in the results from the statistical analysis. It was, however, found that their expectations might change during the different periods of their participation (i.e. Initiation, Interaction and Harvest). It was also found that there was a correlation between mutual benefits and the level of participation.

Benefit is the main driving force to participation, which is essential to the sustainability of online knowledge-sharing community. The most beneficial resources in an online knowledge-sharing community are the knowledge that is exchanged. However, individual's benefits may conflict among the participants, as they may act both as suppliers and consumers in knowledge-sharing. And one participant's gains could be the costs to another. In order to balance the benefits among the participants, knowledge-sharing should be based on a reciprocal relationship and/or agreement.

A possible way was established in this study to estimate the relationship between participants' activity and the mutual benefits or cost/gain, although the sample was limited and the result was preliminary. If the sample size could be enlarged, it might be interesting to see if there were any trends in specific groups of informants at different stages of their participation. Further studies are needed for improving and testing the mathematical expression of demand and supply in knowledge-sharing.

5.9. Summary

This chapter has presented an empirical study on user participation and contribution in online research communities, using the VKP. Based on the indications from previous studies on motivations for knowledge-sharing, economic principle of demand and supply was used to propose a hypothesis that mutual benefits have a positive effect on participation and contribution in online knowledge-sharing.

A new angle was adopted for the investigation on the sustainability of knowledge-sharing community. Drawing from economic and social theories, a number of factors were identified as the units for analysis and a mechanism (i.e. the mutual benefit) was established to estimate the level of mutual benefits based on the analysis of supply and demand.

The result of the study demonstrated a positive correlation between mutual benefits and the level of participation. Hence, for a sustainable online community for knowledge-sharing, it is important to design mechanisms to promote the ‘mutual benefits’ in the community.

Chapter 6 Proposed Infrastructure

6.1. Introduction

Based on the findings from the earlier studies on the VKP, OJC and Groove, this chapter proposes an infrastructure of a ‘community based knowledge market’ as the way forward to support sustainable knowledge-sharing in online research communities. The concept of a ‘coordinator’ is introduced in this infrastructure as a key to promote mutual benefits in a knowledge sharing community. Justification, as well as potentials and challenges of the infrastructure are also discussed.

6.2. Implications from the Earlier Studies

Drawing from [i] the experiments with the decentralized VKSEs (in chapter 4) and [ii] the empirical study on the VKP to identify relation among cost, gain and the level of user participation in online research communities for knowledge-sharing (in chapter 5), two features have been identified for the new design of a VKSE. These are [i] a hybrid-decentralized architecture as the infrastructure and [ii] a mechanism to promote mutual benefits among the participants. It has been suggested that these two features will enhance the sustainability of an online knowledge sharing communities. The following subsections discuss the way these two features could be provided.

6.2.1. A Hybrid Decentralized Architecture

The experiments on the decentralized features for VKSEs suggested that the decentralized approach provided good features in flexibility and user autonomy. These were identified earlier as requirements for encouraging user participation in online research communities. However, it was also found that the decentralized approach compromised the features such as efficiency in search and coordination of the online community (see 4.5.3).

To combine the centralized and decentralized features, a hybrid-decentralized underlying architecture for VKSEs was concluded as the way forward. This architecture adapts a hybrid peer-to-peer network (see 4.2) with a ‘super peer’ taking on the additional co-ordination/management role. This ‘super peer’ has to be a lightweight centre and the content is maintained distributed on each peer. Figure 6.1 illustrates a VKSE based on such a hybrid-decentralized architecture. Every participant is directly connected with each other for the knowledge-sharing interactions (the solid lines). The knowledge resources (squares) shared in the community are kept on each member’s peer. These members are also connected to a lightweight server (the dashed lines) for central services, i.e. coordination. The role of this coordinator will be discussed in more detail in the following section.

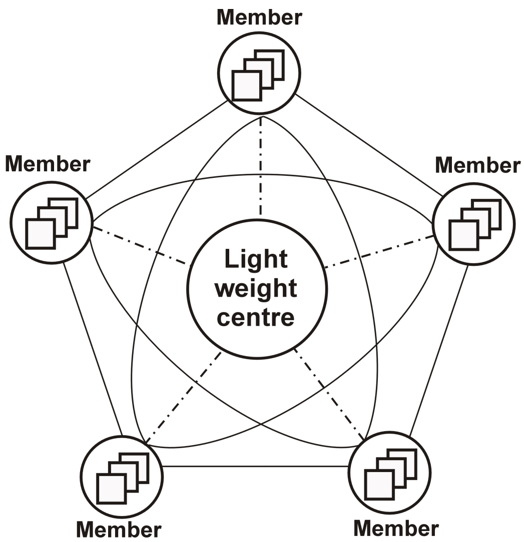


Figure 6.1 Basic Hybrid Decentralized Architecture Underlying a VKSE

6.2.2. Promotion of Mutual Benefits

The empirical study on the VKP identified mutual benefits for the participants as the key to sustainable knowledge-sharing in online research communities (see section 5.7.5). It would be interesting if a VKSE can have built-in mechanisms for promoting mutual benefits within an online research community. A possible way to implement such a mechanism is by: [i] initiation of reciprocal agreements on an exchange of knowledge resources among the providers and the recipients of the knowledge resources; and [ii] monitoring and regulating the sharing of knowledge resources in the community to guarantee that the agreements are carried out properly and every participant’s benefit is protected. The ‘coordinator’ will play a crucial role in implementing this mechanism.

6.3. The Role of a Coordinator

This section describes the role of a coordinator which is a crucial part in the proposed infrastructure for online knowledge sharing communities. The rest of this section describes the reasons for the need of a coordinator in a VKSE and the ways a coordinator might operate in online knowledge sharing activities.

6.3.1. Rationale for a Coordinator

As described in 6.2.2, to promote mutual benefits in an online knowledge sharing community, knowledge exchange needs to be based on some reciprocal agreements amongst the community members. These agreements should regulate the rules for receiving and contributing knowledge resources in the community so that the members’ interests are protected. For these agreements to take effect, a third party, apart from the provider and the recipient of knowledge resources, needs to monitor and regulate the processing of the knowledge exchange. Appropriate action could be triggered by the coordinator based on each community member's balance of cost and gain at a given time of their participation in knowledge sharing activities.

It may be argued that the agreements can be set up directly between a provider and a recipient of knowledge resources. However, in a community, the knowledge exchanges are taking place amongst a group of members. One member may provide some knowledge resources to another member, but may not necessarily get the resources needed from the same member. Besides, the balance of the cost and gains in the whole community is achieved over a long period of time and among a number of participants in the community. Therefore, a coordinator is needed to coordinate the knowledge exchange in the community.

6.3.2. Coordinating Services

In a VKSE, the coordinator can be built on a light weight central server which provides coordinating services in the community. These coordinating services may include:

[i] members registration and profiling: such as the subjects they are interested in, the duration of their participation and the role each play in their groups, e.g. group member, group leader, and so on;

[ii] knowledge resource registration and profiling: information of the knowledge resources shared in the community can be registered with the coordinator for search or resource directory services in the community, such as to which subject the piece of resource related to and possible use of the resource. In addition, user feedback on the knowledge resources they received can also be put into the knowledge resource's profile, in the form of comments or rating;

[iii] knowledge exchange monitoring: all the knowledge exchanges can be monitored by a coordinator, records can be built for each community member of their contribution/reception of knowledge resources and help to each other; and

[iv] community member status monitoring: community members' status, (e.g. Initiation, Interaction, and Harvest) can be identified by the coordinator based on their user profiles, and the appropriate balance of cost and gain in knowledge sharing can be estimated for them;

[v] agreement enforcement: this includes taking appropriate action on specific community members or in the community, such as issuing a warning to the appropriate member(s) for not contributing and rewarding others who have made substantial contribution. These conditions can be pre-set in the agreements.

6.4. An Infrastructure for a Community Based Knowledge Market

A 'community based knowledge market infrastructure' is proposed to provide a conceptual foundation for the design and implementation of the new generation of VKSEs for sustainable knowledge-sharing in research communities. Apart from the two features identified in the above sections, which are required to support the proposed infrastructure, a knowledge market paradigm (KMP) should also be adopted. The key concepts of the paradigm and their relationships to each other are explained below.

6.4.1. Knowledge Market Paradigm

The knowledge market paradigm (KMP) consists of components such as knowledge resources, knowledge resource suppliers, knowledge resource consumers, agreements and coordinators. This paradigm views a knowledge-sharing community as a market for knowledge resources, participants of the community act as suppliers, consumers and coordinators. All the knowledge resource transactions are based on the agreements set between the suppliers and consumers. The knowledge resource transactions are monitored and regulated by the coordinators, in order to make sure that the mutual benefits are protected. The following subsections explain the main components of the KMP and the notion of a ‘transaction’ which involves all these components.

6.4.1.1. Knowledge Resources

Based on the discussion on the concept of knowledge and knowledge-sharing in chapter 2 (see 2.2), a piece of knowledge resource in the KMP is defined as an item containing information or expertise passed from a provider to a recipient within a specific context for knowledge creation and innovation.

