Transitions of Japanese manufacturing methods from the viewpoint of constructing and utilizing explicit and tacit knowledge ~The rise of New Empiricism~

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Abstract

Since 2007, after receiving a Grant-in-Aid for Scientific Research (Exploratory Research) provided by MEXT, we have been performing research and promoting follow-up classes regarding the utilization of TRIZ in university education at Niigata University. Regarding the introduction of TRIZ and other creativity methods in school education, we aim to nurture extensive creativity by raising the independence of the students, as well as to introduce learner-oriented teaching methods. In this paper, upon reviewing the transitions of Japanese manufacturing methods, we discuss the rise of the new empiricism and "High-Concept" by Daniel Pink from the point of view of explicit and tacit knowledge.

1. Introduction

In the present paper, we compare creative thinking methods utilized in Europe and the US with techniques of traditional Japanese methods, and examine the future role of creative thinking methods. Since many such creative thinking methods exist, as a prototypical example of a European creative thinking method, we discuss the TRIZ.

In Japan examples of technical innovations in advanced technology fields, which is rooted in the skills of Japanese crafts culture, are beginning to appear, and those skills are gradually being revised.

Although creative thinking methods, such as TRIZ, represent the integration of the explicit knowledge related to the invention technique, they also constitute collections of methodologies regarding the inventions which have profound implications on the life of mankind. In this regard, they are inextricably connected with tacit knowledge and are therefore difficult to be regarded as matters of science. On the other hand, in actual research development and production sites, problems emerge which are thought to be the result of overconfidence in knowledge bases. There are also problems regarding school education caused by unbalance between explicit knowledge and tacit knowledge.

Based upon the above, we discuss the new empiricism in creative education system, comparing Japanese new craft culture and "Conceptual Age" by Daniel Pink.

2. Current state of TRIZ

Based on the previous experience of the author in utilizing TRIZ, its advantages and shortcomings can be summarized as follows.

2.1 Cases in which TRIZ is effective

- Regarding solutions to short-term technological problems, there is a positive effect in cases where trained engineers and competent advisors cooperate with each other.
- Technological advancement can be achieved by using TRIZ in cases where a technical solution has not been obtained for a long time.
- There are cases where positive effects are achieved through the independent use of TRIZ software by skilled engineers possessing deep insight into technology and good command over knowledge bases.

2.2 Cases where the utilization of TRIZ is problematic

- Since there are individual differences between engineers, and therefore the applicability of TRIZ is also different, there are cases where positive effects can not be anticipated if the TRIZ training is applied to all engineers uniformly.
- If young engineers acquire an immense knowledge base such as TRIZ at an early stage, they might experience difficulties in the construction of tacit knowledge.
- Even in the case of skilled engineers, when TRIZ is used without performing sufficient research regarding the target technological problem in the field, it is possible that only a shallow understanding of the problem itself is obtained with respect to the relevant field.

- Even if a good idea is obtained through the use of TRIZ, the more innovative the idea, the higher the development time and cost, and therefore even experiments might not be conducted.
- Even if there is a good idea, it is possible that designers with insufficient knowledge in the field might not regard it as valuable.
- There is a possibility that engineers who are exceptionally compatible with TRIZ might develop too fast along the spiral of only explicit knowledge, thus experiencing burn out (TRIZ virus).[1]
- The teaching of systematic knowledge bases in school education might result in reduced eagerness to learn.

3. Traditional Japanese manufacturing methods

Traditional and modern Japanese manufacturing methods are briefly introduced below.

3.1 The ideology of Shuhari

The ideology of Shuhari was born from the Higashiyama culture in the shogunate of Ashikaga Yoshimasa. It started with Nogaku (Kan'ami) and spread to tea ceremony, and it was adopted by martial arts. The essence of Shuhari has also been a continuous part of the apprenticeship system of craftsmanship since the Edo period. The following is a summary of the statements regarding the Shuhari of tea ceremony as written by Yamagami Soji.[2]

- 15-30 years of age is the "Shu" stage. Devotion to the study of "Shu" by following the teachings of the master.
- 30-40 years of age is the initial stage of "Ha" (the original method is developed at the half–way point).
- 40-50 years of age is the intermediate stage of "Ha". Striving for originality and innovation (using techniques completely opposite to those of the master).
- 50-60 years of age is the final stage of "Ha". The performances of the master are carefully reviewed, and preparations are made for the following transition.
- 70 years of age, the stage of "Ri". Strives for the objectives and blessed with talent. Extraordinariness is achieved only when the craftsman encounters masters who are already in the stage of "Ri".
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3.2 Apprenticeship systems in the Edo period

