# Knowledge Management in Scientific Labrotories: A Survey-based Study of a Research Institute*

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**ABSTRACT**

Research on knowledge management in academia is recently becoming a hot issue and a promising research area. This paper concentrates on understanding the problems of knowledge creators per se, as disclosed in field research by a survey of the scientific knowledge management and creation process in one research institute. By using comparison, classification, cross tabulation, and other analysis methods, some subtle issues and hidden problems have been discovered in this survey. Along with these findings, we also present our corresponding analysis and propose a system thinking framework for knowledge management (KM) in scientific labs, which described here is seen as an effort to properly put all the organizational variables into best use with the support of relevant information technology to facilitate the KM process with the main research purpose of labs through the acquirement and creation of knowledge sources.

**Keywords:** knowledge management, laboratory knowledge management, scientific knowledge creation

## 1. INTRODUCTION

Although knowledge management (KM) has gained very tremendous and quick development in the business field in the past more than decade, it is only recently that some researchers and scholars have realized it is important to apply KM practice to facilitate the scientific knowledge creation in academia [1][2]. As we know, universities and research institutes as a social community play a vital role in creating and transmitting scientific knowledge, which is the fundamental source and driver for society progress and development. Thus, enhancing the creativity as well as the management of knowledge in academia is quite significant to the world.

In research institutes, a laboratory is an academic space and a basic organization entity devoted to produce scientific knowledge and emerge technology. As mentioned in Nakamori [3], "it is vital to begin to continuously and systematically develop the theory of technology creation, verifying the theory in scientific laboratories, and improving the theory by feedback from practice". In the work described here, we focus on KM in academia, especially the process of scientific research and scientific knowledge creation in scientific laboratories. Our goal is to investigate their current situations, special and diverse requirements as well as complaints, and to discover both their hidden troubles and obstructions and the corresponding underlying reasons, so as to improve creativity support and decision-making throughout the research institute, thus advancing and improving the creation of scientific knowledge.

The most important contribution of this paper is that it is from a novel viewpoint to analyze this problem and put forward a systems-thinking framework for knowledge management in scientific laboratories. The point is that our study is based on the feedback of knowledge creators in a typical knowledge creation organization, which makes our analyses and conclusions more comprehensive and persuasive from both theoretical and practical point at view.

The rest of this paper is organized as follows. Section 2 presents an overview of the survey and the outlines of the survey results. The analyses as well as discussions with respect to the survey findings are presented in Section 3, along with our suggestions and perspectives. Section 4 contains concluding remarks and discusses future research possibilities.

## 2. A KNOWLEDGE MANAGEMENT SURVEY

### 2.1. Methodology of Survey

Our target institute is a relatively new (1990) Japanese national institute, established to do research at the

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highest levels in selected fields of science and technology. We considered this institute to be a representative research institute for our study, because: (1) It consists of three schools: Material Science, Information Science and Knowledge Science. In term of knowledge management, they are typical representatives for the study of basic, information, and interdisciplinary science. (2) It enrolls only master students and doctoral students. From this point of view, it is more like a knowledge creating organization than a general educational organization, such as a university that includes undergraduate college students. (3) There is a high proportion of foreign students and scholars, which enables a comparison between natives and foreign scholars.

The respondents of this survey included all students (doctoral students and master students), post doctors and research associates/assistants. We did not include professors because we considered that they were a different group who used quite different methods to do their research as compared with our designated respondents, which would make it difficult to get valuable information from the same questionnaire. In the survey we also considered many contributing factors, such as knowledge management technologies, personal IT skills, cooperation environments, laboratory knowledge management (LKM), knowledge sources for research, creativity support, and life environments.

### 2.2. Important Findings

#### 2.2.1 Personal IT Skill and Technical Support

The respondents were asked to describe their personal IT skills in order to explore the relationship between personal IT skills and efficient personal knowledge management. In Fig. 1, about 73.58% of respondents in School of Materials Science (MS) could only use the computer to deal with basic applications and operations, such as writing papers with text processing software, and less than 16% of them thought that their IT skill was excellent or good; while this ratio was up to 82.76% for respondents in School of Information Science (IS). The school of Knowledge Science (KS) is the middle level compared with IS and MS.