6.4.1.2. Suppliers

In the KMP, the provider of the knowledge resource is considered as a knowledge resource supplier, who is responsible for offering the knowledge resource to the others in the community. All knowledge resources have a supplier (or a set of suppliers). A supplier can be an individual or an institution, who has the ownership of the knowledge resource. In addition, the supplier sets the terms and conditions under which the knowledge resource can be accessed. For example, the supplier may decide to make the knowledge resource universally available and free to all or to limit access to particular classes of users. A knowledge resource supplier may offer multiple knowledge resources for others to consume.

6.4.1.3. Consumers

The knowledge resource consumers are those who receive and use the knowledge resources from the suppliers. A knowledge resource consumer can be an individual or an institution. They consume the knowledge resources for the purpose of knowledge creation.

6.4.1.4. Agreements

The binding between the supplier and the consumer is through an agreement. The agreement is reciprocally set up in order to set out the terms and conditions under which the consumer will be supplied the knowledge resources. These terms and conditions are based on the balance of the cost or gain of the consumer's status (i.e. Initiation, Interaction and Harvest as described in 5.7.4). These agreements can either be predefined or to be defined during the knowledge-sharing interactions.

6.4.1.5. Coordinators

In order to make the agreement take effect, the knowledge sharing activities, as well as the participant's status (e.g. Initiation, Interaction and Harvest as described in 5.7.4) need to be monitored, so that actions can be taken accordingly to promote mutual benefits in the community. Therefore, a coordinator should be involved to regulate the supply and consumption of knowledge resources based on the agreements. In this paradigm, the coordinator may be one of the participants (either a supplier or a consumer) in the market place or it may be a neutral third party. It has been suggested in section 6.3 that this role could be 'automated'.

6.4.1.6. A Knowledge Resource Transaction

A knowledge resource transaction is a process where the interaction between supplier and consumer takes place. There are three steps in a knowledge resource transaction.

The first step is for a knowledge resource supplier to define a knowledge resource he/she wants to make available to others. This step can be called *initiation*. New knowledge resources may come into the environment at any time and existing ones may be removed at any time. The initiation process involves three types of activity: [i] specification of how the resources are to be realized by the supplier using an appropriate resource description language. These details can be delivered to a coordinator and may or may not be available to other participants in the community, [ii] specifying access information for the knowledge resource, such as who can access the resources and what are the likely agreement options to get it, [iii] advertising the resources in the community.

The second step is *negotiation*, which involves knowledge supplier and knowledge consumer to establish an agreement for passing the knowledge resource. If the negotiation is successful (i.e., both parties come to an agreement) then the outcome is an agreement which consists of a set of terms and conditions. However, the negotiation may fail, in which case a resource supplier may be unable or unwilling to provide the resource to the consumer. The negotiation can also be established via a coordinator, in which case the terms and conditions in the agreement are automatically set by the coordinator based on the monitoring of the status of the supplier and the consumer. The coordinator then can make the agreement ready for the suppliers and consumers to subscribe.

The final step is *execution*. After an agreement is established, the supplier has to undertake the necessary actions in order to release the knowledge resource to the consumer. The transaction of the knowledge resource should be monitored by the coordinator. In the case that the supplier or the consumer is unable to fulfil the terms specified in the agreement, enforcement activities will be undertaken by the coordinator. These enforcement activities should be covered by the terms and conditions that the resource supplier and consumer have signed up in the agreement.

6.4.2. Applying the Hybrid-Decentralized Architecture to the KMP

This section explains how a hybrid-decentralized architecture can be applied to the KMP for a knowledge market place.

The suppliers and consumers interact with one another for knowledge resource transactions in an environment which can be viewed as a knowledge market place. An online community can have multiple knowledge market places built in it for sharing of different kinds of knowledge resources. For example, in the case that the knowledge resources are particularly sensitive or valuable, rules of membership could be set in the community for a specific marketplace, so that the components (suppliers, consumers and coordinators) can interact more freely within that ‘private’ market.

The hybrid-decentralized architecture is suitable for such knowledge market places to be built. The reason is that the coordinator in a marketplace provides central services, such as monitoring the knowledge resource transactions, whereas an exchange between the supplier and the consumer can be conducted directly in a peer-to-peer manner. In other words, the agreements are handled by a central server (coordinator), and the transactions of knowledge resource are carried out in a peer-to-peer model (between suppliers and consumers).

Figure 6.2 illustrates the underlying hybrid-decentralized architecture to support more than one online community. Every participant (peer) can join multiple market places in the community. The members who act as knowledge suppliers and consumers are directly connected with each other for knowledge resource transactions (the solid lines). These participants are also connected (the dashed lines) to a lightweight centre (coordinator) for the services as monitoring the knowledge resource transactions and the manipulation of the agreements.

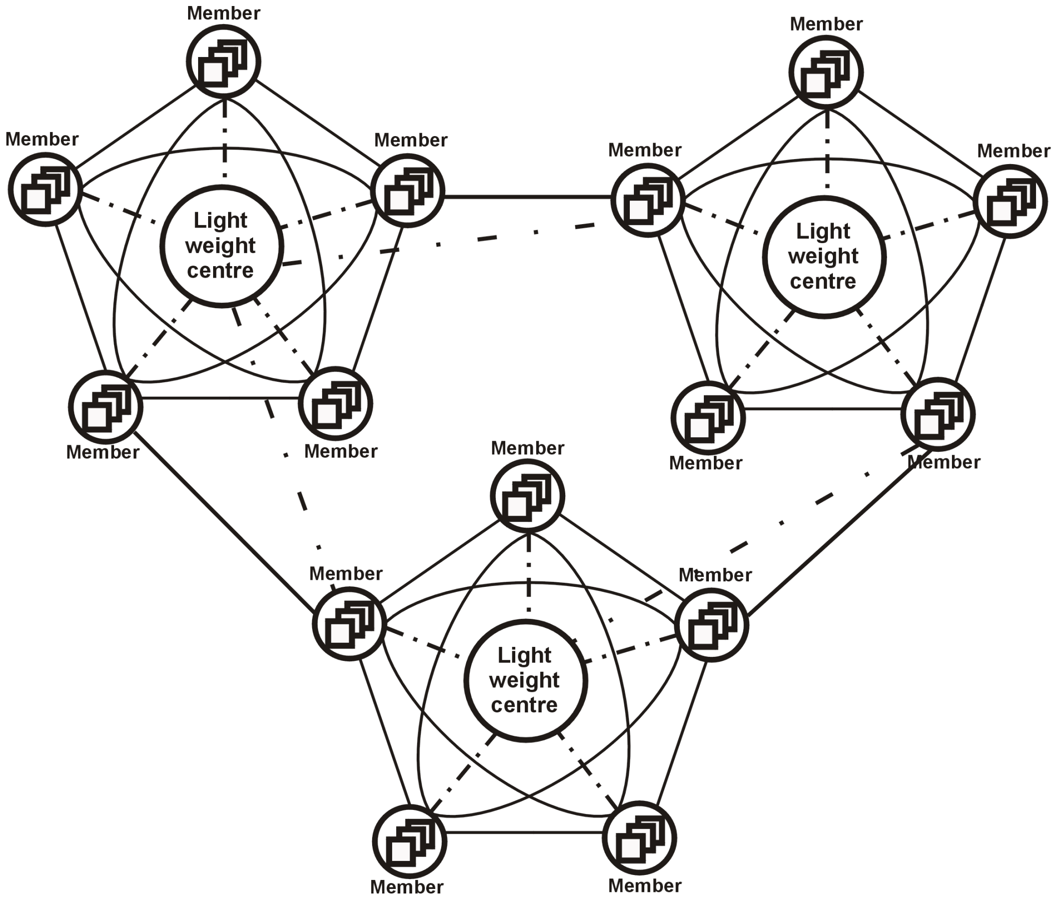


Figure 6.2 An Extended Hybrid-Decentralized Architecture for Online Communities

Extrapolating from the above, Figure 6.3 demonstrates the infrastructure for a community based knowledge market. Main components and their relations are: knowledge resource supplier (Small circle) that supplies knowledge resources (Small squares) to knowledge resource consumers (Big squares) under particular agreements. Each supplier-consumer interaction (Solid lines) takes place in a given knowledge marketplace (Ovals with fine line), which is coordinated by a coordinator (Big circles).

