Can Peer-to-peer Networks Facilitate Information Sharing in Collaborative Learning?

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Abstract

Many peer-to-peer (P2P) networks have been widely used for file sharing. A peer acts both as a content provider and a consumer, and is granted autonomy to decide what content, with whom, and when to share. Is a p2p network an ideal vehicle for information sharing in collaborative learning? This study adopts the Theory of Planned Behavior as a basis to study the sharing behaviors on a P2P network. Due to the lack of empirical data, we built a P2P network platform to conduct an experiment in a collaborative learning setting. Through the analysis we found the intention of sharing is only positively related with subjective norm. Based on this result, we assert that subjective norm, especially the discipline from the instructor, plays a critical role in motivating students to share knowledge on a P2P network for collaborative learning. From this empirical study, a hybrid architecture combining P2P networks with servers could be more favorable for collaborative learning.

1. Introduction

Peer-to-peer (P2P) technology has been crowned as one of the four technologies that will shape up the next generation of Internet. However, studies on P2P networks have been mostly concentrating on intellectual property rights or technological architecture. It's a pity that the potential breakthroughs of P2P technology seem to be underestimated. Lethin [15] suggested that we should not understand and explore P2P networks only from technological viewpoints. When thinking of the potential P2P applications, we are soon attracted by its, innate sharing nature. Recall that people may not be willing to share their knowledge identified by many studies [16]. We may doubt that P2P networks are capable of sharing information rather than knowledge. As everyone knows, knowledge is an asset for individuals and organizations, and is increasingly distributed across individuals, teams, and organizations [21,22]. Therefore, the ability to create, acquire, integrate, and deploy distributed knowledge has emerged as a fundamental organizational capability. Individual learning and new knowledge creation occur when people combine and exchange their personal knowledge with others [11,12]. Thus, information sharing is an essential activity for knowledge creation and sharing.

Collaborative learning is a situation in which two or more people learn or attempt to learn something together [7]. We judge that P2P networks may facilitate information sharing in collaborative learning based on following reasons:

Perception of control on files. Since files are located in peers' computers, users may sense that they own these files and allow only qualified users determined by them to retrieve them. However, in traditional client/server learning platforms, once files are uploaded onto a server, users may lose control of these files, and anyone can access them easily. The sense of ownership and control power may encourage sharing behavior and facilitate information sharing in collaborate learning.

Maintaining peers' own knowledge maps. People learn through the processes of knowledge maps construction. In a traditional client/server framework, files are collected from various sources, and it's relatively hard to create and maintain personal knowledge maps. However, in P2P networks, because files are saved in users' private disks, they can create their knowledge maps with less effort. For each new file retrieved, an individual peer can categorize it, and in turn maintains its own knowledge map accordingly. In terms of learning process, this setting may be helpful for learners to trace learning paths.

Encouraging information sharing behavior through price mechanism. As we discussed earlier that information sharing is an essential activity for knowledge creation. Although the free riding problem has been identified in some P2P networks [1], we speculate that this problem can be somewhat resolved in the collaborative learning setting. If we embed certain token and pricing mechanisms in a collaborative learning setting, and grant tokens to

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students for their sharing, their file sharing behavior may be motivated. For example, we can design several interactive learning activities that students are asked to read and then comment others' opinions. By doing these, students are granted tokens which are included in the score. It's a process of learning by sharing based on the intrinsically sharing nature of P2P networks.

The main objective of this research is to investigate whether information sharing in collaborative learning can be effectively facilitated by P2P networks. In order to achieve this objective, we need to record peers' behavior on P2P networks, *e.g.*, what kinds of files they share, how frequent they share or download files, with whom do they share. Thus, we designed an experiment to perform collaborative learning activities on a P2P network, and, invited students to participate in this experiment through a semester. Via observing activities on the P2P network and collecting the transaction log between peers, we reviewed these objective data. In theories regarding user behaviors, this study employs the Theory of Planned Behavior (TPB, [2]) as the basis of research model. We designed questionnaires based on TPB model and ask students to fill them out during the experiment, so that we can understand the participants' subjective feelings. As a result, the objective transaction data and subjective survey help us to draw a more complete picture of the participants' behavior on a P2P network, and thereby, to gain insights into the possibilities of P2P network in a collaborative learning setting.

