Design and Evaluation of Creative Environments in Academia

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ABSTRACT

This paper introduces a COE (Center of Excellence) program "Technology Creation Based on Knowledge Science: Theory and Practice" sponsored by MEXT (the Ministry of Education, Culture, Sports, Science and Technology, Japan) at JAIST (Japan Advanced Institute of Science and Technology). One key issue for this program is the design, consolidation and evaluation of graduate school research facilities and the surrounding environment as a "Ba" (a Japanese term meaning: place, center, environment, space, etc.) for creating science and technology. In this paper we discuss evaluation of "knowledge creation Ba" using systems concepts, and report on a preliminary survey.

Keywords: knowledge science, systems concepts, scientific knowledge creation, creative environments.

1. INTROCUCTION

At the foundation of the COE program for knowledge bases, there is an academic field called "knowledge science", which models the knowledge creation process and conducts research on knowledge management, and JAIST is the only institution in the world where a School of Knowledge Science has been established as a research department. The school aims at producing research results relating to knowledge creation, including knowledge conversion theory, methods of knowledge systematization, and methods of developing creativity, in the area of management studies.

However, future "knowledge science" will transcend not only management studies, but also the barriers between areas of study, and in Japan in particular, "knowledge science" must be accepted and practiced by researchers in key scientific fields (biotechnology, nanotechnology, environment studies, information science), so that creative results can be theoretically brought into being. To achieve this, it is necessary to have a "Ba" for developing and practicing knowledge creation theory (socialization, externalization, combination, and internalization) in science and technology research. Awareness of this problem is what led to the proposal of the COE program.

We begin this paper by introducing the research and education goals in the COE program, and explain systems methodologies which are currently developed for promoting the program. Toyama and Nonaka [1] defined a "knowledge creation Ba" as a "dynamic context which is shared and redefined in the knowledge creation process". This paper considers the advantages and disadvantages deriving from the vagueness, depth, diversity and freedom of this definition, and stresses the need to design "knowledge creation Ba" using systems concepts. A conceptual framework for systematization is proposed by introducing a holistic perspective to knowledge management. Finally, we discuss evaluation of "knowledge creation Ba" using systems concepts, and report on a preliminary survey.

2. RESEARCH AND EDUCATION BASE

As mentioned above, JAIST led the world in starting its School of Knowledge Science, and the School has deepened its investigation of mechanisms for creating knowledge and value. These results have usually been limited to the field of management, but in Japan, where we are aiming to become a science and technology oriented nation, there is a strong need for contributions by "knowledge science" in the fields of natural science in particular.

Taking "knowledge science" as the foundational concept, it urgent that we educate graduate students to become "knowledge coordinators" who play the role of solving problems on the theoretical side, and "knowledge creators" on the practical side who can conduct research and development in an organizational framework in key fields of science and technology based on that theory. This section presents examples of developing science and technology personnel based on this sort of knowledge science.

2.1. Base of Excellence

In the 21st Century COE Program, "Research Base Formation Cost Subsidies" have been provided since 2002 as a new project within MEXT, based on the "University Structural Reform Policy" (June 2001). These subsidies were established because, in order for

Japanese universities to provide education and research activities on a par with world-class universities, it is crucial to further foster a competitive environment via competitive principles based on third party evaluation, and achieve more vigorous competition between all universities - national, public and private.

This program provides targeted support to achieve development of creative personnel for improving the level of research and leading the world, by forming research education bases at the highest level in the world at Japanese universities, thereby aiming to promote the building of universities with international competitiveness and individuality.

2.2. A Center for Theoretical Research and Practice

Starting from the second half of 2003, the "Center for Strategic Development of Science and Technology" was established at JAIST, as a base for linking research organizations, government and corporations from both inside and outside of Japan, in order to continuously supply intellectual energy from outside JAIST. At the same time, we are building a cross-departmental research education system which will enable expression to the full extent of synergistic effects between different fields, and function as a "Ba" for theoretical research and practice in knowledge creation within JAIST.

