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Multi-user Shared Failure Analysis of Organizational Information Systems

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Organizational knowledge is a key factor in improving office work efficiency. To support organizational knowledge sharing, it is important to analyze organizational knowledge and the knowledge sharing process. There are several on-going researches to support organizational knowledge sharing. However, relatively little is known about a methodology to identify the organizational knowledge in each working organization. This paper describes the difficulties in such organizational knowledge analysis from experiences in a know-how management system. Then the need for a methodology is discussed. A shared failure analysis to examine user shared failures in information sharing is proposed to identify organizational knowledge and transition processes. Three methods of multi-user shared failure analysis are explored. They provide a new methodology to explore knowledge sharing process.

1. Introduction

There is a growing concern about utilizing organizational knowledge[1)~3)]. Flexible work style, internationalization of personnel, downsizing and business restructuring leads to the need to maintain and utilize organization's intellectual assets. To cope with this important issue, system designers need to know more about organizational knowledge and its dynamics. There are few methodologies for this purpose. Without timely identifying organizational knowledge contents and their process for building, it is very difficult to support sharing organizational knowledge. The lack of methodologies to analyze organizational knowledge is critical to promote organizational knowledge utilization. This paper describes the difficulties in such organizational knowledge analysis from experiences in a know-how management system. Then the need for a methodology for organizational knowledge analysis is presented. As a methodology, shared failure analysis is proposed to identify organizational knowledge and transition process. Three methods of shared failure analysis of organizational knowledge are explored. This multi-user breakdown analysis approach provides a new methodology to explore multi-user knowledge sharing process. In this paper, the diversity of keyword usage is presented as a key to group characteristics analysis. This is followed by a discussion of breakdown analysis approach using retrieval failures. The results of the analysis and a discussion conclude the paper.

2. The FISH Experience

We installed a know-how management system called Flexible Information Sharing and Handling system (FISH)[10)] in early 1991. We define *know-how* as unstructured and fragmented knowledge acquired from the job. The purpose of FISH is to identify and share on-the-job fragmented knowledge. From our experience, the cognitive mismatch among members became apparent. This mismatch is always present in a multi-user information sharing context. It is critical especially in a context of know-how sharing, because there are not many things provided systematically for sharing. An example, the number of authoring users for each keyword during three-year experience is shown in **Table 1**. A surprising majority of keywords are used only one know-how author. More than three quarters of keywords were used by only one author. No other users other than the author used them as keywords for their own know-how. A similar result was obtained in the January 1993 preliminary analysis, which leads to the assumption that this tendency is quite solid. The number of users retrieving each keyword is shown in **Table 2**. It includes the keywords which are not included in FISH. It shows the similarity to Table 1. The numbers excluding those keywords which are not registered in FISH are shown in **Table 3**. The number of research group members was about 20 during the experience period. It means only 2% of keywords were used by more than half of the members. To make the matter worse, the fre-

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Table 1 Number of authoring users for each keyword.

users	occurrences	percentage	accumulated percentage
1	1026	76.6%	76.6%
2	185	13.8%	90.4%
3	73	5.4%	95.8%
4	26	1.9%	97.8%
5	13	1.0%	98.7%
6	5	0.4%	99.1%
7	3	0.2%	99.3%
8	2	0.1%	99.5%
9	5	0.4%	99.9%
13	1	0.1%	99.9%
16	1	0.1%	100.0%

Table 2 Number of retrieval users for each keyword.

users	occurrences	percentage	accumulated percentage
1	717	68.35%	68.35%
2	148	14.11%	82.46%
3	79	7.53%	89.99%
4	35	3.34%	93.33%
5	22	2.10%	95.42%
6	11	1.05%	96.47%
7	7	0.67%	97.14%
8	10	0.95%	98.09%
9	4	0.38%	98.47%
10	4	0.38%	98.86%
11	5	0.48%	99.33%
12	1	0.10%	99.43%
13	1	0.10%	99.52%
14	2	0.19%	99.71%
16	1	0.10%	99.81%
17	1	0.10%	99.90%
18	1	0.10%	100.00%

quently used keywords does not directly indicate the expert knowledge of the group. Routinely used keywords are telephone and public transport information, which do not characterize the organizational knowledge in a typical manner.