2. Literature Reviews

2.1 Peer-to-Peer Networks

A computer in a P2P network can perform as a content contributor and demander simultaneously. ,. In a P2P network without centralized management, peers are treated as distributed actors which contribute and consume digitized goods on the network.

The study developed a P2P system based on JXTA platform established by Sun Microsystems. JXTA is a network programming and computing platform that is designed to solve a number of problems in modern distributed computing, especially in the area broadly referred to as P2P computing or P2P networking. JXTA inherits three merits of design: *interoperability, platform independence,* and *ubiquity*.

Prior studies on P2P networks mainly focused on technological architecture or intellectual property rights. Some scholars suggested that more social or users' viewpoints should be incorporated in P2P studies [14,15,19]. For example, the problem of free-riding is an important issue exposed by Adar and Huberman [1], and it cannot be ignored when thinking of usages of P2P networks. They found that more than 70% of users on Gnutella network do not share any resource to the system, 90% do not answer any queries from others, and 50% of requests are satisfied by top 1% peers.

Besides, Lee [13] asserted if we want to improve P2P system, we should know what users are concerned about. He surveyed the features users may anticipate when P2P networks are taken into account. The result shows that price is the most important attribute they care about. They will use a P2P system when it is free of charge. The next feature is system efficiency. The P2P system used in this study is free of charge, and its speed and stability are satisfying because it's built upon JXTA architecture. Thus, we perceive that the applied P2P system may be free from user resistance.

2.2 Knowledge Sharing on P2P and Client/Server Networks

Evaristo and Desouza [8] compared knowledge sharing and management issues on both client/server and P2P networks in various aspects. Many studies report that members of organizations fear to share knowledge because they are afraid of losing their competitive advantages resulting from sharing too much personal knowledge. A client/server architecture inherits the delay from the moment the knowledge is created in individuals' minds to that it is posted to the server. Individuals may delay posting not only for gate-keeping purposes but also to allow for confirmation of events, sometimes to the point of irrelevance. For this way, the concept of real-time availability of knowledge may not be workable. Since individuals get used to store the draft notes and working documents of insights on their local repositories than on the main server, this concern is minimized in the P2P approach. Furthermore, on the P2P networks, there may exist dialogues among various agents of a team and develop a spirit of community, as each agent interacts with peers to gain knowledge. Hence, socialization and externalization are pivotal for tacit knowledge exchange. On the client/server architecture, once an author posts his/her knowledge to the server, the author may lose his/her control ability over knowledge access and usage. On the contrary, on a P2P network, individuals can choose what knowledge to share. Since individuals control their own knowledge repositories, they are less likely to view sharing of knowledge as a threat to their value [8]. Evaristo and

Desouza's findings are quite supportive to the reasons of knowledge sharing on P2P networks.

Besides, Davenport and Prusak [5] have illustrated knowledge sharing as a "market". They thought knowledge flowed in organizations, where existed "knowledge market". Market forces power the movement of knowledge in organizations. Like markets for goods and services, the knowledge market has buyers and sellers who negotiate to reach a mutually satisfactory price for the goods exchanged. Knowledge market transactions occur because all of the participants in them believe that they will benefit from them in some particular way. But for a mutual economic market, there are three roles acting in the knowledge market.

(1) Knowledge buyers are people trying to resolve an issue whose complexity and uncertainty precludes an easy answer.
(2) Knowledge sellers are people in an organization with an internal market reputation for having substantial knowledge about a process or subject. One of the challenges of knowledge management is to ensure that knowledge sharing is rewarded more than knowledge hoarding.
(3) Knowledge brokers (gatekeepers, boundary spanners) make connections between buyers and sellers.

In our study, our P2P network embedded with price mechanism plays the role as a knowledge market in collaborative learning. Details of the price mechanism are further introduced in the Section of research methodology.

3. Research Methodology

3.1 Research Platform

We have designed a P2P system, called SOKUL (Self-organized Knowledge Network for Ubiquitous Link). It is established upon JXTA platform and equipped with several typical P2P functions. SOKUL users can see which peers are online available after activating the SOKUL.

Instant message. Users can divide peers into subgroups and issue instant messages to communicate with other online peers, just as Microsoft MSN does.

Discussion board. Peers can post or reply messages on discussion board for other peers to read. A snapshot of instant message interface and discussion board is shown in Figure 1.