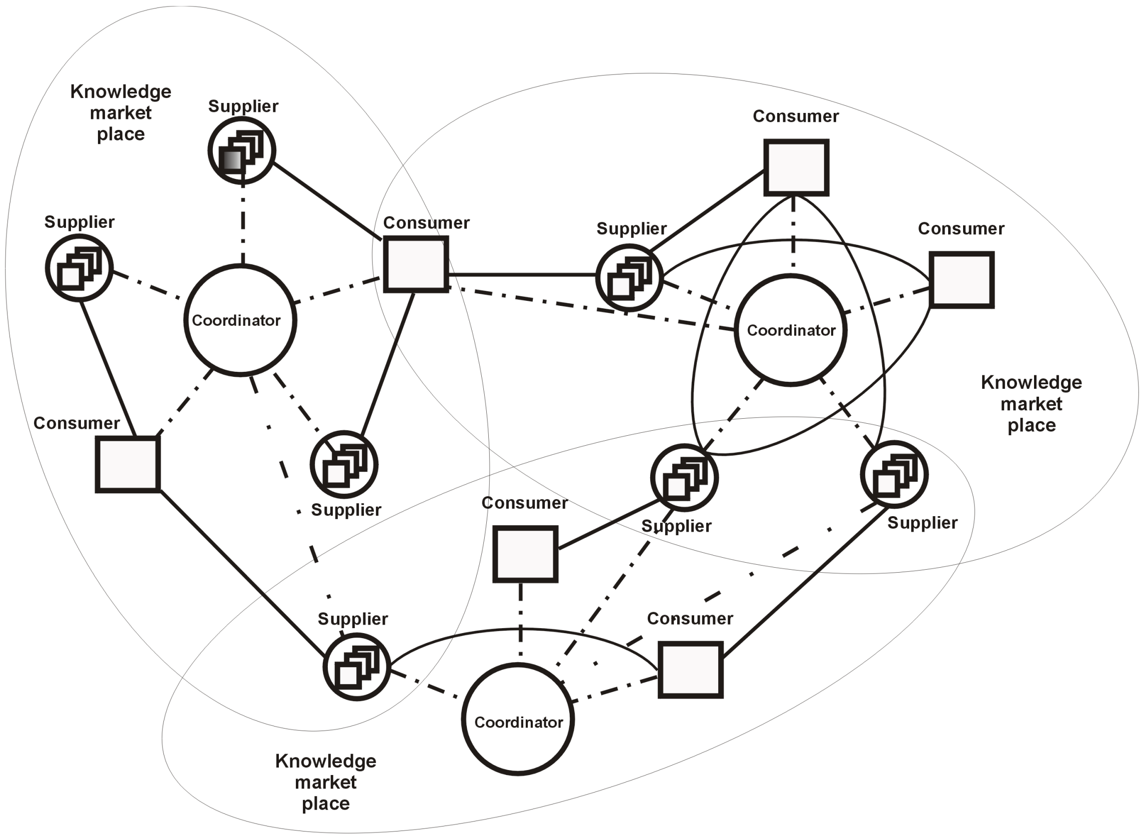


Figure 6.3 A Community Based Knowledge Market Infrastructure

6.5. Potentials and Challenges

Potentials and challenges of the community based knowledge market infrastructure are discussed in this section.

6.5.1. Potentials of the Community Based Knowledge Market Infrastructure

This infrastructure is proposed based on the earlier studies in this research. It is expected to meet the requirements on VKSEs for sustainable research communities as described in chapter 3. Potentials of it are discussed below with respect to supporting flexibility, user autonomy and mutual benefit in online research communities.

Firstly, the proposed infrastructure is expected to support flexibility in online knowledge-sharing. It allows participants to discover, transparently access and process relevant knowledge resources wherever it may be located in the community. The overall system is simply viewed as a number of knowledge resource marketplaces. Facilities can be implemented on the peers and on the servers for various kinds of ways for knowledge-sharing interactions. Various market places can be built in an online community for the sharing of various types of knowledge resources.

Secondly, user autonomy is expected to be supported by this infrastructure. This infrastructure allows different stakeholders to retain ownership of their own knowledge resources while allowing others to access these resources under the appropriate terms and conditions. The knowledge resource suppliers determine how the sharing of resources is realized and set the policy for accessing the resource. Sense of ownership and control over the knowledge resources are supported.

Thirdly, it is able to promote mutual benefits in the online communities as it offers a uniform means of supporting knowledge exchange in online community based on users' agreements. Conditions that have to be fulfilled for the balance of costs and gains for each participants in the community can be defined in the agreements and enforced through appropriate monitoring of the knowledge transactions and participants' status by the coordinators. However, this monitoring is required over a period of time to be effective.

Finally, this infrastructure also maps easily onto the current web services architecture (Booth, Haas al et. 2004). The concepts in the web services architecture, such as 'identifiers', 'formats' and 'protocols' have their applications in the KMP infrastructure: 'Identifiers' for representing knowledge suppliers, consumers, coordinators and resources; 'Formats' for setting standardized documents as profiles and agreements; and 'Protocols' for the knowledge resource transactions. Therefore, the future development and deployment of the infrastructure can be benefit from the development of the web services.

6.5.2. Challenges of the Community Based Knowledge Market Infrastructure

This section identifies the key challenges that need to be overcome to make the proposed infrastructure a reality. Table 6.1 summarizes the key functionalities of the supplier, consumer and coordinator of the infrastructure. Two areas of challenges of implementing these functions are discussed: supplier-consumer interaction and coordination of the knowledge market.

Knowledge resource supplier (peer)	**Knowledge resource consumer (peer)**	**Coordinator (server/super peer)**

• Knowledge resource initiation • Knowledge resource advertisement • Negotiation • Agreement specification	• Knowledge resource discovery • Negotiation • Agreement specification	• Supplier and consumer registration • Knowledge resource registration • Supplier and consumer status monitoring • Knowledge transaction monitoring • Agreement enforcement

Table 6.1 Key Functions of the Community Based Knowledge Market Components

6.5.2.1. Supplier-Consumer Interaction

One of the challenges is the automation of the supplier-consumer interaction by implementing agents to represent suppliers and consumers. More researches on the intelligent agents are needed to address the complexity of supporting the supplier-consumer interaction. In addition, in some cases, the suppliers and consumers may not wish to automate all of the interactions since they may wish to retain a degree of human control over these decisions. In this case, mechanisms for integration of intelligent agents and human decision-making need to be implemented. More studies are needed on this issue. Negotiation protocols are needed for the initiation of agreements. The format of negotiation messages and the set of rules for interaction between the supplier and consumer need to be defined.

6.5.2.2. Coordination of the Knowledge Market

The coordinators are responsible for regulating, controlling and ending of knowledge resource transactions based on their satisfaction of the agreements. In order to coordinate the transactions, the coordinator needs a representation scheme for describing the various components and their relations in the community based knowledge market. A means of describing how the various ‘entities’ are allowed to interact with one another in the context of the market, and what monitoring mechanisms are to be put in place to ensure the market’s rules are held. In addition, protocols need to be put in place to monitor the performance of the agreements and the status of the suppliers and consumers in the knowledge market. Current researches in web services (Alonso 2004) will be beneficial to overcoming this challenge.

6.6. Summary

Based on the indications from the early studies, an infrastructure for community based knowledge market has been proposed for supporting sustainable knowledge-sharing in online research communities. The infrastructure applies a hybrid-decentralized architecture to a knowledge market paradigm. It is expected that the market paradigm would encourage the provision of mutual benefits to online community members thus enhancing active user participation.

Chapter 7 Conclusions and Future Work

7.1. Overview

In this thesis, factors affecting sustainability of online knowledge-sharing in research communities were studied. Attention was paid to both the social and the technical issues. Three main conclusions can be drawn from this research.

- Mutual benefits among participants are important in motivating active user participation in online knowledge-sharing.
- A decentralized VKSE can provide online knowledge-sharing communities with better flexibility and user autonomy but it needs to be augmented with some centralised management features.
- The proposed community based knowledge market paradigm offers a promising approach to address the issue of sustainability in online knowledge-sharing communities.

7.1.1. Mutual Benefits in Online Knowledge-sharing

In the empirical study on user participation and contribution in online research communities, using the VKP, an attempt was made to quantify costs and gains for the individuals in a community. A 'factor of mutual benefits' was calculated based on balance of perceived costs and gains. The results indicated the following trends: [i] an individual's level of participation is inversely proportional to his/her perceived costs over gains, and [ii] the level of participation correlates with the factor of mutual benefits among the users. It was also found that the users' expectations on costs and gains might change during the different periods of their participation (i.e. Initiation, Interaction and

Harvest). The results suggested that the promotion of mutual benefits might lead to increased user participation and thus a more sustainable online knowledge-sharing community.

7.1.2. Decentralized Features

From the requirement study, it was found that a decentralized platform for online knowledge-sharing might be the way forward. Researchers require flexibility and user autonomy in online knowledge-sharing, as research communities are loosely networked rather than structured organizations.

The results of the experiments with the decentralized VKSEs demonstrated their technical feasibility and received some encouraging user feedback. The perceived benefits of flexibility and user autonomy in such an environment should encourage user participation and contribution. On the other hand, deficiencies of a pure decentralised approach were identified. Therefore, a hybrid-decentralized approach was suggested as a platform for an ideal VKSE.

7.1.3. Infrastructure for Community Based Knowledge Market

Based on the above findings, a novel infrastructure was proposed. It adopts a community based knowledge market paradigm with two main concepts (i.e. ‘agreements’ and ‘transactions’) which capture the behaviour of ‘suppliers’ and ‘consumers’ of ‘knowledge resources’. The infrastructure uses a hybrid-decentralized architecture, with the light-weight servers playing the role of the coordinators which handle and monitor the agreements. The transactions of knowledge resources, however, are carried out in a peer-to-peer model. It is expected that the market paradigm can ensure the provision of mutual benefits to on-line community members and improve sustainability.