If scientific knowledge is created in a sustainable, organized fashion using this research education system, a state-of-the-art model can be provided regarding methods for setting priority research areas and promoting research, and this is expected to have a major impact on research and development management in universities, research organizations and companies.

Research departments for interdisciplinary fields and research departments advocating humanity/science fusion have previously been established at many universities. However, creative research results will be difficult to produced if the theory of promoting fusion is not consciously put into practice. At JAIST, we are trying to construct a "Ba" for knowledge creation theory research and practice through the collaboration of researchers and graduate students in different fields, and trying to hammer out our own unique approach in connecting our efforts with scientific knowledge creation.

As a precondition of that, the School of Knowledge Science at JAIST is conducting research relating to systems for supporting knowledge creation, and relating to the concentration and sharing of social information. In this regard, we have an infrastructure in place for developing "knowledge coordinators". Also, in the School of Material Science and the School of Information Science of JAIST, we are conducting world-class research education based on the advanced science and technology projects, and thus have an infrastructure for developing "knowledge creators".

Figure 1 shows the idea of establishing interdisciplinary research and education projects. Scientists create new scientific knowledge (Y) based on the existing knowledge (X). The capability of the function or map (F) depends on the individual scientists. If the techniques of knowledge science are used, it is possible to raise the performance of this function. Knowledge science can contribute to this from three aspects. One is knowledge creation support systems (W), which include such systems as shown in Fig. 1. The second is accumulation of social information, which are carried out by techniques of knowledge discovery, knowledge modeling or technology road mapping. The third is to design the system and environment for knowledge creation, which influences the function (F) directly. We will establish such interdisciplinary research projects and educate graduate students in this environment, then produce "knowledge creators" and "knowledge coordinators".

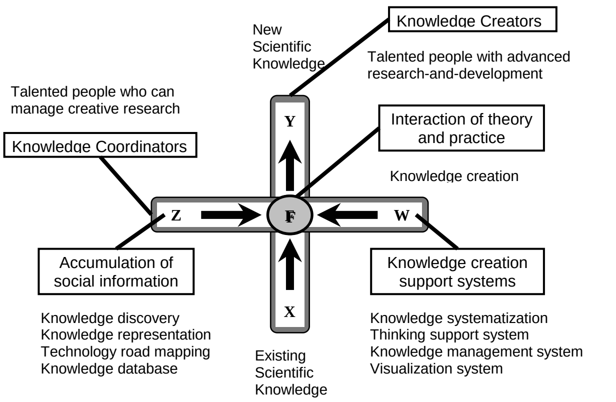

Fig. 1. The idea of promoting technology creation based on knowledge science.

By using this environment and establishing a "Cross-Departmental Program: Integrated Science and Technology Course" comprised of professors selected from each School, we are clearly distinguishing ourselves from previous organizations in that we will provide powerful promotion of research for achieving fusion of different fields. The results of this new attempt will be: methodologies and techniques resulting from theoretical research; data, information and models for collection and systematization; knowledge creation support systems; and science/technology created as a result of practice. The biggest result, for which expectations are particularly high, is scientific knowledge creation theory established through the cooperation of all members of JAIST who will participate in this program, in the "Ba" for theoretical research and practice.

The end product of education is the personnel developed continuously and in an ever-expanding fashion via the education program at this base, and the aforementioned "Cross-Departmental Program: Integrated Science and Technology Course" and the Center for Strategic Development of Science and Technology which was established centered around this base. For working adults, the aim is to eventually grant them a degree in knowledge science by having them earn specified credits, through re-education based on the aforementioned scientific knowledge creation theory, and through advanced basic research experience at JAIST. We also plan to actively accept students from companies, as part of joint research programs.