As we know, the laboratory homepage is not only a portal (or introduction) for outside researchers, but more importantly, is also a significant knowledge source or "database" shared by all the members of that laboratory. If we focused on the homepage in the various school (see Fig. 1), we found that from IS to KS and then MS, the complaints (very unsatisfied and somewhat unsatisfied) on the construction of lab homepages increased largely and quickly. In combination with the previous results, we found that not only do the IT skills of the researchers themselves limit efficient personal knowledge management to some extent, but also that the unevenness of technical support should be seriously regarded and improved.

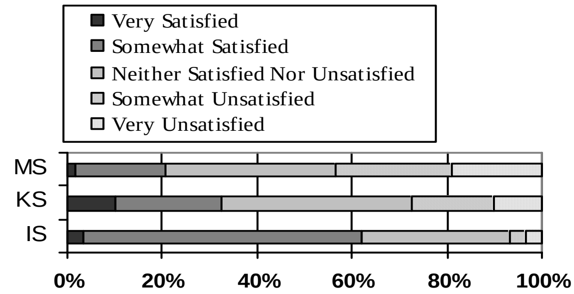


Fig.1. Satisfaction with lab's homepage.

#### 2.2.2 Use Extent of IT in Lab

The survey sought to establish the use of technology to support a laboratory knowledge management strategy. The most notable aspect of technology use in laboratories, as reflected in the survey responses (see Fig. 2) is the extensive use of text processing and presentation software (85%), and of Internet and on-line databases(81%), and search engines(87%). That is a natural result for researchers and students, because those are basic tools for expressing research result and searching relevant research information. In addiction, on-line chatting software and document repositories were also widely used (used extensively or a certain extent) in the laboratories (63% and 51%).

But we also can see that more than 50% of respondents had no plans to use BBS or electronic bulletin board in their laboratories; further, more than 60% had no plan to use data warehousing and data mining, groupware such as IBM Lotus Notes as well as video conferencing, all technological tools which are often regarded as effective tools for knowledge management in the business area.

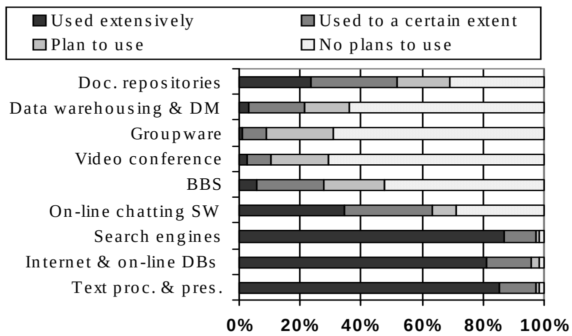


Fig.2. Technologies used in lab.

### 2.2.3 Knowledge Source of Researchers

Scientific knowledge creation involves five major integrated research activities *corresponding to the five dimensions of i-System* [3][4], as represented in Fig. 3. Researchers (not including professors, as we defined in Section 2.1) usually get support and help from four knowledge sources: their supervisor or professor's guidance and advice, their colleagues' cooperation and help, self-study, and help from outside scholars. To clarify the relationship as well as the influences between the knowledge sources and the research activities, we designed this question that asked the respondents to rate the corresponding knowledge sources on the level of their importance to their research activities.

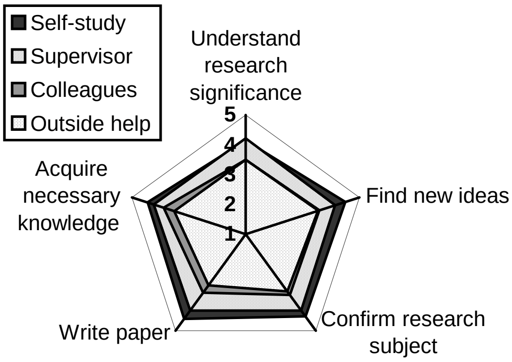


Fig.3. Important of knowledge source to different research activities.