File sharing. Sharing files is the core function of P2P networks. On SOKUL, users can set the level of sharing to prohibit undesired peers to download their files (Figure 2). Partial match function is also available for users to locate target and related files. Moreover, peers can evaluate downloaded files, and comment on them; then, other users may judge whether these files are worthy of downloading or not according to these evaluations.

Price mechanism. To prevent from free-riding problem as identified by Adar and Huberman [1], SOKUL has embedded the pricing mechanism. Each student in a course is offered a certain number of tokens as virtual money initially. When their shared files or posted articles are bought, *i.e.*, downloaded by others, they earned the requested tokens. In contrast, if they want to buy (*i.e.*, download) others' files or posted messages, they have to pay labeled tokens. They can change the charges for specific files to earn more tokens, especially when the files have been evaluated as high quality. Every file also has its resell price listed, which means when someone purchases a file from the author, and then others buy the files from the downloader, they should pay the resell price to the original author, by the way to encourage creation and distribution.

Figure 1. The environment of SOKUL

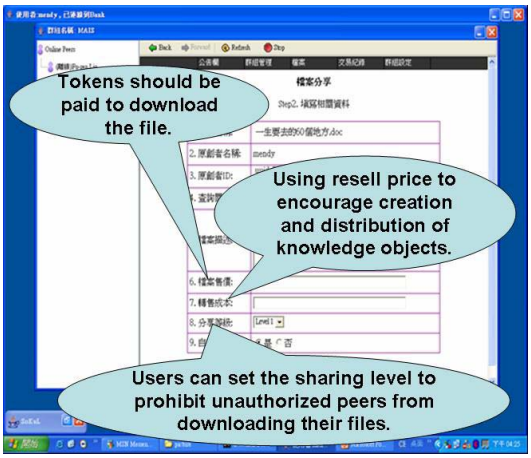


Figure 2. File sharing and pricing mechanism on SOKUL

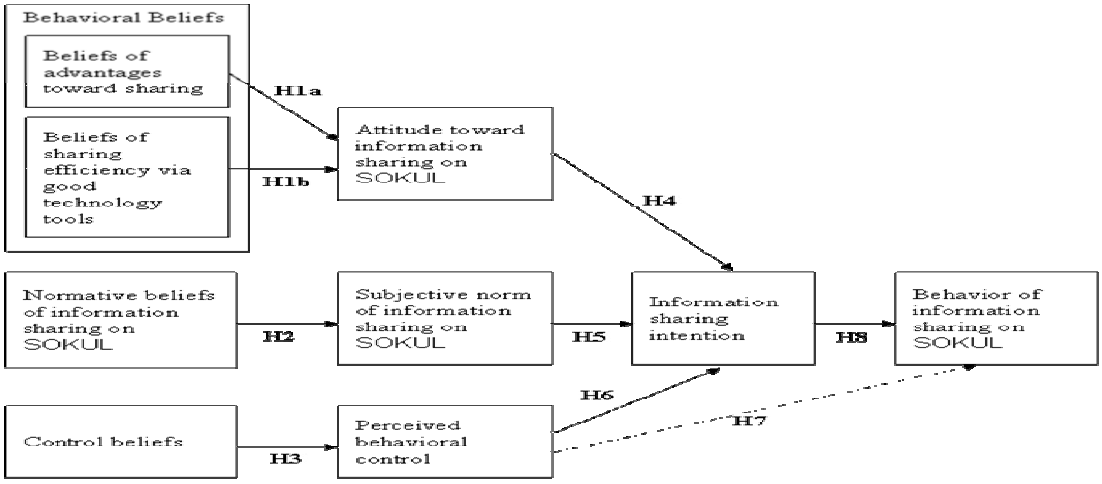


Figure 3. Research model based on TPB model

Portable design. Specially, SOKUL is allowed to be portable between different computers. Users can save SOKUL in USB devices such as flash disks or mp3 recorders. When plugging the USB device into computers, SOKUL will be automatically activated as a peer, so that users can act on any computer they want. After finishing the works on other computers, users can backup files to save into the USB device for later use. Such a portable design is convenient for students who do not have personal computers.

