

BASIS OF SYSTEMS ANALYSIS METHODS FOR BUSINESS PROFESSIONALS

Takeshi Kosaka

*Tokyo University of Science
500 Shimokiyoku, Kuki, Saitama, Japan*

ABSTRACT

A continuous effort for high performance and high flexibility is a must for an organization to survive in a global oligopolistic market. Literature shows that the power of workers is a key to it. Given this fact and the importance of information systems in organizations, needed is a systems analysis method for the empowerment of an individual worker within a community of practice, however there is little research on it. By studying classics on resistance to change and organizational development, we derive the basis for the methods for business professionals or workers to reflect on their experiences, create new ideas, and communicate with colleagues. In the light of the basis, we have a brief examination of existing methods, revealing that there are no methods satisfying the basis.

KEYWORDS

Systems analysis, Business professionals, Workers, Information systems, Organization development.

1. INTRODUCTION

Global economy does not allow low performance and less flexible companies to survive in an oligopolistic market. Companies are forced to pursue higher performance and more flexibility than ever. Investment in information systems is necessary, but is not enough. The performance and flexibility of organizations depend on intangible assets including internal motivation of workers more than tangible assets like information systems. However, systems analysis and design methods for business professionals or workers are basically missing from the SA & D universe (Alter, 2005). We will explore the issues for the performance and flexibility of an organization, and to articulate the basis for a systems analysis method with which a business professional or a worker can reflect on his experiences, build new ideas and communicate with peers.

Research findings show that high performance and high flexibility of change are mainly attained by the initiatives and efforts of workers (Stacey et al, 2000; Spear et al, 1999; Coch et al, 1948). However the realities are often opposite. Business professionals are generally considered simply users of information systems (IS) rather than workers who perform tasks with IS. With the high rate of IS failures the problems have often become whether IS are usable or not rather than useful or not. Consequently, it often appears that the problem is assumed to be the design of the information technology interface and how to involve users in the process of that design, rather than an exploration of the problem situation and the potential for improvement (Champion et al, 2007). For high performance and high flexibility we have to again return to a work system which is a system to be served by IS, the purposeful action which IS serves, in terms of Checkland et al (1990).

Although the focus on IS is still prevalent, an era of business professionals' initiatives is coming with the emerging technologies for Business Process Management. What kind of systems analysis methods is required in the initiatives? Current SA & D techniques are for IT professionals (Alter, 2005). In most cases, the available models address the worker from a third person perspective - treating her as a 'black box' and affording no features for addressing the worker's internal processes or experiences (Whitaker, 2007). Business professionals who perform their tasks, by nature, have ample opportunities for reflecting on their own experiences. It is, therefore, desirable for them to be able to start thinking anytime without any help from IT professionals or consultants. The method for business professionals or workers is expected to address

the needs for a business professional or a worker to start thinking without influence or assistance from management and IT professionals, reflect on his experiences from his personal and/or collective perspective, create new ideas based on his and/or collective reflection, and communicate with colleagues and share his experiences, meanings and new ideas.

We will visit classics because this area of research is just beginning and therefore it is worth reviewing the classic findings related to this area. We set out to review two classics in organization development (OD) research. As well pointed out, users participation and leadership are considered the most important. As the leadership is not appropriate in our research interest, the first is for examining the needs for participation. The findings in the first literature show that total participation is a key for attaining high performance and that group dynamics are the mode of participation, suggesting the importance of a collective subject as well as an individual subject. Therefore, the second is for knowing what OD has tried to actualize participation.

From the two classics the issues for high performance and high flexibility are derived. Then, the basis for systems analysis methods for business professionals is discussed and supplemented with a few additional issues based on the reflection on the recent work situations since the publication of the two classics. Then, a brief critical examination of the existing methods is made in the light of the basis, revealing there are no appropriate methods satisfying the basis for systems analysis methods.

2. REVIEW OF CLASSICS

OD research has been showing that job re-design by workers is more effective than 'one best way' inspired by management. We see it in the classics of 'resistance to change' research, and then learn about methodologies for job enrichment from the classics.

2.1 Coch and French's study: Overcoming RTC with participation

The Coch and French's paper published in 1948 in Human Relations has been widely referenced as a cornerstone in research into change. They studied the workers' resistance to changes (RTC) in products and methods at the main plant of the Harwood Manufacturing Corporation in USA, addressing worker's autonomy or 'job design by worker' as a key for high performance.