7.2. Research Objectives Revisited

The research objectives were set out as follow:

- To undertake a requirement analysis for a VKSE to support sustainable knowledge-sharing in online research communities;
- To undertake an empirical evaluation of the Leeds VKP to identify issues;
- To design and evaluate a decentralized VKSE using a real case study to better understand this approach; and
- To determine what mechanisms are needed to encourage user participation and contribution in online research communities, and thus achieve sustainability.

In order to achieve the first objective, a literature review on the deployment of representative VKSEs for online research communities was conducted. An empirical study on the VKP on user requirements provided some primary data for further analysis on the problems and requirements. Four areas of requirements were articulated based on these studies, namely – comprehensive functionalities for knowledge sharing processes, flexibility, user autonomy and realization of benefits in online knowledge sharing.

For the second objective, social and economic theories were employed to formulate a hypothesis and measurements for the empirical study. Data collected from the questionnaires and semi-structured interviews were systematically analysed. The relationships of users' perceived cost, gain and their level of participation were uncovered. Mutual benefit was found to be an important factor in encouraging user participation in online knowledge sharing in research communities. Although the sample was small and the result was preliminary, this study set out a new angle for studying the sustainability issue.

The third objective was achieved by the experiments with two decentralized VKSEs, one using an Online Journal Club prototype and the other using Groove. These two studies demonstrated some good features in flexibility and user autonomy, although there were problems still to be solved. The limitations of the experiments included the small sample size and the use of simulated scenarios.

Drawing from the knowledge gained from the above work, a knowledge market paradigm was used to construct an infrastructure for the next generation of VKSEs. Novel mechanisms were proposed which may promote sustainability in online research communities.

7.3. Future Work

There are several directions in which this research can proceed. These directions can be categorized into two broad areas: extensions to the mutual benefit model, and deployment of the proposed knowledge market community infrastructure.

7.3.1. Extensions to the Mutual Benefit Model

A possible way was established in this research to estimate the relationship between participants' activity and their perceived cost/gain in online knowledge-sharing activities. This was achieved by introducing a concept of mutual benefit and constructing a mathematical expression for the 'factor for mutual benefits' among the participants. However, further work will be needed:

[i] Studies to improve the mathematical expression of demand and supply in knowledge-sharing. Risk analysis in finance and economics can be applied in the further studies to include more variables into the expression of mutual benefit factor, so that more complex conditions can be factored into the situation.

[ii] More empirical studies to investigate the knowledge-sharing behaviour of different communities of researchers can be conducted to see if different kinds of agreements are needed for different research communities.

7.3.2. Deployment of the Knowledge Market Community Infrastructure

A novel infrastructure of a knowledge market community has been proposed in this research to address the issue of supporting sustainable knowledge-sharing in online research communities. The next step will be the construction of a 'proof-of-concept' prototype. There will be challenges in two areas:

Firstly, studies on the protocols for setting agreements for sharing knowledge resources in an online community can be conducted. Distributed computing, networking and software agent technologies can be involved in the further investigations on this issue.

Secondly, studies on languages for describing, advertising and locating the content shared in the community can be conducted. This work can build on the effort made in Semantic Web activities. In addition, mechanisms for dynamic linking, visualization, navigation and browsing of content from many perspectives over large sets of information will be needed for the use in large research communities.

7.4. Contributions of this Research

This section describes the contributions of this research:

- Firstly, it has been found that a decentralized approach to support online knowledge sharing in research communities is feasible and it may improve the flexibility and user autonomy in online knowledge sharing.
- Secondly, it has been found that mutual benefits in knowledge sharing have an influence on user participation in an online knowledge sharing community.
- Thirdly, it has proposed that the knowledge market infrastructure, which incorporates a coordinator in a decentralized VKSE, may enhance mutual benefits for the participants and thus improve the sustainability of knowledge sharing in online research communities.

Appendix A VKP User Feedback

1. Content Analysis of User Feedback

Table A1 demonstrates the content analysis of the VKP users' feedback. Main issues raised in the user feedback have been coded into three categories: [i] flexibility, [ii] user autonomy and [iii] knowledge sharing culture. Categories, sub categories, frequency of the words/phrases coded under the categories and percentage of the users who reported the issues are listed in the table.

Category	Sub category	Word/Phrase	Frequency	% of user

Flexibility	Sharing at different organizational levels	Group(s)/Sub-group(s)	37	65%
		Access control	14	
		Public/private (access)	13	
		Multi-level/levels (group)	11	
		(group/community) Structure	6	
		Hierarchy/hierarchical	5	
		(sharing) Depth	3	
	Sharing in various situations	(various) Tools/means/ways	24	76%
		(sharing) Opportunities/chances	17	
		Formal/informal	10	
		(various) Situations/Environment/Context	10	
		Social	6	
	Extension of knowledge sharing network	External contact/partner/organization	22	53%
		Networking/network	15	
		Connection/connect (with people/groups)	12	
		Extension/extent/extended (network)	8	

User autonomy	Sense of ownership	(self) Maintain/manage/keep/take care of (shared knowledge resources)	27	71%
		Own/ownership (of knowledge resources)	21	
		Permission	19	
		Lose/lost (knowledge resources)	11	
		(ownership) Acknowledge/acknowledgement	9	
		Intellectual capital	6	
		Procession (of knowledge resources)	4	
	Sense of control	Misunderstand/ Misuse/ Misinterpretation/ Misinterpret	33	76%
		Permission	19	
		(usability) Problems/uneasy/easy (to use)	18	
		Access control	14	
		Restrict/restriction	10	
		Control/controlled	7	
		Authorize/authorization (of using knowledge resources)	5	
		Lose/lost (control)	3	
Knowledge sharing culture	Knowledge sharing custom	Custom/culture/norm	16	47%
		Habit	2	
		(get) Used to (sharing knowledge)	4	
		Development/deployment (of knowledge sharing culture)	5	
	Established practice	Email/Mailing list	14	53%
		Limit/reduce/redundant (use)	12	
		Meeting/meet/face-to-face	9	
		Systems/software/websites (for sharing knowledge)	7	

Table A1 Content Analysis of the User Feedback

Appendix B OJC Implementation Specification

1. Developing Environment

The developing environment was as following:

Integrated Development Environment (IDE): Forte for Java 4.0 CE

Java compiler version: JDK 1.4.0

JXTA library: The JXTA library version currently used is JXTA Project Stable Builds JXTA 1.1 (build 65e, 07-11-2002) downloaded from: http://download.jxta.org/stablebuilds/index.html.

2. Component Specification

1) PeerCore

There is only one Peer Core instance for each peer. On creating, the Peer Core object creates a Communication instance and a Peer Search object associated with the peer. The Peer Core instance joins the peer into the default JXTA NetPeerGroup. Details of the peer are then published on JXTA peer-to-peer network in a peer advertisement, which is an XML based document.

Start Up starts running the Communication object of the peer. The Communication object is a java thread.

```
public interface PeerCoreInterface{
public void startUp();
public Communication getCommunication();
public PeerSearch getPeerSearch();
public PeerID getPeerID();
public String getPeerName();
public PeerGroup createGroup(String groupName, String
    login, String passwd);
public PeerGroup createGroup(PeerGroup rootPeerGroup,
    String groupName, String login, String passwd );
public boolean joinGroup(PeerGroup pg, String loginName,
    String passwd);
public void leaveGroup(PeerGroup pg);
}
```

Java code 1: Peer Core interface

Get Communication returns the Communication object created by Peer Core.

Get Peer Search returns the Peer Search object created by Peer Core.

Get Peer ID returns identification of the peer within JXTA NetPeerGroup in Java string format.

Get Peer Name returns name of the current peer as a string of characters.

Create Group creates JXTA peer groups within a parent peer group. There are two options for creating a peer group. If the parent group is included as an argument, the new group will be the child of the specified parent group. Otherwise, the parent of the new group will be JXTA NetPeerGroup. In this case, the new group is the root group of a journal club. If new group is created successfully, the group will be returned. Otherwise, the service returns null.

Join Group joins the peer to the specified peer group passed in as an argument. In view of the Journal Club, this action joins a member into a journal group. This service will return false if the join is not successful.

Leave Group lets the peer resign from specified group that it has joined in previously.

2) PeerSearch

Peer Search uses JXTA discovery service to search for peers and peer groups. Each JXTA peer group has a discovery service accompanied with. The scope of the discovery is in the peer group that the discovery service resides. Peer Search instance of a peer is created by Peer Core at start up.

Search for Peers searches for peers with a given name. Because the search is asynchronous, results of the search, which are in form of peer advertisements, will be received asynchronously. The amount of time out specified is the time Peer Search will wait for results. The results will be stored in a Java vector. If peer group argument is used, the scope of the search will be limited within the specified group. Otherwise, the entire default JXTA NetPeerGroup will be searched.

```
public interface PeerSearchInterface{
public Vector searchForPeers(String peerName, int timeout);

public Vector searchForPeers(PeerGroup pg, String peerName,
    int timeout);
public Vector searchForGroups(String groupName, int
    timeout);
public Vector searchForGroups(PeerGroup pg, String
    groupName, int timeout);
public Vector peersInGroup(PeerGroup pg, int timeout);
public Vector groupsInGroup(PeerGroup pg, int timeout);
}
```

Java code 2: Peer Search Interface

Search for Groups works the same way as ***Search for Peers***, but it searches for peer groups instead.