As shown in above figure, for all research activities except "understanding the social and practical significance of the research", the order of the importance of the knowledge sources is the same, that is, self study > supervisor > colleagues > outside help.

### 2.2.4 Laboratory Management

When asked about the satisfaction on the factors related to laboratory management, only 56.56% of the respondents were satisfied (somewhat satisfied or very satisfied) with the device management of laboratory (experimental apparatus, computers and software management); while the satisfaction with the other items (document management, equipment usage training and lab homepage) was less then 50% for all and decreased in turn (see Fig. 4)

### 2.2.5 Evaluation of Seminar and Group Discussions

When asked to evaluate the effect of regular laboratory seminars or group discussions, there was no big difference between native (Japanese) and foreign (non-Japanese) researchers as we expected. But when asked about the reasons for their dissatisfaction, they gave different weights to the various reasons. As shown in Fig. 5, 76.92% of foreign respondents thought that language was one of the important reasons for inefficient or meaningless seminars, compared with only 23.08% of Japanese respondents (notice this was a multiple choice question, and the totals given here were considered by respondents as individual responses to each reason/factor). A reason behind this phenomenon is that at JAIST only masters-level courses require foreign students to have good Japanese language ability, but for doctoral courses, English is enough. Thus, if a foreign PhD candidate who is not good at Japanese attends a seminar or group discussion, but the speaker can only speak Japanese (suppose the speaker is a Japanese masters student and not good at English), undoubtedly that seminar will be meaningless and quite tedious for him. Unfortunately, this case is quite common because of the labs' seminar regulations (60.7% respondents said they had regular meeting at least once a week) or for other reasons. In contrast to this case, another interesting phenomenon is that significantly more Japanese respondents than foreigners complained that the atmosphere of discussion were not open and free, the topics were not related to her/his interests (there were various unrelated research topics in the lab), and/or there were some other reasons for dissatisfaction.

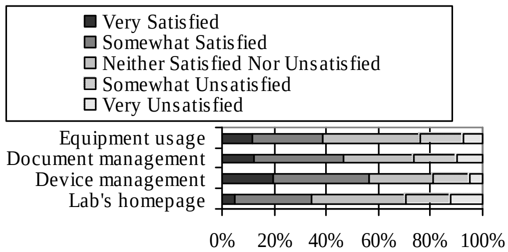


Fig.4. Satisfaction with the factors of laboratory management.

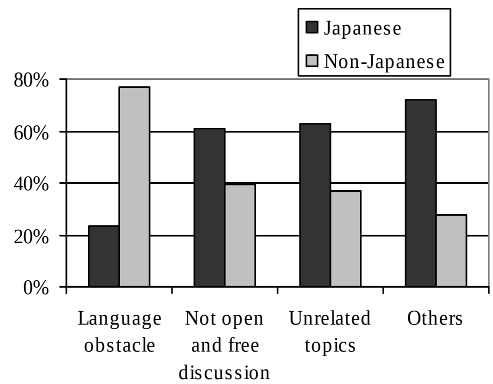


Fig.5. Obstructing factors to efficient seminar or group discussion.

### 2.2.6 Research Cooperation

When asked whether the respondents joined one or several self-managed or appointed teams composed of individuals capable of learning from each other, 42.62% of the respondents selected "No, I almost always work alone". Compared with another question – "when you encounter problems and feel depressed, could you get encouragement from others", we found that the respondents who worked alone also got much less timely encouragement and help from others at the same time (see Fig. 6).

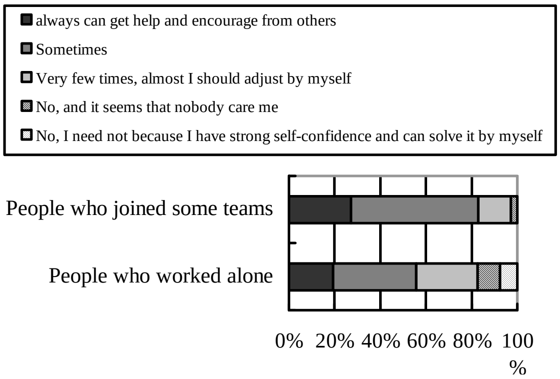


Fig.6. Encouragement and help from others when encountering problems or feeling depressed.