For currently active graduate school students (to be selected from the three research departments established at JAIST: the School of Knowledge Science, the School of Materials Science and the School of Information Science), we will provide internships at research sites of companies and other external research organizations. We will provide double-major education, with science education based on knowledge creation theory for humanities-based students, and, similarly, humanities education based on knowledge creation theory for science-based students. In recent years, this kind of double major education has been recognized as essential for building a knowledge society, but in reality, it is extremely difficult to achieve. However, at JAIST, we intend to take up the challenge of this difficult issue, taking the aforementioned scientific knowledge creation theory as our foundation.

2.3. Research Projects

In addition to promoting theoretical research in knowledge science, and developing technology in materials science and information science incorporating the methodologies of knowledge science, this base program is strongly promoting research relating to project management, social cooperation, international networks and cross-field education systems at the Center for Strategic Development of Science and Technology. First of all, the theoretical research projects in the School of Knowledge Science and Information Science are as follows:

- Knowledge management using systems methodology
- Knowledge discovery from large scientific databases
- Technology road-mapping techniques and applications
- Evaluation of concept creation process in R&D organizations
- Knowledge creation support systems
- Information sommelier education - aiming for a fusion of technology and art

The following lists cross-field projects between Material Science and Knowledge Science. These are the front-line troops of "scientific knowledge creation and practice based on knowledge science", which is the main theme of this base program. These projects require the research results discussed in this paper, i.e. on the design and evaluation of "Ba" for technology or knowledge creation:

- Advanced biomaterials research based on knowledge creation theory
- Strategic knowledge creation relating to super molecule biomaterials
- Knowledge creation experiments in nanomaterials research
- Strategy of technology development in transition metal catalyst research

In order to fuse theoretical research and practical research, we are promoting the following projects and work at the Center:

- Conditions and knowledge minimum for research and development coordination
- Methodologies for expressing and integrating diverse types of knowledge
- Laboratory knowledge management methodology
- Knowledge management information infrastructure
- Development of cross-departmental education system
- Building international networks and creating a knowledge map
- Industry-government-academia collaboration and regional vitalization

For the above, this paper amounts to an interim report relating to the design and evaluation of "Ba" developed based on the discussions in the knowledge science project "Knowledge management using systems methodology" and the Center project "Laboratory knowledge management methodology".

2.4. Systems for Integrating Knowledge

Leading contemporary systems thinkers promote the idea of methodological pluralism and/or mutual complementarism in Jackson [2]. What is meant by "pluralism" is that, in order to study and handle complexity, it is necessary to develop and utilize a wide range of heterogeneous methodological techniques. "Mutual complementarism" suggests that, as problems confronting humans are a complex mixture of hard and soft issues, the diverse and heterogeneous methods/techniques should be used in an informed and synergistic way in Zhu [3].

Here we consider systems for integrating and managing different types of knowledge, and for creating new knowledge. This is one type of research in knowledge science for creating "justified true belief" or "systemic knowledge". This research uses the approaches of the natural sciences and the social sciences in a mutually complementary fashion. This is a methodology which organically combines: methods of scientific analysis exploiting things like physical laws and data analysis techniques; techniques from information science like large-scale computer simulation; social science techniques relating to formation of partnerships between members of an organization or society; and techniques based on systems science for overall management of these.

A knowledge creation system is comprised of five subsystems in Nakamori [4]. However, for the 2nd, 3rd and 4th of the subsystems we shall introduce below, it is generally difficult for them to complete their missions themselves, and in that case, they comprise a lower level system with exactly the same structure as the overall system.

1. Intervention: Taking action on a problem situation which has not been dealt with before. First we ask: what kind of knowledge is necessary to solve the new problem? Then the following three subsystems are called on to collect that knowledge.
2. Intelligence: Raises our capability to understand and learn things. The necessary data and information are collected, scientifically analyzed, and then a model is built to achieve simulation and optimization.
3. Imagination: Creating our own ideas on new or existing things. Complex phenomena are simulated based on partial information, by exploiting information technology.
4. Involvement: Raising the interest and passion of ourselves and other people. Sponsoring conferences and gathering people's opinions using techniques like interview surveys.
5. Integration: Integrating heterogeneous types of knowledge so they are tightly related. Validating the reliability and correctness of the output from the above three subsystems.