3.2 Research Model

In theories regarding behavior, we managed to employ TPB model as our research model and interpret our survey results for three reasons. First, as Oram et al. [19] stressed, the most important implication P2P networks offered is that it gives back the rights of contents, selection and control to users. Theory of Planned Behavior (TPB) model fits the best to this study than others related theories such as Theory of Reasoned Action (TRA, [3,9]) since TRA model neglects the construct of perceived behavioral control, which is an important dimension in our study. Second, Although Mathieson [17] asserted technology acceptance model (TAM, [6]) has been found to explain more variance than TPB; however, TPB provides more specific information regarding the factors that users consider when making a decision. Besides, TAM focuses more on the acceptance of technology; however, TPB emphasizes the factors and results of behaviors. Third, Armitage and Conner [4] analyzed 185 studies in various domains employing TPB theory, and almost all of them concluded with significant supportive evidences.

Figure 3 shows the research model based on TPB model. Comparing with original TPB model, this research model separates the behavioral belief into two parts: one is the personal belief of sharing action, and the other one indicates the belief of personal acceptance for information technology. To achieve research objectives, other constructs in original TPB model are adjusted in relation to information sharing on SOKUL accordingly. Figure 3 clearly points out the main constructs of this study, such as beliefs of information sharing, attitudes toward information sharing on SOKUL, subjective norm of information sharing on SOKUL, the influence of intention for information sharing, and finally the real behavior behaved by peers.

In the TPB model, behavioral belief is the subjective possibility by individuals that the behavior will result in a given outcome [2]. Considering peers' perception of using P2P software, we propose two aspects from peers' altruism and acceptance of information technology. On a P2P network, peers' subjective beliefs, for example, participating in information sharing activities will benefit both providers and receivers, and may influence their attitudes toward information sharing. Peers may consider sharing information if their kind behaviors are helpful to others; on the other hand, if their sharing indeed helps others, it may also benefit them; for example, their reputations will be raised. This leads to the first hypothesis:

H_{1a}: A stronger belief of the advantages toward sharing will lead to more positive attitude toward information sharing on SOKUL.

No matter how frequent the technology is updated or how new the technology is, the acceptance from users is the most important. In using

SOKUL as an information sharing platform, peers' belief of the relation between good technologies and information sharing efficiency may also influence their sharing attitudes. This leads to the following hypothesis:

H_{1b}: A higher level belief of sharing efficiency via a good technology tool will lead to more positive attitude toward information sharing on SOKUL.

Normative beliefs refer to the perceived behavioral expectations of such important individuals or groups as the spouse, family, friends, teachers, or coworkers [2]. In TPB model, because the expectation of those important referents will become the subjective norm for individuals, this kind of normative beliefs may relate to subjective norm of information sharing on SOKUL. This leads to the second hypothesis:

H_2: A higher level of normative belief toward participating in sharing activities on SOKUL will lead to a higher level of subjective norm for information sharing on P2P networks.

Control beliefs are related to the perceived presence of factors that may facilitate or inhibit the performance of a behavior [2]. As what Oram et al. [19] articulated, the most important social implication of P2P networks is that it returns the rights of contents, selection and control to users. However, whether users can beware that the power of control is a critical point. Users may have some concerns in reality, but they have to generate the beliefs after judging whether those concerns will really encourage or impede them to participate in information sharing activities. These control beliefs may result in the power of perceived behavioral control. This leads to the third hypothesis:

H_3: A higher degree of control belief will lead to a higher degree of perceived behavioral control toward information sharing on SOKUL.

According to TPB model, individual's attitudes toward the behavior have to do with the intention to perform the behavior. In this research, peers' attitudes may also influence on their intentions to share information or participate in any information sharing activities. This leads to the fourth hypothesis:

H_4: A more positive attitude toward information sharing on SOKUL will lead to a greater intention for information sharing on SOKUL.

The subjective norm in TPB model is defined as perceived social pressure to perform or not to perform a behavior [2]. In the domain of information sharing, some studies support that subjective norm will influence intention [20]. This study will investigate the relation between subjective norm toward information and personal intention. It leads to the fifth hypothesis:

H_5: A higher level of subjective norms toward information sharing on SOKUL will lead to a greater intention for information sharing on SOKUL.