As we know, timely outside encouragement and help is a very important factor in study, it can affect a person's mood and moral, and have a further impact on their study efficiency, performance, and achievement. Thus, from this point of view, we can not say that cooperation is a trivial factor in scientific knowledge management and creation, but rather that is a weak point that should be reinforced and improved.

### 2.2.7 Most Difficult Problem in Research

When asked about the most difficult problem in their research according to the definitions of research activities in Fig. 3 (with the addition of one more factor, "do experiments", which is a vital research activity for those in the hard sciences), almost 30% of the masters students respondents thought that *acquiring necessary knowledge and information* was their biggest problem, which was also true for post doctors (about 33.33% of them). 50% of PhD candidates selected how to *find new ideas in their research subjects*. The results for research associates seem even for each factor.

### 2.3. Survey Conclusion

The image as defined by the respondents shows both positive and negative characteristics in the survey. On the positive side, there was a high awareness of knowledge issues, knowledge resources, and the concept of knowledge management. And 74.6% of the respondents believed (strongly agree and agree) that successful KM in lab can largely encourage every member to contribute and share experiences and ideas. But some results were negative, in that they showed there were still some serious obstacles and hidden problems preventing efficient knowledge management and personal research. Some important findings as well as the conclusions discovered by this survey are as follows:

- There is a serious disparity in the technical supports and average personal IT skill between the different schools at this institute.
- The respondents are not familiar with or have not understood the function and advantage of IT tools in the process of managing knowledge.
- There is no systemic KM framework for the scientific research in the lab. In this case knowledge is highly fragmented and inefficient to access what, when and where needed.
- Many respondents feel that they are not sufficiently supported in acquiring necessary knowledge, forming ideas and lack scientific corporation and dispute.
- The most difficult research problem varies with respect to respondents of different status, such as master's students and PhD candidates.
- Some varying requirements and obstacles between foreign researchers and Japanese have also been exposed.

Summarizing the above analysis, we think a system thinking framework for KM in scientific laboratories is highly needed.

## 3. SYSTEMS THINKING FOR KM IN SCIENTIFIC LABORATORIES

Knowledge management deals with the management of knowledge-related activities [5][6]. A number of individuals and organizations have developed frameworks for knowledge management, but many of KM frameworks focus only on the knowledge cycle process or tasks. Other critical elements of KM such as integration of KM with the organizational goals, the people involve in KM activities, and cultural context are neglected [7][8][9]. Thus, systems thinking is necessary and benefits to adequately fulfill the knowledge management needs of organizations.

Systems thinking is a conceptual framework for problem-solving that considers problems in their entirety [10]. Problem-solving in this way involves the relationships between the various parts of the system and the approaches that enhance understanding of, and responsiveness to the problems. Regarding an *overseeing* framework, systems thinking can strengthen the effects and efficiency of KM.

Based on the analyses given in Section 2, for knowledge management in scientific laboratories to be consistent with systems thinking, it should consider the entire KM factors, for example, research goals, knowledge, technology, learning and sharing, people and cultures, etc. *These parts can be classified as knowledge source, technological infrastructure, organizational variables and KM processes.*