Some common keywords are widely used so that the know-how author may expect that the common keyword has the better possibility to attract others' attention to the know-how. At the same time, it is likely that a know-how author inputs some other author-specific keywords other than the common ones, because each know-how can be accompanied by multiple keywords. After a three-year experience, keywords are divided into two groups: one group of very frequently used but general keywords, and the other of know-how author-specific keywords. It raises important issues of multi-user information sharing:

Table 3 Number of successful retrieval users for each keyword.

users	occurrences	percentage	accumulated percentage
1	273	50.93%	50.93%
2	107	19.96%	70.90%
3	63	11.75%	82.65%
4	28	5.22%	87.87%
5	21	3.92%	91.79%
6	8	1.49%	93.28%
7	7	1.31%	94.59%
8	10	1.87%	96.46%
9	4	0.75%	97.20%
10	4	0.75%	97.95%
11	4	0.75%	98.69%
12	1	0.19%	98.88%
13	1	0.19%	99.07%
14	2	0.37%	99.44%
15	1	0.19%	99.63%
17	1	0.19%	99.81%
18	1	0.19%	100.00%

(1) the biased usages of keywords show that members have different cognitive views on the shared items,

(2) considering the fact that even with such diversified and isolated keyword usage, FISH survives years and has provided a base for organizational information sharing. How information is shared with such a gap in keyword perception gives a new understanding of the sharing process,

(3) the diversity can be used to analyze each group's group-specific characteristics.

We take this diversity as a starting point in order to approach users' perception of know-how from FISH keyword logs. Just counting interactions are not useful for analysis of knowledge construction. Methodologies which can focus on the core of organizational context and its dynamics should be developed. We are interested in meaningful knowledge construction, not simple information sharing. One of the common methods is interviewing members. However, users are often unaware about their knowledge construction and its dynamics. Also, interviewing has its shortcomings. It takes time. It is hard to make inter-group comparisons. Information sharing experience is not routine experience Information sharing in an everyday routine does not represent the whole organizational knowledge. It is like an iceberg, of which only a small part of it is visible. The total number is not always a good indication about organizational knowledge. It is necessary to develop a methodology which can be applied to various knowledge constructions.

3. Shared Failure Analysis

3.1 What Is Meant by Shared Failures?

To analyze keyword usage diversity in multi-user information sharing, it is necessary to establish a methodology suitable for multi-user issues. We take a breakdown analysis approach. Winograd and Flores described breakdown analysis as follows: "*Following Heidegger, we prefer to talk about 'breakdowns'. By this we mean the interrupted moment of our habitual, standard comfortable 'being-in-the-world'. Breakdowns serve an extremely important cognitive function, revealing to us the nature of our practices and equipment, making them 'present-to-hand' to us, perhaps for the first time. In this sense they function in a positive rather than a negative way. New design can be created and implemented only in the space that emerges in the recurrent structure of breakdown*"[16].

Breakdown is a status in which a user faces a new (maybe out-of-order) situation due to the mismatches between the state of one's mental model and the reality provided by the system. A clumsy user interface can cause a lot of breakdowns. Also, cognitive mismatch among users are sources of breakdowns. Breakdown can be used as a method to analyze how the system is used by users because it can give typical cues to insufficient system design. Especially, in multi-user oriented systems, such breakdown analysis can be a good method to analyze multi-user shared perception. We use the shared failure in the log to analyze the shared failure to capture the cognitive understanding of social behaviors.

3.2 Related Studies

The organization of work is a complex, ongoing interaction of people with each other and with technologies[14]. It confirms the necessity of multiple disciplines with a variety of research paradigms[4]. The process is extensively influenced by members' cognitive views. The important open research issue is *how the cognitive aspects can be analyzed.* The methodology is a critical issue in multi-user information sharing in an organizational context. For example, surveys are used to assess user perception[9]. However, they are not sufficient for in-depth cognitive analysis because they are generally designed for general analysis. In order to understand human behavior, shared failure analysis offers an interesting methodology. It is a negative side of view to understand human behavior. It is feasible because the successes of organizational behavior are more difficult to analyze than the failures. Therefore, shared failures have been studied for cognitive aspects of user interfaces, software design and multi-user interfaces. Breakdown usage in cognitive process evaluation was discussed[6]. Multi-user cognitive aspects of network trouble shooting were discussed with an emphasis on breakdown in real world collaboration[8]. Also, breakdown analysis to build up a multi-user design model was discussed[15]. Initially, breakdowns were used for user interface evaluation. Recent research showed the feasibility of breakdown analysis on multi-user applications. The insights into the use of breakdowns to understand multi-user interface therefore inspired our study.