Ajzen [2] stated that intention is not only decided by personal attitudes and subjective norm, it should also include a person's perception of his/her ability to perform a given behavior. Only under greater control abilities, then, the intention may be generated; furthermore, the behavior may be directly performed. On a P2P network, peers have to be conscious of their control abilities of some factors, and then it may influence the intention and behavior of information sharing. This leads to the sixth and seventh hypotheses:

H6: A higher degree of perceived behavioral control will lead to a greater intention for information sharing on SOKUL.

H7: A higher degree of perceived behavior control will have positive effects on an individual's sharing behavior on SOKUL.

Because intention is closer than attitude and subjective norm to real behavior, if we want to predict someone's behavior, we have to understand his/ her intention at first [9]. This leads to the eighth hypothesis:

H8: A greater intention to share information on SOKUL will have positive effects on an individual's sharing behavior.

3.3 Experimental Design

We chose a class from the Department of Information Management of a university in central Taiwan, and invited students in a Management Information System (MIS) class to participate to the experiment. The experiment lasted 10 weeks (from 03/07/2006 ~ 06/07/2006). One class consisting of forty-nine students is randomly divided into six groups. Every group had to deliver their group reports about industries or companies related to MIS topics every week, and students were encouraged to share their reports on SOKUL. We arranged several learning activities and ask students to interact through the platform. We incorporate price mechanism and ask students to read and synthesize others' shared texts. Their grades are partially determined by the tokens. Therefore, they have to buy and sell files to complete their learning activities. In other words, they have to read and integrate others' opinions and then making comments.

Through the process of combination, synthesis and critical thinking, knowledge can be created or shared. Then, through the internalization process, they can build their own knowledge structure. Learning by sharing is the anticipated educational process. If a student plays the role as a free rider, he'll run out of tokens and get a bad grade. Through the pricing mechanism, the P2P platform has formed some sort of knowledge market as mentioned by Davenport and Prusak [5].

After eight weeks of experimentation, we distributed questionnaires to students and collected answers in the class. The questionnaire is shown in Appendix. At the end of the experimentation, we used the data from questionnaires to analyze and compare the results with the log data from SOKUL to assess whether what subjects thought really matched with what they behaved.

4. Research Results

4.1 Experimental Results

We recorded students' interactions on SOKUL during the experimentation. The activities of sharing information were not active. As we can see in Table 1, the means of every online activity are low. The frequency of login is higher, which indicates most students would sometimes login onto SOKUL and see what is going on. But they usually remained inactive.

The behavior of reply is lower than expected, which means students are not eager to participate. To see what kinds of information shared on SOKUL, we look further into the contents and categorize them as six types. Acknowledgement means transferring confirmation message. Emotional expression denotes interflows of emotional expressions between members. House keeping stands for coordination messages. Information exchange is to share information or experiences relate to their tasks with members. Idea release signifies actions proposing ideas or suggestions toward some topics. Creative revision integrating knowledge, documents or experiences into new knowledge objects. House keeping and information exchange are comparatively higher, which means they primarily adopted SOKUL for coordination and providing related information. Fewer deep discussions or emotional interflowing between students were incurred.

As for file sharing, they viewed SOKUL as a platform for handing over assignments and data storage. Interestingly, they seemed not concerning about what others have done because downloading personal reports are quite few.

Knowledge market is not functioned well. They seldom bought others' documents. The behavior of reselling is very few, again, which denotes they are not care about what others sold on SOKUL.

Pearson correlation coefficients with attitude are general low. Only behavior such as posting information and uploading files has higher values. They are typical sharing behavior, but it's interesting that reply may not be considered as sharing behavior because the coefficient is low.

In order to dig out students' thoughts, we also interviewed eighteen students to understand their opinions toward information sharing on SOKUL in the class.

