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Innovation Study for Materials Science Laboratory Management, Supported by Knowledge Science Tools: Five Cross-Disciplinary Projects

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Abstract

It has become a topical and widely accepted argument that innovation is the key to revitalizing competitiveness of a country, company and university. As a graduate university having the School of Knowledge Science, and the School of Materials Science, we have organized to make "innovation studies" for Materials Science Laboratory, supported by Knowledge Science tools with collaboration of these two schools as 5 cross-disciplinary projects. Knowledge Science side has provided knowledge tools, and Materials Science side has applied them to produce more creative and innovative research systems and research findings.(trial to induce innovation)

Principle of innovation has been explained by our model in this paper, based on the innovation portfolio strategy by Niwa's diagnosis model[4] (by prof. K.Niwa).

Targets(subjects) of innovation for laboratory management have been examined based on the Schumpeter classification[7]

5 projects have been evaluated as proceeding level, the type by Niwa model and the subject by Schumpeter model.

Finally, we would like to conclude for this type of cross-disciplinary research, that the open minded collaboration and forward-facing presentation of the results are inevitable.

Keywords: Innovation, Laboratory management, Cross-disciplinary, Knowledge tools,

1 Instructions

In Japan and other advanced industrialized countries the whirlwinds of innovation are blowing. In the early 1990s Japan experienced a major shift as its international competitiveness began to decline. Under the conditions of the so-called "lost" 16 years that have since passed, the idea that innovation is the key to revitalizing competitiveness has become a topical and widely accepted argument. Governments and industry associations are vigorously trying to promote innovation in organizations, economic activities, and technology development, and similar efforts are being pursued in all major industries and enterprises too. Local innovations are also being attempted at the regional level.

The source[8] of the competitiveness of a country, university, and company are (advanced) science and technology, for which this university is named. In America, a massive change in the structure of science and technology, evident on an international scale, occurred over a 50-year period beginning with the establishment of the National Science Foundation in 1950 by the famous Vannevar Bush (previously Director of the Office of Scientific Research and Development), and the effects of this continue to reverberate to this today. Bush believed that, in essence, science flowed from the desire of scientists to satisfy their curiosity, but also that the resulting knowledge should be applied to promote the prosperity of the nation. This concept has long shaped[11] America's science and technology policy and its influence has remained firmly in place down through the years, as evidenced by the Young Report of 1985 ("Global Competition: The New Reality") a report of the President's Commission on Industrial Competitiveness, and the "Palmisano Report" ("Innovate America") issued in 2004 by the NII (National Innovation Initiative). Last year Japan's the Cabinet Office launched a similar initiative—the "Innovation 25" project . As a result, vigorous innovation-oriented initiatives are now being taken at industry, government, and academia levels.

The Japan Advanced Institute of Science and Technology (JAIST) is a graduate university consisting of three schools—the School of Knowledge Science, the School of Information Science, and the School of Materials Science. Since its program on the theme of “Technology Creation Based on Knowledge Science” was certified by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) as a 21st Century COE (Center of Excellence) Program in October 2003, the School of Knowledge Science has continued to implement the program[1]. This year marks the concluding year of the program. After an interim appraisal in October 2005 the program was partially revised. This program is made up of four basic initiatives. Of these, Project No. 2 consists of five cross-disciplinary projects relating to innovation. The key purpose of these five innovation projects is to stimulate and promote innovation, with the aim of improving the management and results produced by materials science laboratories, through the utilization of knowledge science. To achieve this, cross-disciplinary teams made up of professors and students from both knowledge science and materials science laboratories were formed to pursue research together. Here I will report on the progress and results that these teams have produced to date. This initiative represents a very interesting trial on innovation research by a multi-disciplinary team (combining humanities and sciences).

1) Design of the cross-disciplinary innovation creation projects

1-1) Themes and composition of 5 cross-disciplinary projects

The objective of research in each project is to improve the management and productivity of materials science laboratories. Studies were conducted under the following titles.

2A: Innovation in the mature polyolefin chemical industry

2B: Knowledge creation initiatives backed up by a research philosophy

2C: Knowledge representation(animation) theory for coordination

2D: Knowledge management of laboratories based on cultural anthropology

2E: Knowledge management of experimental laboratories using mobile blog albums

Each project team is composed of 2 to 4 professors and 2 to 3 students (Masters and PhD) from various disciplines, led by a materials science professor. The teams meet once to several times each month.