3.3 Shared Failures in FISH

There were several failures observed in FISH. For example,

(1) failure to set up the command environment (e.g. path names),
(2) failure to type a command,
(3) forgetting a names of commands,
(4) failure to identify keywords,
(5) misunderstanding of the background when he/she saw a piece of know-how.

The most frequent failure in FISH is the failure to identify keywords which are primary access cues to know-how in FISH. Therefore, a user encounters a serious breakdown when he cannot recall the exact keywords to describe know-how. The log of failed keyword usage is a rich source for shared failure analysis. It can be used to understand what a user had in mind, what a user looked for in FISH, and what is the common multi-user use of keywords. It can be a valuable feedback to the designers.

The original system did not have the facility for shared failure analysis. We started to collect retrieval log records in July 1992. Until the end of April 1993, there were 3262 items compiled. There were 749 FISH retrieval failures. The monthly result is shown in **Table 4.** The column of failures show the occurrence of breakdowns in the FISH log. The column of total shows the total number of FISH retrievals. The failure-ratio shows the percentage of failures in retrievals.

It should be noted that the ratio of failure was rather stable during this period. However, it cannot be determined whether this indicates any special characteristics of the group or just the fact that users gave up further retrieval at-

Table 4 Failures Occurrences in FISH retrieval failures.

month	failures	total	failure-ratio
Jul	34	141	24.1%
Aug	95	354	26.8%
Sep	86	356	24.2%
Oct	51	268	19.0%
Nov	80	310	25.8%
Dec	87	348	25.0%
Jan	51	261	19.5%
Feb	103	360	28.6%
Mar	109	423	25.8%
Apr	44	163	27.0%

```
name keyword indicator DOW month day time     zone year
-------------------------------------------------------
kenji MCC     x       Thu  Jul   23  17:06:51 JST 1992

                                    DOW: Day of Week
```

Fig. 1 An example line of log records.

tempts in vain.

Before getting into the details, it is important to distinguish system-specific aspects and user or group-specific aspects of shared failures. With FISH experience, the author learned that users tend to use a single simple keyword at retrieval even when several improved retrieval methods are provided. It is even true in general usage of many internet retrieval engines. Generally speaking, the first choice of a main retrieval keyword depends on the users' cognitive map of the target domains. In other words, the retrieval failures reflect the user or group-specific tendency rather than the system characteristics.

3.4 Method

A log of keyword at retrieval was recorded. An example of log record lines is shown in **Fig. 1**. The column name shows the login name of a user. The column indicator shows with an 'x' mark when the retrieval failed. The items like day-of-week, month, day, time, time-zone, and year show the time of retrieval. JST stands for Japan Standard Time. The author analyzed the keyword search failures from three viewpoints: (1) *multiple failures*, (2) *multi-user failures*, and (3) *failure sequences*. In multiple breakdowns, keywords which caused multiple failures for a user were examined. The fact that the same user repeated the same failed keyword indicates some belief by the user. In multi-user shared failures, keywords which caused failures for multiple users were examined. The fact that multiple users have failure experiences with the same keyword indicates shared belief in some knowledge. In failure sequences, each user's series of failures over a short time span were examined. The attempts indicate the user's perception of keywords, which may be implicitly linked in one's mind. The first two viewpoints will clarify the features of multi-user shared failures. The last one is used to show the failure content from a user's resolution strategy.

4. A Case Study Using Shared Failure Analysis

4.1 Multiple Failures

There were 60 multiple failures in our observation. Thirty out of 60 were single-user failures. This is about 8% of all breakdowns. Single-user failures are noticeable because some users repeatedly failed on the same keyword. It should be noted that there exists some strong mental belief that such a keyword is stored in FISH.

It should also be noted that three character systems are used, (a) the alphabet, (b) roma-ji (alphabetic spelling of Japanese words), and (c) Kanji (Chinese characters). In the following description, a keyword in single quotation marks is roma-ji, and in double quotation marks is Kanji.

(1) Directory information category (person and organization)
Five keywords: MCC, NJK, n-k, "saito", "Toshiba".

(2) Computer services category
Seven keywords: cpu, cron, ct, mhf, news, "cable", pbx.

(3) Office procedures category
Ten keywords: cdp, 'keikaku', 'meisi', namecard, 'ryohi', 'soukai', "kenchiku", "kenkai", "kenchiku", "shoumouhin".

(4) Computer programming category
One keyword: wait.

(5) Research procedures category
One keyword: 'sadoku'.