With the changes in methods and jobs, workers responded with the following resistance: "The resistance expressed itself in several ways, such as grievance about the piece rates that went with the new methods, high-turnover, very low efficiency, restriction of output, and marked aggression against management." (Coch et al., 1948)

Despite these undesirable effects, the change was necessary to maintain competitiveness. Efforts were made to solve this serious problem by the use of traditional means such as monetary allowance. However, these actions did little or nothing to overcome the resistance. The factory management felt that the resistance demanded further research into workers' concerns and solutions.

The first step taken in the overall program was to devise a preliminary theory to account for the RTC based on general observation and performance data. It was interesting to note that the re-learning period for experienced workers was longer than the learning period for new recruits. The fact indicates that RTC is primarily a motivational problem not technical ones like skills. It was also discussed in the paper that 'we-feeling' known as group dynamics facilitated RTC.

Coch and French set up an experiment with the thought that the most appropriate methods for overcoming the RTC would be group methods because the resistance is a combination of an individual reaction to frustration with strong group-induced forces. The experiment was designed employing variations of participation. The first group involved participation through representation. The second and third group consisted of total participation by all members in designing the changes. The fourth group with no participation was also observed as a control group.

The result of the experiment showed clearly that the rate of production and rate of recovery were directly proportional to the degree of participation, while aggression and turnover were inversely proportional to it. As a result, total participation was shown to be more effective than participation through representatives in the changes of production methods.

Although it has been criticized over the years, mostly because of their research design and management in a real factory setting, their study remains a significant contribution to research on RTC as a valuable research resource.

Coch et al (1948) shows total participation is importance in case of labor shortage. The findings have increasing significance today because current companies depend on scarce knowledge workers. The findings also show that group dynamics are the mode of effective participation, suggesting the importance of a collective subject as well as that of an individual subject.

2.2 Hackman et al's study: A new strategy for job enrichment

What has organization development (OD) revealed to actualize participation? We will learn it from another classical research in OD: Hackman et al (1975). They formulated a methodology for job enrichment about how to motivate an individual worker (Fig.1).

Behavioral scientists have found that three “psychological states” are critical in determining individual person’s motivation and satisfaction on the job: (a) ‘experienced meaningfulness’ of the work: The individual must perceive his work as worthwhile or important by some system of values he accepts, (b) ‘experienced responsibility’ for outcome of the work: He must believe that he personally is accountable for the outcomes of his efforts, and (c) ‘knowledge of results’ of the work activities: He must be able to determine whether or not the outcomes of his work are satisfactory. When all three are high, then internal motivation, job satisfaction, and work quality are high, and absenteeism and turnover are low. Here, it is noted that ‘experienced meaningfulness’ and ‘experienced responsibility’ are of subjective reflection.

What job characteristics or dimensions elicit these psychological states? Hackman et al (1975) identified five core job dimensions. Three of the five core dimensions contribute to ‘experienced meaningfulness’: (1) Skill variety: the degree to which a job requires the worker to perform works that challenge his skills and abilities, (2) Task identity: the degree to which the worker does a job from beginning to end with a visible outcome, and (3) Task significance: the degree to which the job has a substantial and perceivable impact on the lives of other people in the immediate organization or outside. If the job is high in all three dimensions, the worker is quite likely to experience his job as very meaningful.

As other core job dimensions, they identified autonomy toward ‘experienced responsibility,’ and feedback toward ‘knowledge of results’: (4) Autonomy: the degree to which the job gives the worker freedom, independence, and discretion in scheduling work and determining how to do it. This leads a worker to experience increased responsibility in his job, and (5) Feedback: the degree to which a worker, in carrying out the work activities required by the job, gets information about the effectiveness of his efforts. These five core job dimensions are of objective description.

Hackman et al (1975) further identified five “implementing concepts” for job enrichment. As shown in Fig.1, the implementing concepts are linked to the core job dimensions, which combine to affect psychological states (subjective reflection), which are critical in determining whether or not a worker is internally motivated to work effectively. Each implementing concept is a specific collective action step aimed at improving both the quality of working experience for the individual and his work productivity. They are: forming natural work units, combining tasks, establishing client relationships, vertical loading, and opening feedback channels (omitted here).