**3.1 Knowledge Source**

What is knowledge? There were a lot of discussions concerning knowledge. The definition of "justified true belief" was introduced by Plato, which is often quoted as a definition of knowledge in the philosophy. That is, knowledge can be described as a belief that is justified through discussion, experience, and perhaps action. Actually, knowledge can be classified from different perspectives. For example, Polanyi [11] indicated that human knowledge exists in two forms: explicit knowledge (written, codified and formalized) and tacit knowledge (internal, highly personal and unformulated).We can share knowledge with others by exchanging information in appropriate contexts, since the shared knowledge is not only explicit knowledge, but also tacit knowledge. In the process of knowledge management practice, improved knowledge sharing is the most difficult problem [12]. The quality of the knowledge to be transferred/learned (tacit versus explicit) affects knowledge sharing [13]. Tacit knowledge is created solely by individuals, whereas explicit knowledge can be acquired from external sources. Because of disparate characteristics of two categories of knowledge, we should treat them differently. Goh [14] suggested that tacit knowledge demanded a 'softer' and more interpersonal means of transfer but explicit knowledge required a 'harder' and more technologically driven approach.

Associated with the *i*-System theory [4] and analysis in Section 2.2.3, if we hope to solve problems (Intervention), usually we can search required knowledge from three important dimensions -- scientific, social and creative dimensions (intelligence, involvement and imagination). And then we construct the new knowledge or systemic knowledge (Integration) from above three fronts. And usually, researchers can get support and help from four knowledge sources to finish this process: their supervisor or professor's guidance and advice, their colleagues' cooperation and help, self-study, and help from outside scholars. As can be seen in Fig. 3, for all research activities except "understanding the social and practical significance of the research", *researchers regard self study as the most important factors.* At the same time, we found, to masters student, how to *acquire necessary knowledge and information* was their biggest problem (Section 2.2.7).

From above analysis, knowledge as the footstone for scientific creation, it self is the most important factor to effective KM implementation. We should firstly address the different knowledge source and knowledge types, and then treat the corresponding and right way to acquire them. A corporate listing of people who are knowledgeable in a particular area is one way of organizing tacit knowledge, whereas a computerized knowledge map would be more relevant for explicit knowledge [9]. Likewise, face-to-face conversations, group meetings, academic seminar and forums are better for transferring tacit knowledge whereas shared lessons-learned databases, groupware and electronic data interchange are more appropriate for explicit knowledge. From that point, Information Technology (IT) shows its strong properties to better knowledge acquiring and sharing. The second element of KM framework in laboratories is technological infrastructure.

**3.2 Information Technology Infrastructure**

The interlinked information technologies employed be an organization form its IT infrastructure. For KM, the role of IT infrastructure is to support knowledge repositories, enhance knowledge access and transfer, and facilitate the knowledge environment [15]. It can also enhance the interaction of individual, group, organizational, and inter-organizational knowledge [13]. IT has inborn properties in better organizing our current knowledge and effectively guiding us in searching and learning the right things from right people/place at right time.

The current IT has powerful functions, such as text and data mining, fast data search and sort, classifying data and similarity finding among information, and these have a high potential to notice us hidden information and knowledge behind the huge amount of data and inspire our creativity. In business area, there is successful experience to implement IT-based knowledge management system to support and enhance the life cycle of organization's knowledge. Hence, it is natural that IT as knowledge enabling tools may also benefit the process of *scientific knowledge creation* in academia.

The survey result analyzed in Section 2.2.1 shows that not only do the IT skills of the researchers themselves limit efficient personal knowledge management to some extent, but also that the unevenness of technical support among different schools exists. It should be seriously regarded and improved. For better communication and cooperation, we should provide more technical support and help to researchers who are not familiar with basic network and programming technologies/knowledge. On the other hand, some technological tools which are often regarded as effective tools for knowledge management in the business area are not recognized in academic labs (Section 2.2.3). It is to say the predominance of technology in promoting knowledge integrating, discovering and sharing has not yet been brought into play in lab. The effective IT supporting will enable and facilitate the communication within researchers, collective learning, information and knowledge sharing, collaborative problems solving and new idea generation. For example, web-based knowledge repository for storing and sharing knowledge among researchers, Bulletin Boards System for discussing and communicating to capture the knowledge residing in the mind, an online videoconference for transferring and integrating knowledge from partners abroad or other experts. Therefore, a well supported IT infrastructure should be taken into account by research managers or organizers.

In addition, the application of technology also depends on the people and the support of the management, which are organizational issues. Organizational variables will effect the KM implementation.