4.2 Statistical Results of Hypothesis Test

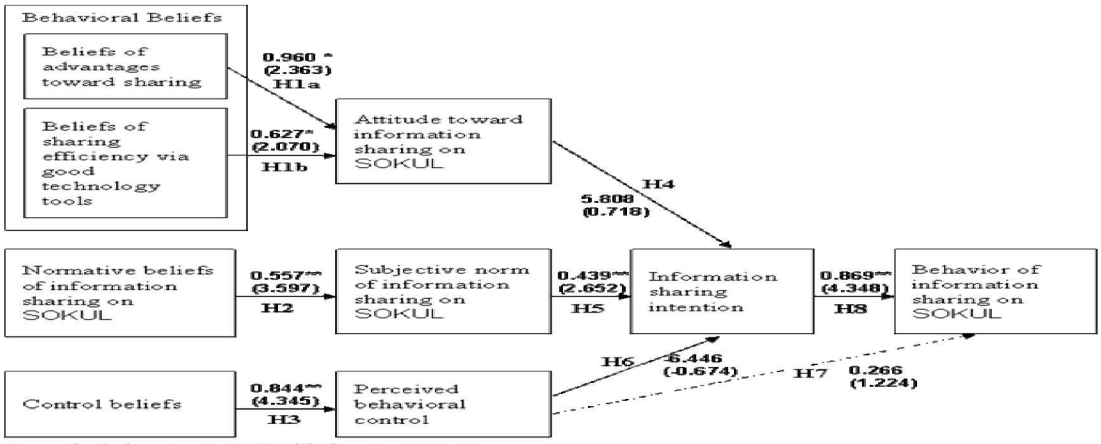
Table 1. Summation of user behavior on SOKUL

		Frequencies							Correlation with Attitude
		Mean	Category						
			Acknowledge	Emotional expression	House keeping	Information exchange	Idea release	Creative revision	
Discussion Board	Post	2.16	6	11	35	42	4	8	0.55
	Reply	0.96	10	8	10	12	2	5	0.24
			Task-related resources	Irrelevant documents	Personal reports				
File Sharing	Upload	1.55	41	3	32				0.68
	Download	2.86	124	2	14				0.19
Token	Buy	0.47							0.22
	Resell	0.06							0.08
Login		10.22							0.20
Online Time		166 min							0.12
Instant Message		1.38							0.35

Before conducting the statistical analysis of experimental results, we have to test the reliability and consistency of the questionnaire. According to Nunnally [18], reliability analysis can be examined by Cronbach`s alpha value. If $\alpha$ is greater than or equal to 0.7, the questionnaire can be treated as a reliable probe. The Cronbach`s alpha value is 0.8994 in this study, which indicates that the questionnaire is reliable. We use the Structural Equation Model (SEM) to test the model and hypotheses. We tested the result of goodness of fit statistics of the proposed model, and compares suggested fitting indices by Hair et al. [10]. We found that χ^2 ratio (χ^2=2.19) and Root Mean Square Residual (RMSR=0.1) meets the suggested values; however, Goodness of Fit (GFI=0.53), Comparative Fit Index (CFI=0.53) do not meet suggested ones. We contribute the reason to the small size of students in the class. The result shows the attitude toward information sharing on SOKUL is positively influenced by beliefs of advantages toward sharing (γ = 0.960, p-value < 0.05) and beliefs of sharing efficiency via good technology tools (γ = 0.627, p-value < 0.05). This significance means that the attitude will be influenced by the personal beliefs. Thus, H_{1a} and H_{1b} are supported. Regarding the subjective norm of information sharing on SOKUL, it is positively influenced by normative beliefs of information sharing on SOKUL (γ = 0.557, p-value < 0.01); thus, H_2 is significantly supported. Perceived behavioral control is positively influenced by control beliefs (γ = 0.844, p-value < 0.01); thus, H_3 is also significantly supported. Information sharing intention is positively influenced by subjective norm of information sharing on SOKUL (β = 0.439, p-value < 0.01); thus, H_5 is significantly supported. Other constructs, such as attitude toward information sharing on SOKUL and perceived behavioral control, have no significant evidence to show that these two constructs have any positive or negative influence toward information sharing intention; thus, H_4 and H_6 are not significantly supported. Finally, the behavior of information sharing on SOKUL is positively influenced by information sharing intention (β = 0.869, p-value < 0.01); thus, H_8 is significantly supported. There is no positive or negative influence between perceived behavioral control and behavior of information sharing on SOKUL, which indicates that H7 is not supported. Figure 4 portrays the outcomes of statistical analysis of experimental result, and factor loadings are listed in Table 2.