- Forming natural work units: The principle underlying natural units of work is ownership – an individual’s sense of continuing responsibility for an identifiable body of work. Natural work units are directly related to two core job dimensions: task identity and task significance.
- Combining tasks: This principle suggests that whenever possible fractionalized tasks should be put together

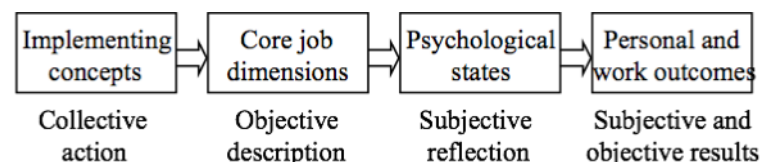


Fig.1 Hackman et al's model and subjectivity

to form new and larger modules of work. As a job-design principle, combining tasks expands the task identity and skill variety that contribute to the overall experienced meaningfulness of the work.

- Establishing client relationships: By enabling workers to have relationships with the clients of their work, improvements can be often realized on three of the core job dimensions: skill variety, autonomy, and feedback.
- Vertical loading: What is intended in vertical loading is to narrow the gap between the doing and the planning / controlling in order to reap some important motivational advantages.

2.3 Ideas learnt from the two classics

Coch et al (1948) show total participation is important in case of labor shortage. The findings have increasing significance today because current companies depend on scarce knowledge workers whose leave means the loss of valuable asset. The findings also show that group dynamics are the mode of effective participation, suggesting the importance of the collective person perspective as well as that of the first person perspective.

Hackman et al (1975) bring subjective experiences by individuals to the fore in the field where objective evaluation has been dominant. This means that effective participation requires not only the third person perspective (3PP), i.e. objective perspective, but also the first person perspective (1PP). The collective person perspective (CPP) mentioned above in the review of Coch et al (1948) combines the 1PP and 3PP into multiple levels of perspectives, which are considered requisite for actualization of participation.

Works such as decision making are usually seen as an unfolding series of problem solving incidents. Workers practice the multiple levels of contextual inquiry for unfolding nature of work around individual, collective and objective perspectives. Therefore, individuals and/or collectives should be empowered to gradually reflect on his and/or their experiences of work in a wider context.

To realize the high motivation and high performance, Hackman et al (1975) derived the implementing concepts, which entail the horizontal reorganization of tasks among people and the vertical one between management and subordinates. These reorganizations have usually been made by the authoritative or legitimate power of management. As mentioned by Coch et al (1948), however, one best way inspired by management is less effective than by total participation. Therefore, this fact suggests that the horizontal and vertical reorganizations of tasks should be made by workers themselves.

3. BASIS OF A METHOD FOR WORKERS

3.1 Issues coming from the findings of the two classics

Having reviewed the two classics associated with participation, we will articulate issues from the perspective of an individual worker as well as new types of work situations since then. Among them, the following four issues are considered important from the standpoint of an individual worker who tries to improve his work or change his organization with colleagues.

- First person perspective to express his experience

In Hackman et al' model, the experiences of a meaningful work and of the responsibility are perceived not by the organization but by individual workers. It is an individual who experiences his jobs as very meaningful, and at the same time the meanings are created and shared. Therefore, first of all, an individual needs to be empowered to express his own experience. The empowerment of each individual to express his experience is at the heart of job redesign and associated IS development.

As appropriately expressed in the title "From human factors to human actors" of Bannon paper, objective perspective cannot capture the subjective experiences of an individual person. What is needed first of all for the empowerment of workers is the singular first person perspective (1PP). That is intra-subjective perspective, in which an active individual is expected to start expressing his experiences.

- Collective person perspective for communicative action

As Coch et al. (1948) pointed out, organizational change is likely to result in success if the individual workers are engaged with the change with colleagues. Mumford (2006) also says that problems of this kind should be solved by a group that experiences them and not by another group such as a supervisory.

Weick (1995, p.40) says sensemaking is never solitary but social because what a person does internally is contingent on others. Communication through language is at the core of sensemaking of their experiences and redesigning their jobs. A group of people needs to be empowered to engage in a constructive dialogue about their jobs instead being enforced to accept works designed by management for a generic type of worker. What is needed for the empowerment of a group of people is the plural first person perspective. That is collective person perspective (CPP), in which a group of workers is expected to share their experiences and to create their own new social reality through communicative actions (Kosaka, 2006).

- Inquiry into division of labor and motivation

The implementing concepts of 'combining tasks' and 'forming natural work units' are concerned with the reorganization of horizontal division of labor. The implementing concept of 'vertical loading' is concerned with the reorganization of vertical division of labor, which is planning and doing.