Figure 2 shows the systems methodology, called the *i*-System which uses approaches in social and natural sciences complementarily. This methodology can be called a knowledge-creating system. The system integrates statistical data and individual persons' fragmentary knowledge, and then creates new knowledge nobody had before. Such knowledge must be tacit, otherwise someone including the system had it; this is a contradiction. Therefore, the system should have a process to convert tacit knowledge into explicit knowledge. This means that the members of the project or relevant people constitute a part of the system.

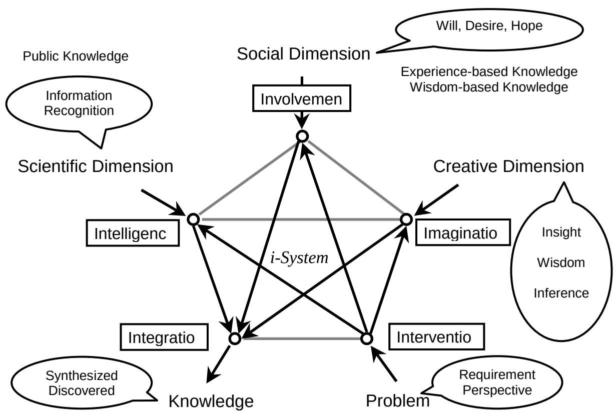

Fig. 2. Systems methodology for knowledge integration and creation.

3. "BA" FOR KNOWLEDGE CREATION

Toyama and Nonaka [1] called the dynamic context which is shared and redefined in the knowledge creation process "Ba", which does not refer just to a physical space, but includes virtual spaces based on the Internet, for instance; and more mental spaces which involve sharing experiences and ideas. They regard "Ba" as a "concept of locationality which includes the space-time which acts as the ground of human existence". Knowledge is not something which can exist independently; it can only exist in a form embedded in "Ba", which acts as a context that is constantly shared by people. Consequently, in order to conduct effective knowledge creation, there is a need to create a "Ba" to act as the existential ground of that knowledge. The "Ba" provides energy to the knowledge creation process, and determines the quality of knowledge which is produced. This section attempts to reconstruct the "Ba" concept from systems theory.

3.1. Revisiting the "Ba" concept

Toyama and Nonaka [1] listed the following as conditions for "Good Ba" to facilitate knowledge creation:

- A self-organized location with its own intention, purpose, directionality and mission, etc.
- Commitment of participants (Commitment to the purpose of the "Ba", and active participation in events occurring in the "Ba").
- Simultaneously providing two viewpoints: from the inside and from the outside.
- Direct experience by participants.
- Dialog is conducted relating to the essence of things.
- Boundaries are open (Participants come and go freely, and the shared context is endlessly changing).
- A "Ba" for practice where explicit knowledge can be internalized through practice.
- Heterogeneous mixing occurs.
- Impromptu interaction occurs.

In order for the word "Ba" to be used as an academic term, people must have a shared understanding of "Ba". But it is not possible to think that "Ba" has been defined yet in this way, as an academic term. This is also suggested by the fact that the Japanese term "Ba" cannot be translated into English and other non-Japanese languages. On the other hand, however, there is another possible interpretation: namely that it is precisely because "Ba" is not clearly defined that it is sympathetically accepted by many people with different standpoints and ways of thinking. While recognizing the depth and versatility of the word "Ba", each person is permitted to freely establish the content and boundaries of "Ba".

It is thought that this freedom was an extremely important condition in developing and disseminating the methodology called "knowledge management". However, in building a system of study called "knowledge science", people must be able to share their concepts of the term "Ba" in that system.

The academic term "system" has also been redefined a number of times over the last half century. Just like "Ba", this word provides a shared concept in different fields of study. However, it must be defined in each field of study, in relation to the distinctive complexity of each field, and it is a term for which that is possible. The definition of Checkland [5] is this: "A system is a whole with a hierarchical structure and emergent properties, which has communication and control capabilities, and which can continue to exist relative to a changing environment." To avoid confusion with the term "system" used in daily life, Checkland believes that we should have set aside the term "holon" for this concept.