The following is an overview of the apprenticeship systems in the Edo period.[3]

- An apprenticeship system is a setup where a person striving to become a true professional is trained while living together with the master and the senior disciples. Disciples are accepted around the age of 12.
- A "technique" is observed and repeated until the body learns it. The master performs demonstrations starting from the basics.
- The apprenticeship lasts for 10 years, where the 10th year constitutes a 1-year free service.
- After this, in order to polish the techniques and become a professional, the apprentice gains experience in another school as an independent freelance professional.
- Subsequently, the young professional usually works under the supervision of the previous master as an outworker.
- The professionals create a guild as a fellow association for the purpose of promoting each other's interests, and work together by joining forces.

3.3 The meister system in Germany

Although it is not a Japanese system, an outline of the meister system in Germany is provided below since it has many common points with the Japanese apprenticeship system. The success of Mercedes and BMW is largely due to the meister system, and Germany recognizes the fact that the source of its international competitiveness is the result of this system.

- The origins of the meister system are in the Middle Ages.
- Presently, after completing compulsory education, a minimum of 3 years of specialized basic training of the profession are undertaken.
- After this, actual experience at the company is gained for a minimum of 3 years, followed by a meister examination. (In the Middle Ages, the apprentice searched for a superior professional and embarked on an ascetic training journey to the meister. In Germany, this "journey imposition" was introduced to almost all types of manual crafts in virtually all areas, and this practice continued until the 19th century.)
- When the title of "meister" is received, recognition is received from society. Recognition is exactly the same or higher than that of the people from the top-ranking companies.
- In Germany, for the purpose of solving employment problems, the manual crafts were revised in 2003

with the result that 53 types of crafts lost the obligation to receive a "meister" qualification. However, important industries, such as cars, metalwork, and electrical work, retained the established system in order to maintain the level of technological sophistication.

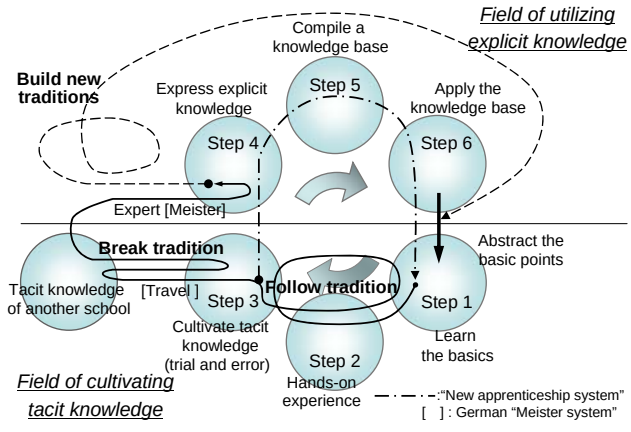
4 Previous Works

4.1 The creation cycle of explicit and tacit knowledge

The concept of "tacit knowledge" refers to knowledge based on experience and intuition, which can not be communicated through language. It was proposed by the Hungarian philosopher and physicist Michael Polanyi in 1969. The opposite concept is referred to as "explicit knowledge". In Japan, Professor Nonaka Ikujiro from Hitotsubashi University has proposed the "SECI model" in order to explain the processes of transformation and transmission of tacit and explicit knowledge in knowledge-creating companies with superior performance.

In the following sections, we discuss from the viewpoint of constructing and utilizing explicit and tacit knowledge.[4]

Fig.1. Creation cycle of apprenticeship in Japan



In Fig. 1, the creation cycle of explicit and tacit knowledge is divided into 6 steps, and the process of transferring skills in the apprenticeship system is presented in a typological manner.

① Step 1: Learning the basics (acquisition of the basics, listening, and watching)
② Step 2: Hands-on experience (repetition of the basics, collaborative work)
③ Step 3: Cultivating tacit knowledge (Nourishing intuition and insight, trial and error)
④ Step 4: Expressing explicit knowledge (verbalization, quantification)
⑤ Step 5; Compiling of knowledge base (systematization and digitalization of explicit knowledge)
⑥ Step 6: Applying the knowledge base (combination and application)

In the "Shu" step of the traditional craftsmanship, steps ①, ②, and ③ are repeated, and methods from other schools are acquired in the "Ha" step. This process of "Shu" and "Ha" is similar to the "professional journey" of the German meister.