For workers a flexible vehicle is needed to appreciate or analyze their present and future jobs in the network of works horizontally and vertically as well as to evaluate flexibility emerged from combination of several works as a whole. For them, incentives for motivation are not necessarily restricted to traditional ones including money and autonomy. Opportunities for education and the future work of higher difficulty could also motivate them.

Knowledge workers have to be provided with an opportunity to know what mechanisms are working. A framework or method with which they can make sense of their work distribution and motivation mechanisms can in itself be a good vehicle that empowers them who are capable to create and manage jobs efficiently and effectively.

- Multiple levels of contextual inquiries

How does an action become meaningful in a community, or how do we make sense of an action or event? Social semiotics begins with an answer to this basic question. Fundamentally, every action is made meaningful by placing it in some larger context (Lemke, 1990, p.187). The meanings we make for actions or events consist of the relations we construct between them and their contexts. Making meaning is the process of connecting actions or events, or things, to contexts. The most important of all semiotic practices are these contextualizing practices (Lemk, 1990, p.187).

'Establishing client relationships' that Hackman et al. (1975) pointed out is considered contextualizing. Seeing the immediate object that an individual works on often does not make sense. Significance of a job is made clear when the object and his action on it are placed in a larger context, in this case, the production of an outcome that is usually delivered to a customer often outside the organization.

Works such as decision making are usually seen as an unfolding series of problem solving incidents. Workers need methods of inquiry based on multiple levels of contextual inquiry for unfolding nature of work. A method of that kind is expected to be a means to empower individuals and collectives to gradually reflect on their experiences of work in a wider context.

3.2 Additional issues

There are a few issues that cannot be derived from the research of Hackman et al. They are related to the growing importance of IT as well as the complexities involved in redesign of jobs since then.

- IT as an environment

Technologies are not present in the model of Hackman et al (1975). They are positioned as an object of free choice. However, technologies are no longer of free choice at present. It is exemplified by the facts that there are few new developments of IS from scratch and that organization changes without IT are almost inconceivable.

Hackman et al (1975) are supposed to consider that people can choose one from several alternative means after a purpose or end is determined. However, with an ecological change such that technologies have become powerful, it is no longer obvious that means are the object of free choice. A philosopher Imamichi says that humans are obliged to choose a purpose on the assumption of obvious pre-existence of technologies. Similar situations have also been shown by organizational researchers of population ecology.

In the past, nature alone was a single environment for human life. Technology became another environment for human in the present age. Technologies are no longer the object of free choice. They strongly influences our mind-set, a way of seeing things and relations as culture does. In job redesign and organizational changes we need to be able to become conscious of technologies and to reflect on our experiences with a view to them.

- A diagrammatic device

From the above discussion, what is needed further is a diagrammatic device that enables individuals to reflect on their experiences and to express their views. In order to redesign jobs or change organizations, business professionals have to take into consideration many issues including technology, division of labor, motivation mechanism, relation to clients and so on. Concepts alone about them are not enough for the business professionals to think with. As they are not job redesign professionals or OD consultants, business professionals need a concrete, easy-to-use method. It must be a method with which they can start thinking from a small number of their immediate things and events.

Since the mid-1990s, effectiveness of diagram in problem solving and findings has been examined by cognitive researchers. For example, Suwa (1999) demonstrated that a human goes through a process where he finds a new aspect of a problem by drawing and externalizing his idea inspired from the diagrams while he is illustrating them. Yamazaki et al (2001) showed that diagrammatic expression works as an externalization resource of internal ideas and helps to find new solutions by facilitating the reflection on his own thought and experience. These findings advise us that the device for reflection and analysis needs to be diagrammatic one with which business professionals can start thinking by drawing gradually from their immediate area of interest to a wider area.

4. CRITICAL EXAMINATION OF METHODS IN RELATED RESEARCH

As well known, systems analysis methods for business professionals or workers are basically missing from the field of IS universe. Current techniques are for IT professionals or consultants (Alter, 2005).

Inquiry into subjective experiences has been researched in phenomenology and hermeneutics. Although there has been ongoing promotion of phenomenology and hermeneutics in the fields such as HCI, design science, and PD, such scholarly work has provided little aid in applying phenomenology and hermeneutics to IS design (Whitaker, 2007).