1-2) Cross-disciplinary integration model

This model offers the knowledge tools from the knowledge science side, and combines these with materials science laboratories and physics theory, to generate management methods that can deliver richer results and more advanced knowledge. This “integration” model is outlined in Fig. 1.[3]

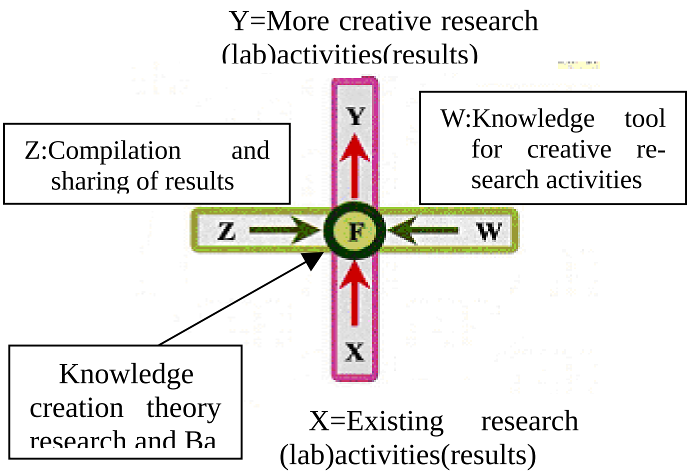

Fig.1 Laboratory innovation creation model

Thus, “more creative research (lab) activities (results)” (Y) can be expressed by the formula below.

$$Y = F_{ZW}(X) \qquad (1)$$

Here, we provide some further explanation to help avoid confusion. This project aims at initially providing knowledge tools from the knowledge science side and applying these to research work on the materials science side, and then finally producing more creative and innovative research systems and research findings (multi-disciplinary). If this integration progresses as described, and new academic disciplines are created out of a genuine integration (inter-disciplinary), we would regard the initiative as very successful.

2) Creation and implementation of the 5 cross-disciplinary projects

Based on the above-mentioned design, we re-started (some projects were started afresh) the five projects from the beginning of the new academic year of 2006. All of these projects were relaunched with the goal of promoting cross-disciplinary study and innovation creation. Accordingly, this report on innovation creation and implementation covers approximately one and a half years of program activities.

2-1) General progression of the projects

Since the intended subject of this research is materials science laboratories for science and technology research, the projects started initially with proposals for the knowledge science side to provide knowledge tools that can be applied to materials science laboratories. However, over time problems arose relating to the application of the knowledge tools that were initially proposed. Conversely, some projects were started by exploring the needs of the materials science side.

A common element of the projects, however, was that initially, when team members from the knowledge science side participated in the seminars of the materials science laboratories and took notes in the labs, this itself caused a certain amount of suspicion and caution and an exclusionary reaction. As the projects were carried out, continuous efforts were made to weaken this sense of opposition. Table 1 includes the results of the attempted integration.

Table 1 Progress status of 5 cross-disciplinary projects

Project2	Cross-disciplinary project(innovation study)				
	Sub-project		Research System		
Item	Project themes	Subject	Research fields	Knowledge Tools	Integration results
Common themes	Innovation creation by cross-disciplinary integration				
2A	Innovation in the mature polyolefin chemical industy	A Lab.	Polyolefin research	Road Mapping Theory	Conceptualization of research theme-time map
2B	Scientific Knowledge Creation based on Research Philosophy	Research life of each professor	MS research (lab culture) Individual character Education	History,litereture, fine arts,psychlogy, liberal arts, Education, knowledge Creation, management	Methods to develop humanity and personality to help produce good researchers and research results
2C	Knowledge representation theory for coodination	Physics theory	Explaining the essence of science & technology to employees with humanities background	・Applying physics culture theory	Core physics principles
		Animation of physics phenomena	Animations to explain the essence	・Media studies ・Animation theory	Physics embodied animation
2D	Knowledge management in laboratories, based on cultural anthropology	D Lab.	Bio-chemistry	Cultural anthropology	
2E	Laboratory knowledge management using mobile blog albums	E Lab.	Management of surface science labs	・Mobile Blog Albums (System sharing of tacit knowledge) ・Methods to activate labs	Management Education ①Sociological surveys ②Support tools (engineering) ③Lab activation (management)

3. Examination of innovation studies

3-1) Innovation portfolio strategy

According to "Management of Technology" (MOT)[4] by Professor Kiyoshi Niwa, portfolio strategies for technological development in the leading-edge fields of corporate enterprise, which are continually exposed to waves of innovation, can be summarized according to the following four innovation patterns.