As conditions of "Good Ba", Nonaka et al. have listed systems concepts themselves, such as being a self-organized location with its own intention, purpose, directionality and mission etc., having an open boundary, having interaction and so on. Furthermore, they refer to the desire of members, and the content of the information flying about. Perhaps Checkland's "system" and Nonaka's "Ba" are trying to express the same thing.

3.2. Redefinition of "Ba" via Systems Concepts

What is the best definition of "system" in knowledge science? Knowledge science addresses not only scientific knowledge, but also subjective knowledge based on experience and insight, so systems in knowledge science must include the participating people, the knowledge of the participants, and previous data and information which have been codified as knowledge. It is natural to think of emergence as the birth of new knowledge by the fusion of diverse knowledge, particularly knowledge in different fields.

A complex whole including human beings and information can be understood as a system. However the system so understood is not a reality per se. This is because wholes like this have a complexity and diversity which must be recognized as a system which differs depending on the subject. Systems like this are called soft systems. Checkland's definition of "system" is aware of soft systems, and can be regarded as having a philosophical background in common with the "Ba" of Nonaka.

Now, in order to improve the possibilities for manipulation and concept sharing, we introduce the following schema:

- Ba = Infrastructure (hard systems) + Actors + Information

Hard systems which do not include people are designed and built as the infrastructure of "Ba". This is the design and building of real systems including things like locations, rules and information infrastructure. It is engineering. The idea is to overlay this with the social science of what sort of people and what sort of information should be added. Substance and energy must be invested in the system but we assume that they have already been woven in as things which the infrastructure should have. The theory of designing all these things is called "Ba design theory", and if it is applied to a site of science and technology development, that is exactly the "scientific knowledge creation theory" we are aiming for.

To achieve a "Good Ba", it must become a self-organized space-time with its own intention, purpose, directionality and mission, due to the interaction of its elements: infrastructure, actors and information. Therefore, being aware of the interaction, we can also suggest:

- Ba = Infrastructure x Actors x Information

If we accept this, there is no incongruity in saying "Ba = System". Here we organize the situation as follows, using systems concepts:

- Ba = { Set of elements, Set of characteristics, Set of relationships }
  - Set of elements = { Infrastructure, Actors, Information }
  - Set of characteristics = { Emergence, Hierarchy, Communication, Control, etc. }
  - Set of relationships = Complex (Investigation of this is the issue)

In order to organize relationships, it is necessary to introduce a conceptual framework for a holistic perspective and systematization. We here introduce the following three subsystems which correspond to the scientific dimension, the social dimension and the creative dimension:

- Intelligence Ba
- Involvement Ba
- Imagination Ba

4. DEFINITION AND EVALUATION OF "BA"

This section discusses evaluation of three "Ba", and evaluation of system performance, based on the aforementioned systems concepts, and reports on the views obtained through a preliminary survey. As shown in Fig. 3, we introduce the concepts of "Intelligence Ba", "Involvement Ba" and "Imagination Ba".

Based on this definition of "Ba", we will evaluate research projects, that is, evaluate the systems elements: infrastructure, actors and information, as well as the system performance: research progress and member growth. Then we will explore relationships between the system elements and the systems performance and thereby we will establish a method of diagnosis of "Ba".

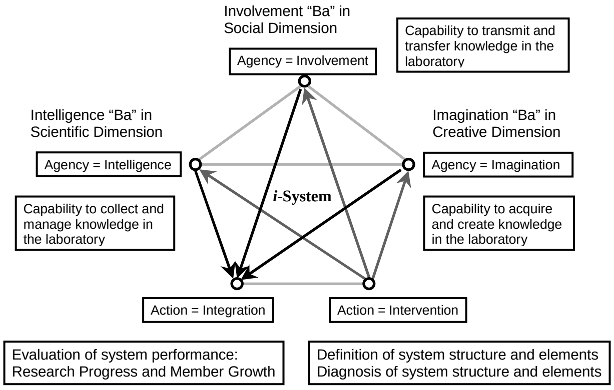

Fig. 3. Definition of ‘Ba’ based on *i*-System.