Peers in Groups or ***Groups in Groups*** searches for all peers or all peer groups with a given peer group.

3) Communication

There is only one instance of the Communication class for each peer. This instance is created by Peer Core at start up and should be accessed through method ***getCommunication*** of Peer Core. JXTA pipe is medium of communication. Each JXTA pipe [2] has its own pipe advertisement, with specified identification. In order to send a message to the pipe, a peer must open an output pipe to the pipe, and to receive messages, a peer must open an input pipe from the pipe. The input pipe must be created before the creation of output pipe. A JXTA pipe may have many output pipes.

On instantiating, the communication object creates a pipe advertisement for itself and publishes the advertisement to the network. Then, it creates an input pipe from the pipe advertisement and starts its listener to listen to incoming messages. The details of services provided by the communication object are described below.

Close Communication closes the input pipe, stops the peer from listening to messages from the pipe.

Send Message sends a message to a peer identified by a given identification. To send a message, it first checks if the pipe advertisement of the target peer is available or not. If there is, it will create an output pipe from that pipe advertisement and send the message through the output pipe. If the pipe advertisement for the receiver is not available, the sender will look for pipe advertisement of the receiver from the network. In order to avoid delays caused by the above procedure to the application, the communication object designed as a daemon thread. It holds a queue of being sent messages. Whenever there is a command to send a message, the message then will be put in the queue. The communication thread will frequently check the queue for waiting messages. If there is a message to be sent, it will carry out the procedure described above.

Ping is to check connection status of the peer to a peer specified by given identification in a given amount of time. The peer first sends a ping message to the specified peer and waiting for reply. If the reply is received within the timeout specified, the ping service will return positive feedback. Otherwise it will return false.

```
public interface CommunicationInterface{
public void closeCommunication();
public void sendMessage(String pid, Message mesg);
public void sendMessage(PeerID pid, Message mesg);
public boolean ping(String pid, int timeout);
public Message createMessage();
public Message createMessage(String type);
public void addFileMsgListener(FileMsgListener fml);
public void addChatMsgListener(ChatMsgListener cml);
public void addSearchMsgListener(SearchMsgListener sml);
public void addSearchResultMsgListener(
    SearchResultMsgListener sml);
public void addControlMsgListener(ControlMsgListener cml);
public void addDiscussionMsgListener(DiscussionMsgListener
    dml);
public void removeFileMsgListener(FileMsgListener l);
public void removeChatMsgListener(ChatMsgListener l);
public void removeSearchMsgListener(SearchMsgListener l);
public void removeSearchResultMsgListener(
    SearchResultMsgListener l);
public void removeControlMsgListener(ControlMsgListener l);
public void removeDiscussionMsgListener(
    DiscussionMsgListener l);
public String getPeerID();
public String getPeerName();
}
```

Java code 3: Communication interface

Create Message creates templates for messages to be sent. Sender identification, name, and type of message, if specified, will be enclosed in a message. The content will be filled by components that use the message. There are five major types of message defined for their purposes of use:

File message: designed for file sharing purpose

Search message: for journal search purpose

Control message: for general control purpose

Chat message: for chatting purpose

Ping message: for ping purpose

There is also a sub-type of search message named *search result message* to carry result of a search for journals.

Add and remove message listeners are to add and remove subordinate listeners, which listen to messages of type defined above through input pipe of the communication object.

4) Listener

The Listener implements JXTA PipeMsgListener interface to listen to messages from Communication input pipe. On receiving a message, it checks the type of the message and forwards the message to subordinate listeners for handling. The way the listener works is like a message filter. Four major types and a subtype of message listener interfaces are defined for using by service components as well as the application.

ChatMsgListener interface provides template for classes whose objects are designed to listen to chat message type.

```
public interface ChatMsgListener{
                    public void chatMsgEvent(Message m);
}
```

Java code 4: ChatMsgListener interface

DiscussionMsgListener interface provides template for classes whose objects are designed to listen to discussion message type.

```
public interface DiscussionMsgListener{
               public void discussionMsgEvent(Message m);
}
```

Java code 5: DiscussionMsgListener interface

```
public interface ClubExplorerInterface{
    public SubGroup getRootGroup();
    public Vector getSubGroups();
    public Vector getPeerMembers();
    public SubGroup getParentGroup();
    public Vector getSubGroups(SubGroup sg);
    public Vector getPeerMembers(SubGroup sg);
    public SubGroup getParentGroup(SubGroup sg);
    public SubGroup getSubGroup(String sgid);
    public PeerMember getPeerMember(String pid);
    public SubGroup getSelectedGroup();
    public void setSelectedGroup(SubGroup sg);
    public boolean setSelectedGroup(String sgid);
    public void updateAll();
}
```

Similarly, ***FileMsgListener***, ***SearchMsgListener*** and ***SearchResultMsgListener*** are designed for using by classes whose objects want to listen to messages of types: file message, search message and search result message respectively.

5) Club Explorer

Club Explorer component is designed for traversing the club hierarchy. The core of ClubExplorer class is JournalClubRoot class, like the root of a tree. Sub groups (SubGroup class) and peer members (PeerMember class) of the club are branches and leaves of the hierarchy tree respectively. Details of sub groups and peer members can be retrieved from Club Explorer by using their keys.

Get Root Group returns the root of the hierarchy as a SubGroup instance.

Get Sub Groups returns direct braches (sub groups) from the current selected branch (or the branch specified as an argument) in a vector.

Get Peer Members returns leaves (peer members) directly from the current selected branch (or the branch specified as an argument) in a vector.

Java code 6: Club Explorer interface

Get Parent Group returns the parent branch of the current selected branch (or the branch specified as an argument).

Get Sub Group returns instance of the sub group specified by the given identification.

Get Peer Member return instance of the peer member specified by the given identification.

Get Selected Group sets the subgroup passed in as the current selected group. If the identification is used, and if the operation is successful, the service will return true. Otherwise, it will return false.

Update All uses PeerSearch object to update the whole hierarchy tree. Individual branch can also be updated individually through methods provided by SubGroup class.

Java code 6: Club Explorer interface

6) Journal Sharing

The aim of Journal Sharing component is to manage shared journals on local peer. The details of shares and journals are stored in local files.

Share File to Peer marks the specified file as being shared to the peer with given identification. The shared file is identified by full file path.

Share File To Group, similarly, marks the specified file as being shared to a group.

Share File to Public shares the specified file to all peers – public.

Get Files Shared to Peer retrieves file paths of all files shared to the specified peer.

Get Files Shared To Group returns file paths of all files shared to a group.

Get All Files Shared to Peer returns file paths of files shared to the specified peer and to public that the specified peer has access to.

Get All Files Shared To Group returns file paths of files shared to the specified group and to public.

Get Peers Shared retrieves a list of peers that are directly granted access to the specified file.

Get Groups Shared retrieves a list of groups that are directly granted access to the specified file.

File Shared To Peer, File Shared To Group and ***File Shared to Public*** check if the specified file is marked as being shared to the specified peer, group or public respectively.

Remove Share From Peer, Remove Share From Group and ***Remove Share from Public*** revoke access right to the specified file from the specified peer, group and public respectively.

```
public interface JournalSharingInterface {
public void shareFileToPeer(String filename, String pid);
public void shareFileToGroup(String filename, String pgid);
public void shareFileToPublic(String filename);
public Vector getFilesSharedToPeer(String pid);
public Vector getAllFilesSharedToPeer(String pid);
public Vector getFilesSharedToGroup(String pgid);
public Vector getAllFilesSharedToGroup(String pgid);
public Vector getPeersShared(String filepath);
public Vector getGroupsShared(String filepath);
public boolean fileSharedToGroup(String file, String gid);
public boolean fileSharedToPeer(String file, String pid);
public boolean fileSharedToPublic(String filename);
public Journal getJournal(String filepath);
public void addJournalToDatabase(Journal j);
public Journal removeJournalFromDatabase(String path);
public Journal removeJournalFromDatabase(Journal j);
public void removeShareFromPeer(String filepath,String pid);
public void removeShareFromGroup(String filepath,String pid);
public void removeShareFromPublic(String filepath);
public void createNewJournalDatabase();
public void saveJournalDatabase();
public void saveConfig();
}
```

Java code 7: Journal Sharing interface

Save Config saves share configuration has been made so far on the local peer.

Get Journal returns details of the specified journal from journal database.

Add Journal to Database adds a new journal with all its details into the database.

Remove Journal from Database removes the specified journal out of the database.

Create New Journal Database creates new database to save details of journals.

Save Journal Database saves the journal database after being modified.