- (i) Sustainable innovation: Further improving the functions and performance of the current leading technology
- (ii) Destructive innovation: Increasing competitiveness by reducing price, even at the cost of lower performance, using alternatives to the existing technology
- (iii) Blue ocean innovation: Increasing competitiveness by lowering standards where acceptable, and adding instead new, different functionality, after analysing the products of other companies in the same industry (i.e. enhancing desirability by subtraction and addition)
- (iv) Revolutionary innovation: Developing products that customers are not aware of, but which they desire after learning about them (i.e. creation of new opportunities for customers)

3-2) Principle of innovation

The essence of innovation is the problem of mapping between a function space to an attribute space. This is based on the fact that what customers want is a function, as explained above in the examples of 3-1). Then, assuming that a certain attribute (part or product) provides this function, successful innovation can be achieved by either providing the same function via an alternative attribute so that a lower price can be offered; by offering an additional amount of performance (alpha) that is desirable to the customer; or provide a new function that the customer was not aware of. Figure 2 below illustrates this point. (Note that the Niwa model does not include destructive innovation by means of new inventions.)

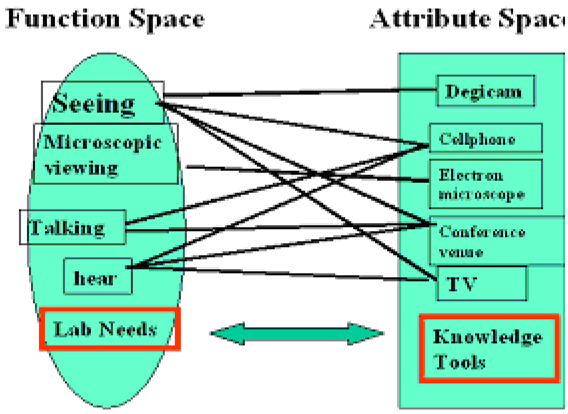

Figure 2 Principle of Innovation

When this principle is applied to these projects, knowledge tools serve as seeds and to attributes. At the same time, the functions of research (labs) that require innovative improvement correspond to needs, located in the function space. In view of this, the most successful project teams will be those that are able to discover (infer) the most needed and desired needs of labs and then quickly provide the labs with knowledge tools that have the attributes to fulfil these functions.

3-3) Focus of innovation based on the Schumpeter model

Here, we attempt to think through the focus of innovation efforts based on the writings of Schumpeter[7] , which are regarded as the "bible" of innovation. Considering numerous examples of corporate activities, Schumpeter categorized the focus of these activities into five classes. Applying this scheme to national, municipal, and individual levels is an interesting concept.[5] The Schumpeter model can be applied to these projects as outlined in Table 2. Unlike the case manufacturing companies, it can be difficult to determine whether something is a production process (item 2 below) or raw material or resource (item 4 below) in the context of the trying to produce good research findings (knowledge).

Table 2 Focus of innovation for labs, based on the Schumpeter model

	"Theory of Economic Development,Vol1" by Schumpeter	Corporate activity	New combination (general)	Application to lab management	Focus of lab applicability
①	New goods	Development of new products	Delivered goods	・Results from research?	Researchers, research results, papers, research themes
②	New Production methods	New Production meth	Delivery method	・Process for producing results	Guidance by professors, research management, knowledge science、
③	New sales channels	New markets	Delivery destination	・Who is enjoying benefits of reseach	Potential employers, society, organizations and companies applying research results
④	New raw material(semi-finished products)supply sources	New raw material and semi-finished product supply sources	Resorce acquisition metods	・Raw materials and resources for producing results	Social needs, classes, research training, accumulated lab knowledge
⑤	Establishment of new organizations	New forms of oraganization	Resorce utilization metods	・Organization and systems for producing results	Supervising professors, lab organizations, research support organizations (e.g. universities)