The "New apprenticeship system" part represented with a alternate long and short dashed line corresponds to the example case of the advanced middle-sized companies such as Okano Kogyo, and when the construction of tacit knowledge is accomplished, the cycle enters steps ④, ⑤, and ⑥. Since the cycle can extend deeply into the areas of explicit and tacit knowledge, it becomes possible to develop technological innovations which would not be accomplished through the utilization of the knowledge base.

Fig. 2 presents the "Creation cycle" of TRIZ using the same 6-step cycle. The TRIZ system covers ⑤ and ⑥. There are many cases in which the external tacit knowledge of outside consultants, etc. is needed in order for step ⑥ to function properly (cf. Ⓐ in Fig. 2).

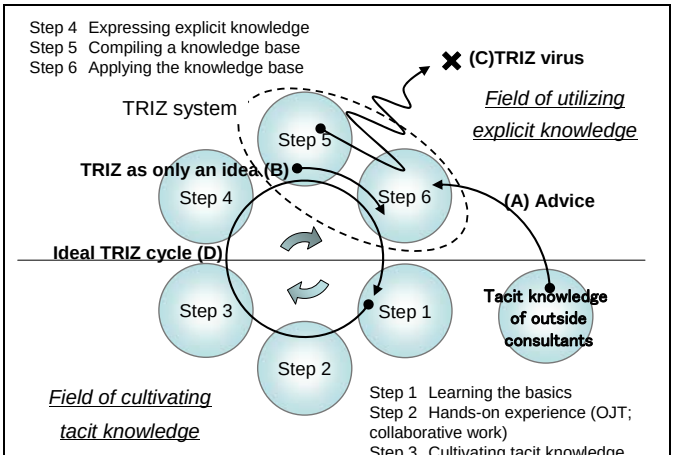


Fig.2. Creation cycle of TRIZ

The arrow corresponding to Ⓑ in Fig. 2 indicates cases where the samples and the experiments necessary for the realization of the technique are not implemented even if a potentially good idea is given.

Ⓒ in Fig. 2 represents burnout in the case where the engineer is cycled over ⑤ and ⑥ only. In TRIZ as well, it is thought that the ideal technological innovation cycle is achieved by cycling over the steps of both the explicit and the tacit knowledge (cf. (D) in Fig. 2).

4.2 Transitions of the Japanese school education system

Fig. 3 presents a schematic image of the transitions of the Japanese school education system, between the Edo period and now by using the aforementioned 6 steps, from the point of view of explicit and tacit knowledge.

While the preceding 6 steps outline how each work stage from step 1 to step 6 transforms the craftsmen or the project, Fig. 3 shows where the emphasis of education of each period is placed in these 6 steps. This figure is drawn on the basis of the knowledge and the value judgment of the author.

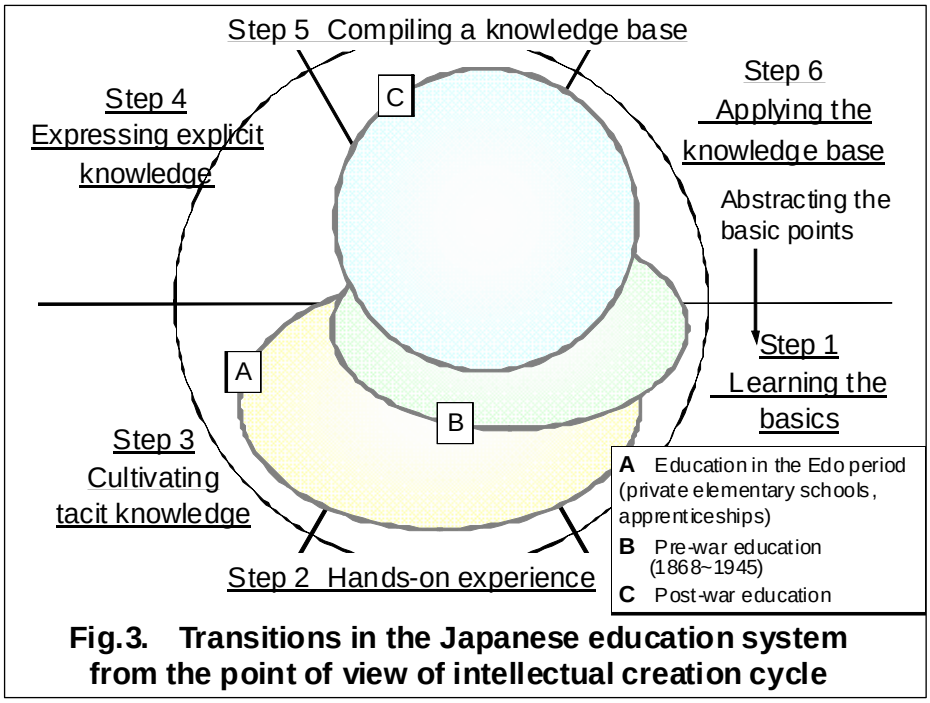


Fig.3. Transitions in the Japanese education system from the point of view of intellectual creation cycle

The Ⓐ circle in Fig. 3 represents the education at private elementary schools and apprenticeships during the Edo period. Tacit knowledge was cultivated through the exhaustive repetition of the basics, and enjoyment was derived from learning. However, the information infrastructure necessary for the sharing of explicit knowledge was not sufficiently developed, and technological innovation was slow.