7) Journal Search

Journal Search component is used to search for shared journals on other peer members of the club that the current peer has access to. Whenever a peer wants to search for journals, it forms a search message, enclosing the search query, and broadcasts copies the search message to its known neighbours. Then, on receiving the search message, a neighbour uses the query in the message to search against their journal database for matching journals. If there are results, the neighbour will send them in search result message to the original peer, which issued the search query. The neighbour then also forwards the search message to their known neighbours.

There are two constants used for each search query: cast factor and path length. The peer that originally issues the search message defines these constants

Cast factor: the number of peers that one peer will forward the search message to. For example if the cast factor is set to five, on receiving the search message, a peer will forward the message to the other five peers if it is possible.

Path length: The number of peers that the search message will go through, starting from the issuer. The search message will be stopped when it reaches the end of its path.

The identification of a peer that the search message gets through is recorded in message path history. Peers, on receiving a search message, will check its path history to avoid forwarding the search message to the peers that the message previously passed through. Services provided by Journal Search interface are described below:

Add Search Peer and ***Add Search Peers*** add a peer or list of peers as the peer’s neighbours for searching.

Set Cast Factor sets value for cast factor.

Set Path Length sets value for path length.

Search for Journals searches for journals using keywords. There are two options for this service. If a value for timeout is specified, the Journal Search object will broadcast the search message and wait for search result messages in this given amount of time. The results of the search will be returned in a vector. If a search message listener is specified instead of timeout, the listener will receive search result messages of the search asynchronously.

Remove SearchResultMsgListener stops the specified listener from listening to search result messages.

```
public interface JournalSearchInterface{
public void addSearchPeer(String pid);
public void addSearchPeers(Vector peers);
public void setCastFactor(int n);
public void setPathLength(int l);
public Vector searchForJournals(String keyword,int timeout);
public void searchForJournals(String keyword,
    SearchResultMsgListener srml);
public void removeSearchResultMsgListener(
    SearchResultMsgListener l);
}
```

Java code 8: Journal Search interface

8) Discussion Manager

Discussion Manager manages discussion messages with club and sub groups. Each group has each own discussion board, managed by DiscussionGroup object. In each group there should be one peer in the role of rendezvous peer (coordinator) to synchronise discussion message for the group on each peer member. When a peer wants to send a discussion message to the group, it sends the message to its known rendezvous peer. The rendezvous peer will then keep a copy of the message on its local board and forward the message to other peers in the group. If the rendezvous peer member is about to go offline, it passes the rendezvous role to another peer member in the group.

Update Discussion updates the discussion board of the specified group. In order to do that, the peer sends an update request to the rendezvous peer of the group. The rendezvous then returns to the peer the content of discussion board of requested group.

Send Discussion Message sends a discussion message to the specified group.

```
public interface DiscussionManagerInterface{
    public void updateDiscussion(PeerGroup pg);
    public void sendDiscussionMessage(String pgid, String
title, String content, String replyTo);
    public void sendDiscussionMessage(DiscussionMessage
dm);
    public DiscussionGroup getDiscussionGroup(String pgid);
    public void saveDiscussionBoard();
    public void startRendezVousService(PeerGroup pg);
    public void startRendezVousService(SubGroup sg);
    public void stopRendezVousService(PeerGroup pg);
}
```

Java code 9: Discussion Manager Interface

Get Discussion Group asks the discussion manager to return the DiscussionGroup object of the specified group.

Save Discussion Board saves contents of all discussions into local storage.

Start RendezVous Service or ***Stop RendezVous Service*** starts or stops the peer as rendezvous peer for the specified group.

9) Chat Manager

Chat Manager helps the peer send chat messages to another peer or all peer in a specified group. In order to receive chat message, chat control object in application layer must implement ChatMsgListener interface.

Send Message sends a chat message to a specified peer member. There are four options for this service just for convenience.

```
public interface ChatManagerInterface{
    public void sendMessage(String pid, String mesg);
    public void sendMessage(PeerMember pm, String mesg);
    public void sendMessage(PeerMember pm, Message mesg);
    public void sendMessage(String pid, Message mesg);
    public void sendMessageToGroup(String gid, String mesg);
        public void sendMessageToGroup(SubGroup sg, String
mesg);
        public void sendMessageToGroup(String gid, Message
mesg);
        public void sendMessageToGroup(SubGroup sg, Message
mesg);
    public Message createChatMessage();
    public Message createChatMessage(String msg);
}
```

Java code 10: Chat Manager Interface

Send Message To Group sends a chat message to all members of the specified group.

Create Message creates a template for chat message or a full chat message with specified content.

3. Local Storage

The JOC local caches consists of two files containing storage objects: [i] the journal file (journal database) which stores the bibliographic information of the shared papers on the peer for remote peers to search and browse and [ii] the share file (journal config) which stores the authenticating information of the shared papers and the remote peers that the papers shared to.

The structure of the journal file is shown in table B1

Field Name	Description
file_path	Stores the file path of the shared paper
title	Stores the title of the shared paper
author	Stores the authors of the shared paper
keywords	Stores the keywords of the shared paper
summary	Stores the summary (abstract) of the shared paper

Table B1 Structure of Journal Database File

The Journal Database file stores the bibliographic information of the papers a user shared in the community. Whenever a user shares a paper to a peer/group, he will be asked to input the metadata of the paper for remote peers to make searches on and browse. This storage can also be considered as the user's local shared resource storage. Users can use this storage to edit and manage his shared resources in the community. The share file's structure is depicted in table B2.

Field Name	Description
file_path	Stores the local file path of the paper shared
peer_id	Stores the remote peer IDs to which the paper is shared to

Table B2 Structure of Journal Config File

This Journal Config file stores information of the peers that the paper is shared to. Field file_path is the same as the one in the Journal database; list of peer Ids that the paper is shared to is stored using the filed peer_id. The Journal Config file is for checking whether a remote peer has the right to view and download the paper.

Appendix C Usability Study Materials

1. An Online Journal Club Scenario

There is a multi-disciplinary research project X cooperated by a company A and two academic institutions: B and C. In order to ensure good communication and effective knowledge-sharing among the distributed participants of the project, a distributed and informal research community – X Online Journal Club is formed around the project, which involved the project members as the core of the club, and other related persons to form the knowledge-sharing community. They use an OJC software application which can be installed on each member's workstation to connect and communicate with other members of the club and perform the basic knowledge-sharing activities in the X OJC, such as sharing research papers they are reading and exchange ideas based on the shared papers. In the OJC scenario, research papers in digital format serves as the knowledge resource for explicit knowledge shared in the community, and the text-based chat and discussions on the issues raised from the shared papers is the main means for tacit knowledge-sharing.

Billy, who is a research student in university B, was working on a research project which contributed to project X. As a member of the X OJC, Billy tended to look into the OJC for help from other expertise on the project whenever he was facing any problems with the project. Once Billy was reading a paper on related work to project X, in which he found an issue that he could not understand very well, he decided to share the paper in the X OJC and look for help there. He then logged into the X OJC, and shared the paper in a specific group which was for the project he was working on. He also started a topic in the group discussion on the problem he faced in the paper and waited for other member's response.

Then he sent his query to the OJC by key-word-based searches on the papers shared in related groups in the OJC; he also browsed the previous discussion on the related issues. By doing this, Billy then found some persons who provided most of the papers on the issues in the groups as the target that might provide help for him, one of them is John, a researcher in university C. Billy then browsed some related resources deposited in the OJC by John. Reading these papers provided Billy with some idea on the issue he had, however, new issues were raised. Next day, Billy needed to clarify a point in John's paper and chatted with John via the text chat facilities to discuss the query. John pointed out the query could be addressed by an un-published working paper, to which he would be happy to grant Billy access till next week. John also mentioned to Billy several names in the club that might provide help. Billy then made searches to locate their shared papers as well as constructed direct communication via one to one chat or group discussion. Meanwhile, as Billy shared the paper and raised the topic for discussion on the issue in the paper in the group on his project, he also got some feedback from other group members.

2. Task List

Tasks specified in the OJC scenario were given to the participants (referred to as member A, B and C in the task description), which include:

1) Construction of groups in the OJC:

A creates an Journal Club

A creates a group-'knowledge-sharing environment' under the Journal Club

B, C join 'knowledge-sharing environment' group

B creates a group-'virtual environment'

C joins 'virtual environment' group

C creates a group – 'a group'

A join 'a group' group

2) Real-time Communication in the OJC

A sends a chat message 'Hello from A' as a public message to all members in the OJC.

B sends a chat message 'Welcome to Journal Club' as a public message to all members in the OJC.