4.1. Viewpoints for Evaluation

Three evaluation items are established for each relating to infrastructure, actors and information, and these are placed into correspondence with the conditions of "Good Ba" according to Toyama and Nonaka [1] as follows:

A1: Infrastructure in "Intelligence Ba":
Are boundaries open?
A2: Actors in "Intelligence Ba":
Do the members have own intention, purpose, directionality and mission, etc.?
A3: Information in "Intelligence Ba":
Are there viewpoints from the inside and from the outside?
B1: Infrastructure in "Involvement Ba":
Does heterogeneous mixing occur?
B2: Actors in "Involvement Ba":
Does the commitment of participants exist?
B3: Information in "Involvement Ba":
Is dialog conducted relating to the essence of things?
C1: Infrastructure in "Imagination Ba":
Can members experience directly?
C2: Actors in "Imagination Ba":
Can actors internalize explicit knowledge through practice?
C3: Information in "Imagination Ba":
Is impromptu interaction possible?

These also correspond with 9 of the 16 items in "learning design to develop living skills" due to Yumino [6]:

A2: Actors in "Intelligence Ba":
- Deep understanding and versatile thinking power
- Sense of responsibility toward learning
- Curiosity

B2: Actors in "Involvement Ba":
- Leadership and follower-ship
- Power of expression
- Empathy and support skill

C2: Actors in "Imagination Ba":
- Creativity
- Power of concentration
- Initiative-taking attitude

Furthermore, the infrastructure and information of each "Ba" correspond to the information technology and knowledge creation theory developed in knowledge science, which we are working to incorporate into the COE program:

A1: Infrastructure in "Intelligence Ba":
Information search/mining systems, databases, knowledge bases

A3: Information in "Intelligence Ba":
Knowledge management theory, innovation theory, business practice theory

B1: Infrastructure in "Involvement Ba":
Information collection/transmission systems, home pages

B3: Information in "Involvement Ba":
Systems methodologies, "Ba" design theory

C1: Infrastructure in "Imagination Ba":
Document management, equipment management, visualization systems

C3: Information in "Imagination Ba":
Road mapping, presentation technology, documentation technology

Figure 4 shows a typical project framework in the COE program. In a laboratory of scientific research, there are two types of difficulties that are mutually related. The "death valley" means that there are a huge number of ideas which are not used in industry. "Deep woods" means that it is very difficult to determine the research direction because of the information flood. In the School of Knowledge Science, we are developing methodologies, methods, and support systems at almost every phase of creative research activities, such as knowledge systematization, technology road mapping, knowledge creation theory, data analysis, management of technology, or marketing. We aim at co-evolution of knowledge science and material or information science, and at the same time, education of graduate students to be "knowledge creators" or "knowledge coordinators".

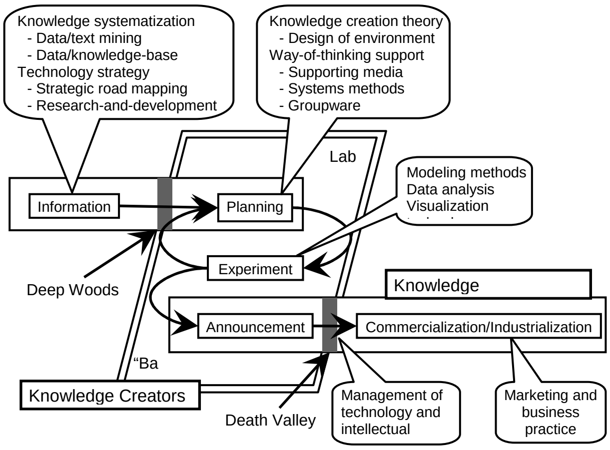

Fig. 4. Framework of an interdisciplinary research project

4.2. Evaluation Structure

Figure 5 shows the keywords related to the evaluation of research progress and member growth. Figure 5 also shows the whole evaluation structure.