(6) Miscellaneous information category
One keyword: quiz.

(7) Misspelling
Four misspelled (unmatched) keywords: fleshman, fleshmen, freshmen, manp.

(8) Misused command parameter One misused command parameter: 01.

4.2 Multi-user Shared Failures

There were 30 multi-user shared failures in

our observation. They are important keys to the question *what type of failure is shared by multiple users*. If it is shared even though it does not exist in the real keywords of FISH, it can be a cue to multi-user cognitive factors of know-how sharing.

There are eight categories in this type of failure.

(1) Technology category
Five keywords in this category: ATM, atm, cscw92, hypertext, isdn.

(2) Directory information category (person and organization)
Five keywords (human names and nicknames, and telephone): haruta, no, ogi, ohta, shimizu, tel.

(3) Directory information category (event)
Three keywords: drinking, 'enkai', 'nomiya'. These keywords are used to show some map of party places.

(4) Computer services category
Five keywords: News, lilac, mhb, nttmhb, pds.

(5) Office procedures category
Eight keywords: 'kenkai', 'kuroneko', 'takkyubin', 'yamato', "kenkaisiryou", "chousho", "buppin", "takkyuubin".

(6) Time table information category
One keyword: bus.

(7) Product information category
One keyword: mac.

(8) Miscellaneous information category
One keyword: test.

Multi-user shared failure analysis gives a good overview of users' cognitive map of organizationally shared information. It can be used to compare typical organizational knowledge analysis. *Technology and directory* information are two notable categories in multi-user shared failures. Both multiple failure and multi-user shared failure analysis indicate that the major organizational knowledge in the current FISH is the category of *office procedure related information*. It should be noted that *misspelling* and *misuse of parameters* were not shown in the multi-user shared failure analysis. Because such low level failures take place in a random manner, so they are rarely shared.

4.3 Failure Sequences

A breakdown sequence is defined as the sequence of failures observed in a 60-minute time span (60 minutes is an ad-hoc value from our observation). It shows a variety of resolution patterns. There were 264 breakdown sequences and 50 isolated failures from July 1992 to May 1993. Eighteen of 264 failures have completely different category keywords, most of which contains 'test' or other incomprehensive words (i.e. a series of digits). So they are excluded from analysis. Of the 246 sequences remaining, 91 sequences showed failure sequences in which more than one failure was shown in a sequence. The user's resolution patterns for the 246 failure sequences is shown in **Table 5**.

Table 5 Resolution patterns in the 246 failure sequences.

Resolutions	numbers	category
Paraphrasing	106	**
Spelling	57	-
Capitalizing	31	*
Repetition	24	-
Shorthand	14	*
Conversion	14	*
Command Usage	10	-

Note:
** : multi-user issues
* : slightly related multi-user issues
- : single user issues

Table 6 Categories used in paraphrasing sequences.

category	number
intra-organizational procedure	16
directory	5
academic society	4
local communication service	4
research/technology	3
local town information	3

Repetition is a sequence of repeated trials of the same keywords. *Capitalizing* is due to the case sensitivity of FISH. A user tries different cases. *Shorthand* is using acronyms or shorthand names as alternatives. *Conversion* is a sequence of conversion trials among different Japanese character sets. *Command Usage* covers miscellaneous wrong command usage patterns, when non-keyword symbols such as '+', '-', and ':' are used. We think that *spelling*, *repetition*, and *command usage* are user interface issues common to single-user interface design. *Capitalizing*, *shorthand* and *conversion* are guessed to be minor user interface issues. *Paraphrasing* shows a perceived potential cognitive mismatch and several attempts of paraphrasing to reach the appropriate keyword. This indicates the user's strong belief that some information exists in FISH. There are 35 paraphrasing sequences which contains more than two keywords, which are categorized in **Table 6**.

This table indicates the characteristics of

the group memory shared using FISH. Intra-organization procedure category, mainly filling out forms and managing them in various different contexts in a different line of workflow, is most demanding. The directory category includes telephone addresses and name lists. The academic society category includes entry information and calendars of academic events. The local communication service category includes information about modems, PBX and local UNIX machines. The research/technology category includes hypertext and CSCW. The local town information category covers various maps, such as party places. In past research carried out by other researchers breakdown analysis was used for prototype evaluation. The pattern analysis of failure sequences can be used for analyzing organizational perception of know-how.