Historically this field has been researched by organizational development (OD) and socio-technical approach (STA). The situations are as follows. A popular text book (Burke, 1994, p.13) on OD mentions “every organization has a technology ... technology represents an integral part of the culture.” Despite mentioning the importance of technology like above, there is no discussion on the technical subsystem including IS in those books: “The emphasis of this book is on the social subsystem, ...” (Burke, 1994, p.13). The situation of STA is not so different from that of OD. As Mumford (2006) pointed out, socio-technical design is not a methodology but rather a philosophy with a humanistic set of principles associated with technology and change. It is not a method for workers, but is a philosophy for action researchers and interventionists.

In spite of the situation as mentioned above in general, some methods related to workers or work systems are now appearing on the scene. To our knowledge there are Whitaker’s method, Alter’s work system method, Bednar’s SST, SSM, and Activity Theory in a reverse historical order. We will have a brief, critical examination of them as follows. Due to space limit our discussion focuses primarily on critics.

- Whitaker’s method

This is a theoretical and methodological toolkit with which the principles of phenomenology and hermeneutics are applied in IS design practice. This intends to enable analysts to emulate the user’s first person perspective to learn enough about actual praxis so as to be able to comprehend worker’s experiences and orientations (Whitaker, 2007). This research provides insightful viewpoints, but, as Witaker points out, the toolkit is aimed at systems analysts not business professionals.

- Alter’s work system method

Alter (2004) acknowledges the absence of methodologies or methods that business professionals can use to reveal practices in an organization, and is trying to develop a work system method for business professionals. The work system method is an approach for understanding and analyzing systems in

organization whether or not IT plays an essential role. His basic assumption is that IS is a special case of work system and therefore IS inherits the properties of a work system. With this assumption in mind he is working on a big project for building an entire system of IS discipline. The method, however, does not have the explicit notion of the first and collective person perspectives to reflect on workers' experiences.

- Bednar's SST

The Strategic Systemic Thinking (SST) framework proposed by Bednar (2000) is a stepping stone towards enabling the refocusing of organizational analysis in IS. It is primarily concerned with providing support for active sense-making process from first and collective person perspectives. Bednar argues that the SST framework is quite flexible in that it supports the temporary construction of an analysis method, but doesn't require the use of a pre-selected one. Although it provides insightful ideas such as collaboration between individual and collective learning, the framework still remains as a meta tool which business professionals can not use directly.

- Soft Systems Methodology (SSM)

SSM proposed by Checkland et al (1993) is widely known as being useful as a guide when exploring a problematic situation. SSM promotes the need to examine practices prior to software development and made an outstanding progress toward understanding the interests of stakeholders in social realities. It still remains, however, in the world of art. For example, Alter (2004) mentions that experience to date shows that typical American business professionals need a systems analysis approach that is more prescriptive than SSM. Associated with SSM is Atkinson's SISTeM. It is similar to that of SSM, but it has two cycles (Atkinson, 2001). This method has the same difficulty as SSM because the first cycle follows SSM.

- Activity Theory (AT)

AT initiated by Vygotsky (1978) is a cross-disciplinary framework for the research of human social practices as a developmental process by inter-connecting individuals and a society. It has an ecological treatment of an artifact such that artifacts are historically constructed and even influence the way of thinking as a culture does. It captures not only a subject's doing towards an immediate object through the mediation of an artifact, but also locates the subject into a social community that might be a collective subject, and take into account both the division of labor which the subject undertakes in the community and the social rules in the community. Through the mediation of the division of labor and that of the social rules, it intends to reveal emergent dialectical relations and conflicts between an individual and the community. AT also has a diagrammatic expression for possible enhancement. As above, AT satisfies several issues we derived, but has several confusing aspects, for example, the ambiguous positioning of subject (individuals or collectives) in the diagram. As mentioned by Bannon (1997), the complexity of AT has frightened off many practitioners from actually trying to apply activity-theoretical concepts in practical situations. There is a need to operationalize AT with use of semiotics if we introduce it for business professionals.

Through this brief critical examination of related methods, we can sum up that this area of research has just started developing and that appropriate methods for business professionals are largely missing.

5. DISCUSSION AND CONCLUSIONS

A continuous effort for high performance and high flexibility is a must for an organization to survive in a global oligopolistic market. Literature on resistance to change (RTC) and organization development (OD) shows that the power of workers is a key to it. Given this fact, needed is a systems analysis method for the empowerment of an individual worker within a community of practice, but there is little research on it.