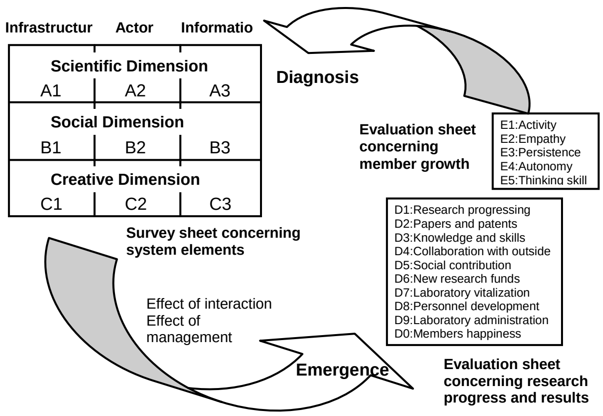

Fig. 5. Diagnosis of system elements considering system performance (emergence)

4.3. Results of Preliminary Survey

Using the evaluation given by a number professors in materials research laboratories at JAIST, we found following relationships between research progress and "Ba" (see also Fig. 6):

- Three factors – "accumulation of knowledge and skills", "vitalization of the research laboratory", and "personnel development" -- are strongly and linearly related to the quality of "Ba".
- Actors in "Intelligence Ba", information in "Involvement Ba", and infrastructure in "Imagination Ba" are linearly related to "knowledge and skill accumulation", "research laboratory vitalization" and "personnel development".
- "Collaboration with the outside", "improvement of social impact", and "acquisition of research funding" are not linearly related to the quality of "Ba". These are things which are related to the hard work of professors, so these results are understandable.
- In the degree of "happiness of members", it is possible to see a linear relationship in the direction opposite to that of "Ba" quality. In particular, actors in "Intelligence Ba", information in "Involvement Ba", actors and information in "Imagination Ba" face in the direction opposite to the degree of happiness of members. It appears that professors believe that students are more miserable the more that "Ba" is consolidated, in particular, the harder the effort that is made to collect, exchange and create knowledge.

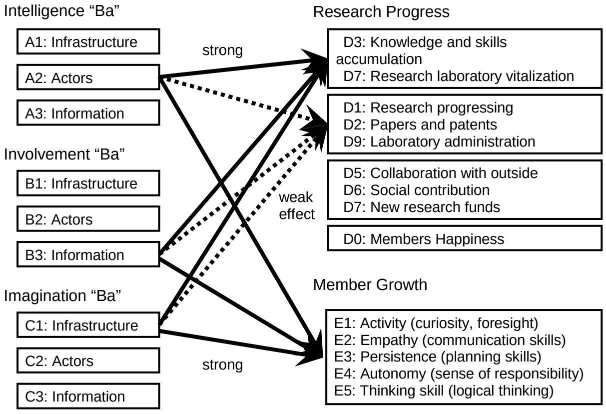

Fig. 6. Linear relationships found by a preliminary survey.

We found the following relationships between member growth and "Ba":

- Among the five skills of members (mainly graduate school students), "persistence" is strongly and linearly related to the quality (good or bad) of "Ba".
- Actors in "Intelligence Ba", information in "Involvement Ba" and infrastructure in "Imagination Ba" are linearly related to member growth.

5. CONCLUSION

In this paper, we introduce knowledge science as a new field of study and discuss the role of systems science as well as social theories in its development. After presenting the MEXT-sponsored 21st century COE program "Technology Creation Based on Knowledge Science: Theory and Practice", we propose *i*-system as a new system methodology for knowledge creation. Finally, we discuss a number of useful perspectives obtained from a preliminary survey. We conclude that both education and research in the science and technology field can be enhanced when "Good Ba" is supplied.

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