A sends a private chat message to C 'Hello, C'

C sends back a private message to A 'Hello, A'

3) File transfer a research Paper

A sends a file transfer request to C

C accepts the request and receives the file from A

4) Share a research paper with other peers/groups

A views her shared papers with B (papers that B has permission to access)

A adds a new paper to share with B

A edits the metadata for the newly shared paper

B browses the paper shared on A, which B has permission to access

A adds a new paper to share with the 'a group' group

A edits the metadata for the newly shared paper

C browses the paper shared within in the group 'a group'

5) Search a research paper other peers/ within groups

A searches for papers within the whole Journal Club by key word 'knowledge-sharing'

A searches for papers on B’s holdings, by key word ‘knowledge-sharing’

6) Discussion

A creates a discussion board in group ‘knowledge-sharing environment’

B sends a message to the discussion board

C sends a message to the discussion board

B log off from the Journal Club

A sends a message to the discussion board

B joins the Journal Club

B views the discussion board

3. User Feedback Form

1. How do you rate the following aspects of the OJC in terms of how easy or difficult you though they were to use:

1) Very easy to use 2) Fairly easy to use 3) Average 4) Fairly difficult to use 5) Very difficult to use

a) Create/join/leave groups	Rating
b) Navigation of groups/members	Rating
c) Browse the papers shared by other members	Rating
d) Search for papers	Rating
e) Share paper with members/groups	Rating
f) Chat	Rating
g) Discussion	Rating
h) User interface	Rating

2. Your comments on any of the above points:

1) What are your perceived strengths/weaknesses of the OJC in terms of supporting an online journal club?

2) Do you have any experience with the physical journal club?

3) If yes to the above question, any comments on the OJC's provision for your journal club activities?

4) Have you used other software systems for research-related knowledge-sharing in online communities?

5) If yes to the above question, any comments on the difference of using the OJC and the system you used before?

6) Your comments on the underlying peer-to-peer architecture of the OJC:

7) What else do you expect from the decentralized features?

Appendix D Groove Evaluation Materials

1. Pre-Task Interview

This pre-task interview focuses on the user's knowledge about VKSEs and online communities for knowledge-sharing.

1) Personal Information: age, gender and position

2) Do you have any experience of online research community?

3) If yes, can you describe your online community? (e.g. goal, members, and major activities in your community).

4) What software system is used to support your community?

5) Any comments on the software system? (e.g. advantages and disadvantages in terms of supporting your community activities)

6) How do you often do you participate in the activities in your online community?

7) What are the activities you usually participate?

8) Have you used any peer-to-peer system before? Such as MSN messenger?

9) Do you know Groove before?

10) If yes, what do you know about the Groove? Any experience?

2. Post-Task Interview

The post-task interview focuses on the user's opinion on the Groove's provision of flexibility and user autonomy in online knowledge-sharing and the possible influence on their willingness to contribute and participate in knowledge-sharing.

Flexibility

1.1) What do you think of the tools provided by Groove to perform the tasks in the scenario?

1.2) What do you think of Groove in supporting your interactions with other individuals, group or community?

1.3) What do you think of Groove's provision for the extending your "knowledge network" in the community?

1.4) Any other comments on flexibility?

User Autonomy

2.1) How describe your control of knowledge resource, such as documents you provided in the Groove?

2.2) How do describe your control in the knowledge interactions with other users in the Groove?

2.3) Do you feel your ownership of the documents you provided in Groove is acknowledged to other users?

2.4) Do you feel you are responsible for managing and updating the documents you provided?

2.5) What do you think of the Groove's workspace look-and-feel?

3) What are your perceived strengths/weaknesses of the Groove over the software system(s) you have used before, in terms of supporting an online research community?

4) Are there any additional features or services you would like to see from Groove?

5) Do you have any other comments on Groove?

3. Content Analysis of the Qualitative Data

Table A1 demonstrates the content analysis of the users' feedback. Main issues raised in the user feedback have been coded into three categories: [i] flexibility, and [ii] user autonomy. Categories, sub categories and frequency of the words/phrases coded under the categories are listed in the table.

Category	**Sub category**	**Word/Phrase**	**Frequency**

Flexibility	Multiple levels of knowledge-sharing interactions	Group(s)/Sub-group(s)	8
		Multi-level/levels (group)	7
		Public/group (communication)	3
		Policies/depth of sharing	3
		One-to-one/personal/private(communication)	3
	Various types of interactions	Various/different (functions/tools/means/ways)	7
		Activities	5
		Function/functions/tools/tool	8
		Means/ways	9
		Interactions	3
		Many/a lot of /lots of (functions/tools/means/ways)	5
		adequate/enough (functions/tools/means/ways)	4
	Extensible knowledge network in the community	Connecting/Connection/Connect	10
		Network/networking	6
		Easy/easier	4
		Extend/extension	6
		Expand	2
	Difficulties in community management	Problems (in managing/management)	6
		Manage/management/administration/organize/running/run (communities)	5
		Difficulties (in managing/management)	2
		Inadequate/inadequacy (in managing/management)	2

User Autonomy	Local control of the knowledge resources	Control/controlled/controlling	8
		Can/able to (control)	7
		Permission/permit	5
		Trace (shared documents)	4
		Security/secure	2
		(be) aware/alert	2
	Local control of the knowledge-sharing interactions	Control/controlled/controlling	8
		Workspace (activities)	5
		Direct/Straightforward (connection/interaction)	4
	Fully local storage of the shared knowledge resources	Storage/store/stored/maintain/maintained/save/saved	11
		Management/manage (documents)	5
		(on own) PC/computer/machine	4
	The 'work space' display of the resources	Workspace (look and feel)	9
		Safe/secure/comfortable	5
		Own/ownership/possession	4
		Claim/claiming (of ownership)	2
	Lack of sense of community	Community	7
		Difficulties/difficult (get the community feeling)	4
		Sense of community	3
	Lack of a community storage	Storage/space/place (for the whole group)	6
		Central (storage for documents)	2

Table D1 Content Analysis of the User Feedback

Appendix E VKP Empirical Study Materials

1. Email for Request for Participation

Dear VKP User,

The VKP Support Team has recently been approached by Yang Tian from the School of Computing at the University of Leeds. Yang is conducting her PhD research into on-line knowledge-sharing systems, and wishes to understand user requirements, behaviour and opinions in the use of such systems, especially relating to the costs and benefits of use.

As a frequent user of the VKP you already have exposure to one such system. Yang would therefore like to conduct a brief interview with you, taking no longer than 45 minutes, in order to collect some valuable research information.

The information provided during the interview will remain confidential and subject to the Data Protection Act 1998, and will not be released to any third party without prior consent. Only statistical information will be used in the research, to help identify critical factors associated with the use of on-line knowledge-sharing environments.

To find out more about this research please contact yangt@comp.leeds.ac.uk.

Thanks in advance.

2. Questionnaire: Use of the VKP

Definition: Virtual Knowledge-sharing Environment (VKSE) is a software, which provides a range of tools for users to deposit, retrieve and exchange knowledge and information with each other.

1. Personal Information

1.1 Age

	a. 25 or younger		b. 26-35		c. 36-45		d. 46-55		e. 56-65		f. 65 or over

1.2 Gender

	a. Male		b. Female

1.3 Position

	a. Research Student		b. Research Assistant/Fellow (or equivalent)		c. Lecturer (or equivalent)
	d. Senior Lecturer (or equivalent)		e. Professor (or equivalent)		f. Others, please specify below ___________________________

2. Knowledge-sharing experience outside the VKP

2.1 How often do you participation in the following activities:

1 = less than once a month; 2 = once or twice a month; 3 = once or twice a week; 4 = several times a week; 5 = several times a day.					
	1	2	3	4	5
Discussing research-related issues with colleagues or other contacts face to face (formal and informal)					
Discussing research-related issues with others via email					
Discussing research-related issues in discussing forums, communities of practice (mailing list, newsgroups)					

Sharing opinions on research-related readings in Reading Groups or similar activities					

2.2 Your opinions on the difference of these knowledge-sharing and those in the VKP

3. Experience of using the VKP for research-related knowledge-sharing

3.1 How long have you been using the VKP?

____________ month(s)

3.2 What is your main purpose for using the VKP? (can choose more than one)

	a. Project related		b. Online communities		c. Personal Information management		d. Others, Please indicate below

3.3 How often do you use the VKP for research (research support)-related purposes?

	a. Once a month or less		b. Several times a month		c. Several times a week		d. Several times a day		e. Not applicable

3.4 How do you judge your activeness in participation?

Levels (very low, low, middle, high, or very high)?

3.5 How do you agree with the following statements about your participation in the VKP?

1 = Strongly disagree; 5 = Strongly agree					
	1	2	3	4	5
I take an active part in knowledge-sharing in my virtual groups/communities in the VKP					
I do my best to stimulate knowledge-sharing our groups/communities					
I often help our group/community members who seek support from other members					
I provide a large amount of useful information/content for others in my group/community					

3.6 How often do you use the VKP for the following knowledge-sharing activities?

1 = less than once a month 2 = once or twice a month 3 = once or twice a week; 4 = several times a week; 5 = several times a day.					
	1	2	3	4	5
Providing information/contents for other people					
Updating my shared information/contents					
Commenting/raising topics for discussion on the shared information/contents					
Replying to help-seekers’ questions					
Getting information/contents from other people					
Asking for help from people with specific expertise					
Reading other people’s comments on the shared documents					
Asking questions					
Participating in the discussions					
Others, please indicate: ____________________________					

3.7 Whenever you get a problem in your research work, do you discuss it in your VKP groups or community?

	a. Yes		b. No

If Yes, Did you obtain any useful information on the problem?

	a. Yes		b. No

If No, can you please indicate why you don’t want to do so?