4.2 Discussion

From the statistical analysis of experimental results, subjects believed that their attitude toward information sharing on SOKUL was positively influenced by their behavioral beliefs, their subjective norms were positively affected by their normative beliefs, and their perceived behavioral control was positively influenced by their control beliefs. However, subjects' information sharing intention is only significantly related to subjects' subjective norms in this study. Subjects' attitudes toward information sharing and perceived behavioral control do not significantly affect their intentions to share information on SOKUL. In order to dig the meanings behind this outcome, we interviewed the instructor and eighteen students individually. These students are randomly chosen from three different kinds of behavioral performance on SOKUL. They are actively, occasionally, and never participating on SOKUL, respectively. Each category has six interviewees. We designed questions based on the experimentation and statistical results to ask them in order to seek mental thoughts from subjects with different participation patterns.



*Remark: * denotes P<0.05; ** denotes P<0.01*

Figure 4. Statistical results of hypothesis tests

Table 2. Factor loadings

	Beliefs of advantages toward sharing	Beliefs of sharing efficiency via good technology tools	Normative beliefs of information sharing on SOKUL	Control beliefs	Attitude toward information sharing on SOKUL	Subjective norm of information sharing on SOKUL	Perceived behavioral control	Information sharing intention	Behavior of information sharing on SOKUL
Y1	0.63								
Y2		0.60							
Y3		0.69							
Y4			0.94						
Y5			0.88						
Y6				0.77					
Y7				0.82					
Y8					0.85				
Y9					0.57				
Y10					0.70				
Y11					0.71				
Y12					0.66				
Y13					-0.05				
Y14					-0.29				
Y15						0.94			
Y16						0.60			
Y17							0.63		
Y18							0.88		
Y19							0.46		
Y20							0.80		
Y21							0.59		
Y22							0.75		
Y23							0.67		
Y24								0.76	
Y25									0.81
Y26									0.81
Y27									0.78
Y28									0.69

We found personal attitude toward sharing was not positive, no matter on SOKUL or other P2P environment. Although these students represent three different usage behavior of SOKUL, none of them was quite enthusiastic in sharing. Knowledge market was not functioning as expected. According to the results of interview, we identify that their personal attitudes toward information sharing were not positive even on other P2P platforms. From statistical analysis results, we found no explicit relations between attitude and intention as we anticipated. The acceptance of SOKUL from students was not high either. By reviewing the raw data, the average scores of these questions were not high. We could neither identify any relations from perceived behavioral control to intention nor to behavior. In other words, there is no evidence showing that students have any control ability to have the intention for sharing information on SOKUL or to perform the behavior of information sharing on SOKUL. Moreover, students have already gotten used to use Microsoft MSN, and most of them lived in the dorm. Under this circumstance, sharing information and files face-to-face via flash disks or through Microsoft MSN becomes very easy for students; SOKUL is not the only means they can use. Furthermore, without any urgent purpose, they also expressed that client/server environment would be more suitable for them to download useful information. In the client/server architecture, when they want to download at anytime, they don't have to wait for owners of files being online. Although they can posses the ownership of files through P2P platform such as SOKUL, and decide whether to share or withhold the files from specific peer, these students didn't show their perception on this feature. On the other hand, they emphasized the speed of information exchange in the collaborative setting and suggested the adoption of traditional client/server architecture. Surprisingly, three interviewees from inactive category view the sense of ownership of files as obstacles to collaborative learning.

The results present that subjective norm of information sharing on SOKUL has positive influence on the intention of sharing information. It reflects the truth that students tend to behave what instructors or classmates expect. From the results of thoroughly examining the raw data, we found students didn't have high consciousness of encouraging each other to share information or files on SOKUL. Indeed, they didn't care about whether their classmates had actively participated collaborative learning activities on SOKUL or not. Contrarily, the scores from questions 15 and 16 show that students concerned more about the instructor's expectation and request than their classmates'. These interviewees expressed that if the instructor continually showed his expectation on them to

actively interact on SOKUL, they would be obedient. The instructor played a more important role in influencing students' behaviors of sharing information on SOKUL than classmates did.

We speculate that a P2P network may not be a suitable platform for students who live in the dorms. Other settings that students live remotely, for example, those attending extended education, may be more suitable for P2P networks to facilitate students' communication and sharing. Besides, in designing collaborative learning activities, P2P networks may be more suitable for synchronous activities, such as exams, homework delivery, or online discussion. For asynchronous activities such as bulletin information and file sharing, traditional client/server architecture has proved to be competent. We infer that a hybrid system which combines P2P networks and client/server architecture may be more favorable for collaborative learning, which could be a topic for future research.