3-4) Key for progress in cross-disciplinary projects

a) Above, we sorted out the principles and focus of innovation, but even with this knowledge projects may not proceed well. Whether or not cross-disciplinary research proceeds effectively towards its goal depends on whether there is matching and synergy between the knowledge tools (seeds) and the needs of the laboratory. Or, even if matching and synergy have not yet occurred, it is essential to set a place and time (for a certain duration) for meetings that promote mutual respect and understanding between people from diverse disciplines. Some of the various knowledge tools that have been provided to the materials science laboratories over the past few years, for example, have not yielded any research fruits, due to incompatibility with the needs of the research lab—or where compatible, due to lack of user-friendliness. Whether a project is accomplished well depends on whether the needs on the function side are fulfilled, regardless of whether the needs like on the knowledge side or materials side. For this reason, success in such research depends on whether or not the final decisions are made on the function space side. Recognition of this fact is important.

b) Another issue is whether or not integration (mutual understanding) between the various disciplines proceeds smoothly—something that relates to aspects of Japanese culture. Making use of the SECI model[6] developed by Ikujiro Nonaka, the first head of the School of Knowledge Science at JAIST, one of the current authors delivered a presentation describing how the process of knowledge creation in Japanese companies features a higher proportions of socialization, S, and internalisation, I, when comparing with Western companies, but lower proportions of externalisation, E, and combination, C.[9] This is illustrated in Fig. 3 below.

Generally, the case of corporate mergers in Japan shows that compatibility between the cultures of the two companies (feelings and behaviour patterns) is even more important than the expected business synergy effect. This fact relates the high values of S and I in the corporate workplace, as defined by the SECI model.

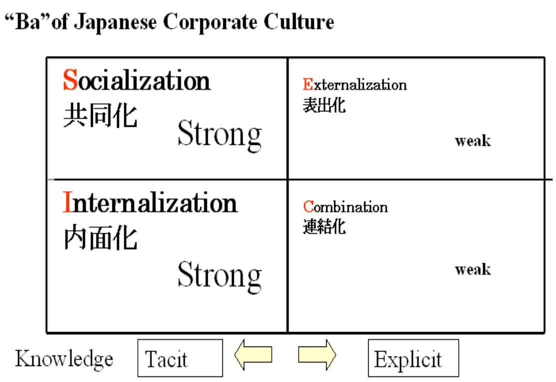

Fig. 3 Field of SECI model in which Japanese corporate culture is strong

In these projects too, cross-disciplinary research between people from different fields proceeded with the highest probability of success in the following cases: Knowledge side students joined the materials science side labs, but had to pass through a period of endurance until they were recognized as colleagues (action started from S: socialization) by the materials science side. During the period of endurance, the knowledge side students explored the needs of the materials science laboratory, all the while keeping in mind the question of how knowledge tools could be of value. It is interesting that the importance of Japanese cultural factors may be so strong even in a university setting.

4) Conclusion

(1) Table 3 summarizes an analysis of the innovations that we tried to induce in the process of pursuing each project, based on the above understanding of innovation. This classification is organized in accordance with each of the Niwa model and Schumpeter model, which are outlined above.

Table 3 Results of project integration and classification of innovation

Project2	Cross-disciplinary project(innovation study)				
	Sub-project		Grouping of innovation		
Item	Project themes	Integration results	Type by Niwa model	Subject by Schumpeter model	Output
Common themes	Innovation creation by cross-disciplinary integration				Knowledge innovator theory
2A	Innovation in the mature polyolefin chemical industy	Conceptualization of research theme-time map	(ii)	②、④	Research (Road)map
2B	Scientific Knowledge Creation based on Research Philosophy	Methods to develop humanity and personality to help produce good researchers and research results	(i) (iii)	②、④	Research philosophy
2C	Knowledge representation theory for coodination	Core physics principles	(ii)	①	Social Application theory for physics
		Physics embodied animation	(ii)	①	Physics embodied animation
2D	Knowledge management in laboratories, based on cultural anthropology			②、⑤	Research cultural theory
2E	Laboratory knowledge management using mobile blog albums	Management Education ①Sociological surveys ②Support tools (engineering) ③Lab activation (management)	(iv)	②、④	Research sociology theory

(2) Cross-disciplinary integration (leading-edge fields of integration) and innovation creation are emphasized in the third phase of the government's Science & Technology Basic Plan[2]. Through these projects, the professors and students who have experienced multi-disciplinary research work have acquired integration skills, while appreciating the difficulty of this. In view of this, we have concluded that such projects are valuable.

(3) The purpose of scholarship is to shape the future of society. In terms of integration, some of these projects were able to achieve sufficient integration, while others were not. Some projects failed to reach integration because the participants pushed their own particular scholastic frameworks too heavily. We thus concluded that a flexible way of thinking, aligned with the aims of the project, is essential for the success of this kind of program.

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