3.8 How many people do you normally interact and share knowledge with in the VKP?

	a. Less than 5		b. 6-10		c. 11-15		d. 16-20		e. More than 20

3.9 Please indicate your overall impression on the usefulness of VKP for knowledge-sharing.

	Not useful		Of very little use		Of little use		Neutral		Some what useful		Useful		Very useful

4. Expectations and barriers of knowledge-sharing in an online environment like the VKP

4.1 What are the reasons for you to participate in your current online community in the VKP?

4.2 What best describe your expectation on knowledge-sharing within the VKP?

	a. I expect I just make my resources available and don't mind whether I can get anything useful from others in the VKP
	b. I don't mind if I share more resources than what I get from others in the VKP; but at least I should receive something useful
	c. I expect a balance of contribution and receiving of useful resources in the VKP
	d. I expect to receive useful resources from others and I will contribute when I can
	e. I only aim for getting useful resources shared by others in the VKP, I seldom have the time to contribute
	f. I have no expectation.

4.3 What reason(s) are likely to stop you from sharing your knowledge resources (documents, ideas, and comments) with others in an environment like the VKP? (can choose more than one)

	a. The quality of the content shared in it is not good enough
	b. I may disclose some sensitive information to my competitors
	c. It takes too much effort/time to share knowledge with others using it
	d. Other people do not share their knowledge resources as much as I do
	e. Other barriers, please indicate ______________________________

5 Considerations for Cost and gain in participating in knowledge-sharing in the VKP

5.1 Have you ever considered about your cost and gain in knowledge-sharing in your groups or communities in the VKP? What are your considerations or opinions?

(The cost can be your time, effort, shared resources or anything you think is reasonable as cost. The gain can be anything you get that you considered as beneficial, e.g. knowledge resources from others, your influence or impact on others. These are based on your own judgment and within your own context for participation.)

5.2 What do you considered as the significant cost?

5.3 What do you considered as the significant gain?

5.4 Your judgment on the balance of cost and gain at current stage:

5.5 Do you think the level of your participation is influenced by the gain?

5.6 If yes to the previous question, what kind of influence it is?

5.7 Do you think the level of your participation is influenced by the cost?

5.8 If yes to the previous question, what kind of influence it is?

5.9 What the level (1=very low, 5=very high) of participation will be in case of [i] cost = gain? [ii] cost > gain? and [iii] cost < gain?

5.10 The following questions are about your judgment on the cost of knowledge-sharing using the VKP

Rating: 1 = Very Low; 2 = Low; 3 = Neutral; 4 = High; 5 = Very High					
	1	2	3	4	5
How do you rate the amount of effort you put into the VKP in order to share knowledge (e.g. providing and updating information/contents) with other users?					
How do you rate the amount of effort you put into the VKP in order to reply to help-seekers (e.g. providing answer to questions raised in the discussion)?					
How do you rate the amount of effort you put into the VKP in order to comment on the shared documents/contents (e.g. providing notes or raising ideas on shared documents in your project workspace)					
How do you rate the amount of time you put into the VKP in order to share knowledge (e.g. providing and updating information/contents) with other users?					
How do you rate the amount of time you put into the VKP in order to reply to help-seekers (e.g. providing answer to questions raised in					

the discussion)?					
How do you rate the amount of time you put into the VKP in order to comment on the shared documents/contents (e.g. providing notes or raising ideas on shared documents in your project workspace)					
How do you rate the amount of information/contents (e.g. published research paper) you provided in the VKP?					
How do you rate the value/usefulness of information/contents (e.g. published research paper) you provided in the VKP?					
How do you rate the amount of the replies to help-seekers (e.g. answers to others' problems) the VKP?					
How do you rate the value/usefulness of the replies to help-seekers (e.g. answers to others' problems) the VKP?					
How do you rate the amount of the comments you provide on the shared documents?					
How do you rate the value/usefulness of the comments you provide on the shared documents?					
Other cost, please indicate below: ________________________________					

5.11 The following questions are about your judgment on the gain of using the VKP for knowledge-sharing

Rating: 1 = Very Low (little); 2 = Low (little); 3 = Neutral; 4 = High (large); 5 = Very High (large)					
	1	2	3	4	5
How do you rate the value of the social network you build in the VKP in relation to your research work?					
How do you rate the amount of information/content (published research papers, tutorials) you get from others in the VKP?					
How do you rate the value (usefulness) of information/content (published research papers, tutorials) you get from others in the VKP?					
How do you rate the amount of replies to your questions/problems					

raised in the VKP?					
How do you rate the value (usefulness) of replies to your questions/problems raised in the VKP?					
How do you rate the amount of other members' comments/ideas on the content shared					
How do you rate the value (usefulness) of other members' comments/ideas on the content shared					
How do you rate the opportunities in sharing and discussing ideas with other users in the VKP?					
Other gains (please indicate, amount and value)					

5.12 How important are the following functions provided by the VKP in encouraging your participation?

1=not important at all; 5 = very important					
	1	2	3	4	5
Personal workspace for personal document management					
Project workspace for group document management					
'Expertise Matcher' and contact books to connect with people of close research interests					
'Discussion groups' for communicate with other users					
'Alerts' to allow notification of events					
Others, please indicate below ________________________________					

3. Informants and Communities Background

Background information of the informants, as well as communities they joined is provided in table D1 and D2.

No	Age	Gender	Position	Subject	Community

1	33	F	Senior Manager	Information Service	Portal
2	22	F	Research Assistant	Geography	Leeds Future
3	57	M	Project Manager	NA	Robotics
4	28	M	Project Manager	NA	Leeds Future
5	50	F	Project Manager	NA	Leeds Future
6	51	M	Professor	Geography	Leeds Future
7	53	M	Research Fellow	Urban Management	Leeds Future
8	36	F	Academic Related	Information Service	Portal
9	47	M	Professor	Mechanical Engineer	Robotics
10	28	F	Research Assistant	Social Science	Children
11	56	F	Professor	Textile Industry	Art-Science
12	35	M	Lecturer	Geography	Leeds Future
13	38	M	Senior Research Fellow	Transportation	Transportation Research
14	48	M	Research Fellow	Transportation	Transportation Research
15	57	F	Senior Lecturer	Culture Industry	Art-Science
16	31	M	Research Fellow	Transportation	Transportation Research
17	31	F	Academic related	Information Service	Portal

Table E1 Background of the Informants

Community/group	Size	Age
Portal	16-20	12 months
Leeds Future	50	12 months
Robotics Design	200	8 months
Children	4	2 months

Transportation Research	15	5 months
Art-Science	6	4 months

Table E2 Community Background

4. Content Analysis of the Qualitative Data

Table E3 demonstrates the content analysis of the VKP users' feedback. Main issues raised in the user feedback have been coded into three categories: [i] motivations, [ii] perceived costs and [iii] perceived gains. Categories, sub categories, frequency of the words/phrases coded under the categories and percentage of the users who reported the issues are listed in the table.

Category	**Sub category**	**Word/Phrase**	**Frequency**	**% of user**
Motivation	Geographically distributed knowledge-sharing	(location)Distribution/distributed	19	88%
		Distance/distant	13	
		Not co-located/different locations	10	
		Separated/separate	4	
	Knowledge transfer from academia to industry or practice	Transfer/sharing	15	50%
		Cooperation/cooperate/collaboration/ collaborate (between academia and industry)	14	
		Industry	10	
		Apply/applied	6	
	Multi-disciplinary knowledge-sharing	Cooperation/cooperate/collaboration/ collaborate (between different discipline)	8	35%
		(sharing between) disciplines/subjects/research institutes	6	

Costs	Cost of efforts/time in knowledge-sharing interactions	Time	47	100%
		Activity/activities	23	
		Effort/efforts	18	
		Value/valuable	16	
		Job/jobs	14	
		Task/tasks	10	
		Providing/provide/ (help/assistance/knowledge)	9	
		Price (of effort/time)	7	
	Cost of efforts/time to learn to use the technologies	Time	47	70%
		Learning/learn	20	
		Effort/efforts	18	
		Familiar/familiarize	12	
		Price (of effort/time)	7	
		Train/training	6	
	Cost of knowledge resources	Private/privacy/sensitive	25	52%
		(giving out of) Documents/files/proposals/papers	19	
		Own/owned/ownership/owner	17	
		Permission/permit	13	
		Value/valuable	8	
		Price (of knowledge resources)	5	

Gains	Gain of knowledge resources obtained	(getting from others) Documents/files/proposals/papers	42	100%
		Get/got	35	
		Useful/helpful (documents/files)	33	
		Value/valuable	21	
		Receiving/received (documents/files)	18	
		Obtain/obtained	10	
	Social gains	(social) Status	14	47%
		Influence	14	
		Recognized/recognition	10	
		Leader/leadership	9	
	Positive organizational outcomes	Success/successful	12	30%
		Publish/publication	8	
		Achieve/achievement	5	
		Acceptance	4	

E3 Content Analysis of Users' Feedback

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