### 3.3 Organizational Variables

In Section 2.2.3, the survey reveals a significant difference between business and academia with respect to knowledge management and creation: researchers in academia regard self study and the guidance of their leader (supervisor) as the most important factors, and put cooperation in a secondary place; while in business activities and projects, cooperation and team work is always regarded as one of the most fundamental factors. A related result is analyzed in Section 2.2.6; near half of the respondents almost always work alone. Compared with another question (see Fig. 6), we found that the respondents who worked alone also got much less timely encouragement and help from others at the same time. So, the problem is, do researchers r*eally not need cooperation very much, or we should improve our management as well as people's cognition of cooperation to encourage team work?* We realize that because of the characteristics of scientific research, cooperation is less important compared with self study and supervisor's guidance, especially for graduate students and higher researchers (PhD candidates, post doctors and research associates), whose research subject is very deep and 'narrow', and usually difficult for others to understand. On the other hand, we do not think that the big variance in importance between the supervisor's guidance and cooperation is reasonable and acceptable. On the contrary, professors and laboratory administrators should seriously consider how to encourage and reinforce collaboration in academia. This is related with the issue of *organizational culture*. The organizational culture includes the shared values, beliefs, norms, expectations and assumptions that bind people and systems [16]. The organizational culture is particularly important in KM because it gives the people a basis for stability, control and direction and helps them to adapt and integrate other variables and technology with the operating environment. For instance, if an organizational culture is open and encouraged to cooperation and exchange, in which there are more relational channels to support and nurture person-to-person communications and team cooperation.

Section 2.2.5 exposed some different requirements and obstacles between foreign researchers and Japanese on idea exchange. To foreign respondents, language was one of important reasons for inefficient or meaningless seminars (we have analyzed the reason in Section 2.2.5.). But to Japanese students, they mainly complained the atmosphere of discussion were not open and free. We believe that the common characteristics of Japanese culture may help explain this fact. As we know, the common impression of the Japanese is that they are well mannered, soft-spoken, and hard-working while maintaining a strict ranking concept in their minds. From this point of view, it is easy to see why very few Japanese respondents might think that seminars are open and free, especially when the speaker is an elder member and their professor is present wearing a serious expression. A discussion of national characteristics is beyond the scope of this paper, but *personal characteristic* is important element for KM since human being are unseparated part of system. People have competence, nature and attitudes. In an organization, the members have similar backgrounds, education levels, and experience, it is likely they will have the same understanding of a mission (issue) and share a strategic similarity [17]. Partner similarity among all members of an organization is likely to reduce barriers to sharing and therefore increase knowledge sharing and transfer.

In addition, with respect to the complain of tedious and useless seminar and discussion between the members who have the language obstacle, we suggest that it is not necessary to ask foreigners who are not good at Japanese to attend the seminars conducted in that language. Considering the actual effect, we think that some laboratories' regulations on seminars and discussions could be improved. Dividing the members of the lab into different groups for discussion may be better and more efficient. It belongs to *managerial issue*s. As mentioned at Section 2.2.4, there are also several unsatisfied problems belonging to managerial rules in labs, for example, the management of equipments, books and journals in lab, the training of equipment usage and the maintenance and management of lab's homepage.

Taken together, culture, people and managerial style, each of them has implications for KM efforts in organizations. We call them *Organizational Variables*. There are other factors as necessary concern in different organizations and situations, but we did not analyze in this paper, for example, organizational structures, reward systems, organizational tasks, and so on. In KM research and practice, it has always been suggested the particular attention should be paid to organizational variables, without which the success of KM cannot be guaranteed.