5. Conclusion

In this research, we firstly argued that a P2P network is a good platform for sharing information effectively. We verified this argument by conducting an experiment on a P2P system, called SOKUL. We invited a class of undergraduate students to use SOKUL to support their collaborative learning activities. We used TPB model as the basis of the research model to assess factors which influence students' information sharing on collaborative learning activities on SOKUL. We collected answers from questionnaires distributed to subjects, and used Structural Equation Model to verify and analyze hypotheses. According to the analytical results, subjective norm is the critical factor to affect the subjects' intention of sharing information in collaborative learning activities on P2P networks. Based on this result, we assert instructor should spend efforts to increase the atmosphere of subjective norm for collaborative learning on P2P networks. It is difficult to collect interaction data from real world since users of P2P networks tend to be anonymous and distributed on the Internet. By conducting experiments, we narrow down the unknown and a wide range of peers on P2P networks, so that we can successfully reach research objectives to observe and investigate peers' real behavior. Findings from the experiment can serve as a foundation for others who are also interested in the field of empirical study for P2P networks in the future.

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Appendix: Questionnaire

A. Background:

1. Have you ever shared files by uploading/downloading?
   □ Yes □ No
2. If yes, how long is the period since your first time to upload/download?
   □ Less than one year □ 2 year □ 3 years □ 4 years □ More than 4 years
3. Have you ever used other P2P software to upload/download files before?
   □ Yes □ No
4. For SOKUL, how often do you use?
   □ Several times a day □ Once a day □ Once 3 days □ Once a week □ Once 2 weeks
5. Each time when you invoke SOKUL, how long did you keep it running?
   □ Less than 30 minutes □ 1 hour □ 3 hours □ Half a day □ All day
6. What is the percentage that you run SOKUL on your own computer?
   □ 0%~20% □ 20%~40% □ 40%~60% □ 60%~80% □ 80%~100%
7. What is your network type?
   □ Modem □ Cable □ ADSL □ Wireless □ LAN

B. Items (Five Scale)

1. I believe it helps others' learning by sharing files on SOKUL in this semester.
2. Being helpful to others will also benefit myself.
3. I believe that good technology tool, like SOKUL, can improve sharing efficiency.
4. My classmates and instructors expect that I should actively participate in information sharing activities on SOKUL in this semester.
5. Generally speaking, I want to meet what my classmates and instructors expect me to behave in school.
6. I expect that my schoolwork will place high demands on my time in this semester.
7. My schoolwork placing high demands on my time in this semester will make it difficult for me to participate in information sharing activities on SOKUL.
8. I think uploading information on SOKUL in this semester will improve knowledge sharing.
9. I think downloading information from others on SOKUL in this semester will increase my knowledge.
10. I think the behavior of uploading / downloading information on SOKUL in this semester is good for knowledge sharing.
11. I think the behavior of posting / replying questions on SOKUL in this semester is good for knowledge sharing.
12. I think information sharing on SOKUL in this semester is efficient.
13. I think SOKUL is a good technology tool for communicating, sharing, and learning.
14. I think it is pleasant for me to use SOKUL for communicating, sharing, and learning in this semester.
15. My classmates and instructors in school will support me in participating in the information sharing activities on SOKUL in this semester.
16. Most classmates who are important to me actively participating in the information sharing activities on SOKUL in this semester.
17. It is easy for me to upload and download information on SOKUL in this semester
18. It is easy for me to post and reply questions or information on SOKUL in this semester.
19. It is useful for me to share files with others by uploading and downloading on SOKUL in this semester.
20. It is useful for me to share with others by posting and replying questions and information on SOKUL in this semester.
21. If I want to, I can use SOKUL as a good information sharing tool.
22. I can fully control over using SOKUL.
23. It is mostly up to me whether or not I use SOKUL for information sharing, communicating, and learning
24. I intend to get familiar with SOKUL actively in this semester.
25. I will actively upload any useful information for others on SOKUL in this semester.
26. I will actively download any information I need from other peers on SOKUL in this semester.
27. If I encounter any problem or have any news, I will actively post it on SOKUL in this semester.
28. If I see any question posted on SOKUL and I have the ability to solve it, I will actively provide my responses in this semester.