We have learnt from the classics on RTC and OD, and derived several issues for the method. Among them total participation and the experiences of meaningful work and responsibility are important in particular. Total participation means every worker must be involved in organizational changes, implying that representatives could not attain maximum performance. And further every worker must be able to experience his work meaningful. It is a subjective experience that is perceived not by an organization but by an individual worker. This requirement brings the first person perspective and collective person perspective to the fore.

Then we derived the basis for methods for business professionals or workers from these findings. The basis includes the following: The method must be a diagrammatic one which facilitates them to start

reflecting on their experiences from an immediate object or problem of interest and to explore into larger contexts, facilitates both individual and collective thinking about division of labor and motivation mechanisms, helps them consider technologies as a sort of environment like culture, and works as a medium for constructive dialogue between people.

It was found that there are several methods that address workers and work systems prior to IS development. However, the methods we surveyed do not meet the basis necessary for methods for business professionals or workers. Appropriate systems analysis methods for business professionals or workers are largely missing at present.

REFERENCES

- Alter, Steven, 2004. Desperately Seeking Systems Thinking in the Information Systems Discipline. *Proceedings of International Conference on Information Systems*. 2004, pp.757-769.
- Alter, Steven, 2005. Tutorial: Sysperanto and the Work System Method. *Proceedings of the Eleventh Americas Conference on Information System*. p.3635.
- Atkinson, C., Eldabi, T. Paul, R. J. and Pouloudi, A., 2001. Investigating Integrated Socio-technical Approaches to Health Informatics. *Proceedings of the 34th HICSS*.
- Bannon, Liam, 1997. Activity Theory. *The COTCOS project*.
- Bednar, Peter M., 2000. A Contextual Integration of Individual and Organizational Learning Perspectives as Part of IS Analysis. *The Informing Science Journal*, Vol.3, No.3, pp.145-156.
- Bertelsen, O., Korpela, M. and Mursu, A., 2004. ATIT2004 Preface. *Proceedings of the First International Workshop on Activity Theory Based Practical Methods for IT-Design*. p.3.
- Burke, W. Warner, 1994. *Organization Development*. Addison Wesley.
- Champion, D., Stowell, F., and O'Callaghan, A., 2007. Client-Led Information Systems Creation (CLIC): Navigating the Gap. *Information Systems Journal*, Vol.15, pp.213-231.
- Checkland, P. and Scholes, J., 1990. *Soft Systems Methodology in Action*. John Wiley & Sons.
- Coch, L. and French, Jr., J. R. P., 1948. Overcoming Resistance to Change. *Human Relations*, Vol.1, pp.512-532.
- Hackman, J.R., Oldham, G., Janson, R., and Purdy, K., 1975. A new strategy for job enrichment. *California Management Review*, Vol.17, No.4, pp.57-71.
- Kosaka, Takeshi, 2006. Introducing Collective Identity into Information Systems Research. *Proceedings of The Tenth Pacific-Asia Conference on Information Systems*, pp.1056-1069.
- Lemke, Jay L., 1990. *Talking Science: Language, Learning, and Values*. Ablex Publishing.
- Mumford, Enid, 2006. The story of socio-technical design: reflections on its successes, failures and potential. *Information Systems Journal*, Vol.16, pp.317-342.
- Spear, S. and Bowen, H. K., 1999. Decoding the DNA of the Toyota Production System. *Harvard Business Review*, Set-Oct.1999, pp.95-106.
- Stacey, R. D., Griffin, D., and Shaw, P., 2000. *Complexity and Management: Fad or Radical Challenge to Systems Thinking ?* Routledge.
- Suwa, Masaki, 1999. Visual Displays as Stimuli to Cognitive Processes. *The Journal of the Visualization Society of Japan*, Vol.19, pp.13-18 (in Japanese).
- Vygotsky, L. S., 1978. *Mind in Society*, Harvard University Press.
- Weick, Karl E., 1995. *Sensemaking in Organizations*. Sage Publications.
- Whitaker, Randall. 2007. Applying Phenomenology and Hermeneutics in IS Design: A Report on Field Experiences. *The Informing Science Journal*, Vol.10, pp.63-96.
- Yamazaki, O. and Miwa, K. 2001. A Study of Changes of Problems Solving Processes by Externalization. *The Journal of Japanese Cognitive Science Society*, Vol.8, No.1, pp.1-14 (in Japanese).