### 3.4 Knowledge Creation Process

Knowledge Creation Process is a set of activities that support individual and collective knowledge and interaction to construct new knowledge. Knowledge is created through interactions between tacit and explicit knowledge. Nonaka and Takeuchi [13] analyzed the interaction between tacit and explicit knowledge and proposed SECI spiral model for *organizational knowledge creation* [8]. Benefiting the revolutionary and basic value of the SECI spiral, EDIS spiral proposed by Wierzbicki and Nakamori [2] to describe the normal *knowledge creation process in academia*—universities and research institutes. In the same nodes as the SECI spiral, EDIS spiral has an opposite direction of transitions and with different transition descriptions: Enlightenment (have an idea), Dispute (presenting the idea to colleagues), Immersion (jointly reflecting on the idea and repeating dispute) and Selection (using selected comments of colleagues).

In the activities of knowledge creation, KM process takes place. With respect to academic activities, these process can be summarized as knowledge acquisition, knowledge transfer/sharing, knowledge application, knowledge creation and knowledge storage. Particular research activities are as follows:

(1) Knowledge acquisition: analysis of data, synthesis of earlier studies, access to database and literature, studying background knowledge, acquisition necessary research-related information and knowledge from difference sources and so on.
(2) Knowledge transfer/sharing: communication between researchers, idea discussion and debate, publishing papers.
(3) Knowledge application: preparing project proposals, reporting results, do experience.
(4) Knowledge creation: constructing new idea and innovation.
(5) Knowledge storage: storage of data sets, references and own work.

### 3.5 A Systems Thinking Framework for KM in Scientific Labs

Knowledge Creation is a core of KM framework in scientific labs. Knowledge source, absolutely, is footstone; reversedly, new knowledge created will enrich the knowledge storage. However, a mount of information and knowledge inundate us. It reminds us that effective knowledge navigation is especially necessary. With the development of IT, it reveals its strong properties in effectively guiding us to search and learn required knowledge. At the same time, IT can help us to better organize the current knowledge/ knowledge source. If scientific laboratories with high IT capability, it will be able to better support knowledge creation. Basic IT infrastructure includes internet and intranet connectivity, and some basic and necessary hardware and software. The provision of these IT infrastructures varies between different labs and its use depends on the people and support of the management, which are also organizational issues. In addition, organizational variables, for example, the diversity of laboratory management, personal characteristic and background, etc., will effect knowledge acquirement from knowledge source. On the other hand, people are one of the knowledge sources. The following figure (Fig. 7) shows the KM framework in scientific labs and the relationship between different elements.

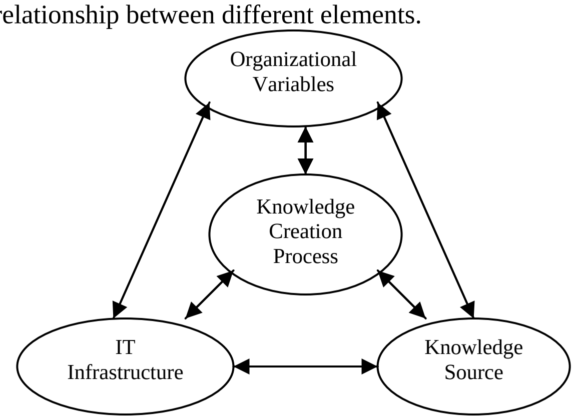


Fig.7. A Systems thinking Framework for KM in Scientific Laboratories.

## 4. CONCLUSION

Scientists and researchers were, are and will be in the tough research competition, and the situation is getting harder and harder. Sharp and creative idea, quick working and publication are strongly required, and more effective research process is necessary even in basic research area. KM framework in scientific labs would provide one solution and be powerful for research promotion scientific knowledge creation.

In this paper, we have identified and analyzed some interwoven contributing factors as well as inhibitors to management and creation of scientific knowledge in academia based on the KM survey of one research institute. We have also proposed the KM framework in scientific labs based on systems thinking. In this framework, KM is seen as an effort to properly put all the organizational variables into best use with the support of relevant information technology to facilitate the knowledge creation process with the main research purpose of labs through the acquirement and creation of knowledge sources.

In a nutshell, our research not only first explores some hidden problems existing in academic KM, but also presents useful suggestions and model for both researchers and managers. Our experiences can be widely used for reference in scientific knowledge management and creation, creativity support in academia, and some other areas. They also provide a perspective for future research.

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