5. Discussion

5.1 Knowledge Analysis

The shared failure analysis can be used to analyze knowledge clusters. Paraphrasing indicates the tendency of the awareness and perception of keyword in a group. In the above case study, the observed major similarity between multiple failure and multi-user shared failure analysis is office-procedure-related and local-computer-service-related information. The major difference between multi-user shared failure analysis result and that of single-user analysis was the use of directory-related-information. The major mismatch in organizational information exists in communication related information. Members have different views of keys for communication in various contexts. Also, the shared knowledge is identified in this methodology. Long-term observation using this methodology will reveal the transition of shared knowledge. Since FISH is an organizational information sharing system, it is vitally important to grasp cognitive aspects in multi-user information sharing. It can be used to enhance multi-group know-how transfer and to break multi-user gaps in information sharing. The multi-user shared failure analysis and failure sequences are effective methods to analyze multi-user factors in an organizational information sharing system. The shared failure analysis shown above is applicable to any multi-user information sharing systems in which reference logs with search parameters are recorded.

Table 7 List of Frequently used keywords at know-how production.

keyword	frequency
mac	91
freshman	71
tel	68
perl	51
ask	48
naoto	37
yam	35
khw	35
kenji	30
paper	30
Mac	29
jimu	27
manager	24
address	23
UNIX	22
mail	22
sg-m	21

5.2 Comparisons

We compare the multi-user shared failure analysis to the ordinary keyword usage analysis. From the keyword usage analysis, the frequently used keywords at know-how production is listed in **Table 7**. It is a general analysis, and there is no organizational specific knowledge on the list. This traditional approach has two shortcomings. First, it focuses on the user input behavior only. We need retrieving behavior analysis. Second, the counting frequency was heavily influenced by the user convention. In this case, 'freshman' and 'ask' are conventions. Freshman is used when it is for new comers. 'Ask' is used when it is a question to some experts. UNIX, mac, and Mac are system names which can be used for various know-how on those systems. It roughly sketches the organizational knowledge, however, there is no specific information concerning with ongoing knowledge construction. Multi-user shared failure analysis solves these two problems in a promising manner. First, it is based on retrieval user behavior. Second, it focuses on multi-user cognitive aspect in this aspect, the in-depth analysis can be done because multi-user cognitive mismatch occurs near to the core of information semantics.

5.3 Limitations of Multi-user Shared Failure Analysis

In our eleven-month observation, only 30 multi-user shared failures occurred in a 20-member group. This low frequency indicates some limitation to the log-based shared failure analysis. Verbal communication failures can be a richer source of failure analysis. However, it

is hard to carry it out over a long-term observation period due to its time consuming nature. Low frequency is always the important issue in non-routine groupwork evaluation[5] and the results confirm this once again.

5.4 Implications to Knowledge Sharing System Design

The shared failure analysis leads to several design implications which can be used in future groupware systems. There are three implications:

(1) Inter-group knowledge sharing
In the past groupware research, there were not many studies on inter-group knowledge sharing. It is important to support multiple groups with different knowledge domains. The shared failure analysis results can be used to improve awareness among multiple groups with different knowledge.

(2) Knowledge sharing stage support
Two different groups in the same knowledge domains can be in the different stages with their experience and system supports. The knowledge sharing stage difference among different groups can be compared by shared failure analysis.

(3) Improved user interface
The shared failure analysis can be used to improve group-specific domain know-how retrieval methods because it shows the group-specific cognitive bias to the know-how sharing.

6. Conclusions

The two-year experience of FISH gave us an opportunity to analyze organizational behavior using real organizational information sharing log data. The nature of infrequent events in organizational information sharing, especially in unstructured and fragmented knowledge sharing, makes it difficult to analyze behavior only from successes. The failures gave us interesting perspective of how users overcome the cognitive mismatches. To explore the methodology to analyze organizational information sharing from dynamic process based perspective, we conducted a shared failure analysis to categorize organizational knowledge. Breakdowns on multi-user information system keyword usage show the cognitive aspects of organizationally shared information. Shared failure analysis gives a new perspective in the analysis of long-term and slow process's hidden characteristics of multi-user information sharing systems. Three methods, (1) multiple failure, (2) multi-user shared failure and (3) failure sequence are proposed. The observation of paraphrasing behavior reveals a group's perception of shared know-how. The use of multi-user breakdown analysis is an effective way to understand multi-user cognitive aspects in knowledge sharing as well as in the content analysis of know-how. Future research includes inter-organization comparison of stored knowledge with the methodology.

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