The Ⓑ circle in Fig. 3 represents pre-war school education. The Ⓒ circle in Fig. 3 represents post-war education. The excessive transmission of knowledge reduces the field of cultivation of tacit knowledge, and the joy of learning is gradually lost.[5] “Less strenuous education” establishes a program with a lower workload of explicit knowledge, but it is not sufficient for the cultivation of tacit knowledge in steps 5 and 6 of the Ⓒ circle, and as a result the basics are not acquired and the will to learn does not increase.

Regarding traditional Japanese craftsmanship, in the "Shu" stage of Shuhari, while basics are thoroughly acquired by repetition, the truly important points are not taught but rather the process of gradually learning through experiencing first-hand and thinking is strictly observed. The "learner-centered teaching techniques" and PBL in Europe and the US and the traditional craftsmanship in Japan place an emphasis on "cultivating senses by thinking by themselves".

Furthermore, since the cultivation of tacit knowledge is related to internal and cultural aspects, it can be said that it is necessary for each country to develop an independent educational curriculum in accordance with the nature, the climate and the characteristics of the nation.

5. Transitions in manufacturing from the viewpoint of explicit and tacit knowledge

In response to the above research, I formulated the following theory with which to view the main currents in Japanese manufacturing since the Meiji Restoration (1867).

- Tacit knowledge is not easy to acquire, but once acquired it remains for life.
- Tacit knowledge persists within the individual even when the social system which embodies explicit knowledge undergoes radical change.
- Basic tacit knowledge is instilled by about 10 years of age.

When people who were 10 years old in the first year of the Meiji era retired at the age of 60, the influence of tacit knowledge garnered in the Edo period all but disappeared from society.

When the Western social and education systems introduced from the Meiji era onwards were unable to replace Edo era tacit knowledge with an accumulation of new and effective tacit knowledge, society began to fall into disorder at the point when the influence of Edo era tacit knowledge disappeared.

The interim period was an era of co-existence of old tacit knowledge and new explicit knowledge, and society prospered in this period.

The same applies to the post-war period. At the end of the Pacific war, Edo era tacit knowledge had disappeared, but why was such a dramatic post-war economic recovery possible?

Although tacit knowledge is normally instilled within high-quality traditional culture as in the Edo era [6], it is also acquired through experience of a number of failures or one large failure. In Japan at the end of the Pacific war, all generations in an instant shared in the profound tacit knowledge bestowed by the experience of defeat. The tacit knowledge arising from defeat was something too deep to express in words, and its psychological underpinnings were the wish for peace, joy in being able to work in peace, and cooperation harmony.

The post-war explicit knowledge following the war's end took the form of a social system based on the US model (see Fig. 4). Japan prospered when this new explicit knowledge and the pre-war tacit knowledge worked alongside each other. The post-war period of rapid growth saw the Tokyo Olympics, the income-doubling program and resumption of normal Sino-Japanese relations, and in the 80s the phrase 'Japan as number one' appeared.

The reason lies in the fact that the IT revolution has driven a rapid increase in the volume of explicit knowledge, and Japan's traditional system of academic training which emphasizes rigorous training in the basics has ceased to be effective. The same situation has occurred in manufacturing. The indigestion of burgeoning information brought about by the IT revolution has led to a weakening of systems for refining *kansei* or intuition.

What was the situation in the Edo period? And why was it that things did not start to go wrong after 50 years? The tacit knowledge of the Edo era represented the integration of an immense amount of tacit knowledge obtained during the hundred-plus years of the Warring States period (mid 15th to mid 17th century), and included the deep wish that the country would not again face the chaos of war. Then, during the 50 years from the beginning of the Edo period, people who thoroughly understood human strengths and weaknesses successfully created a system for cultivating the tacit knowledge necessary to maintain peace and prosperity. The apprentice system, terakoya (elementary schools for children of commoners) and Edo shigusa (manners,

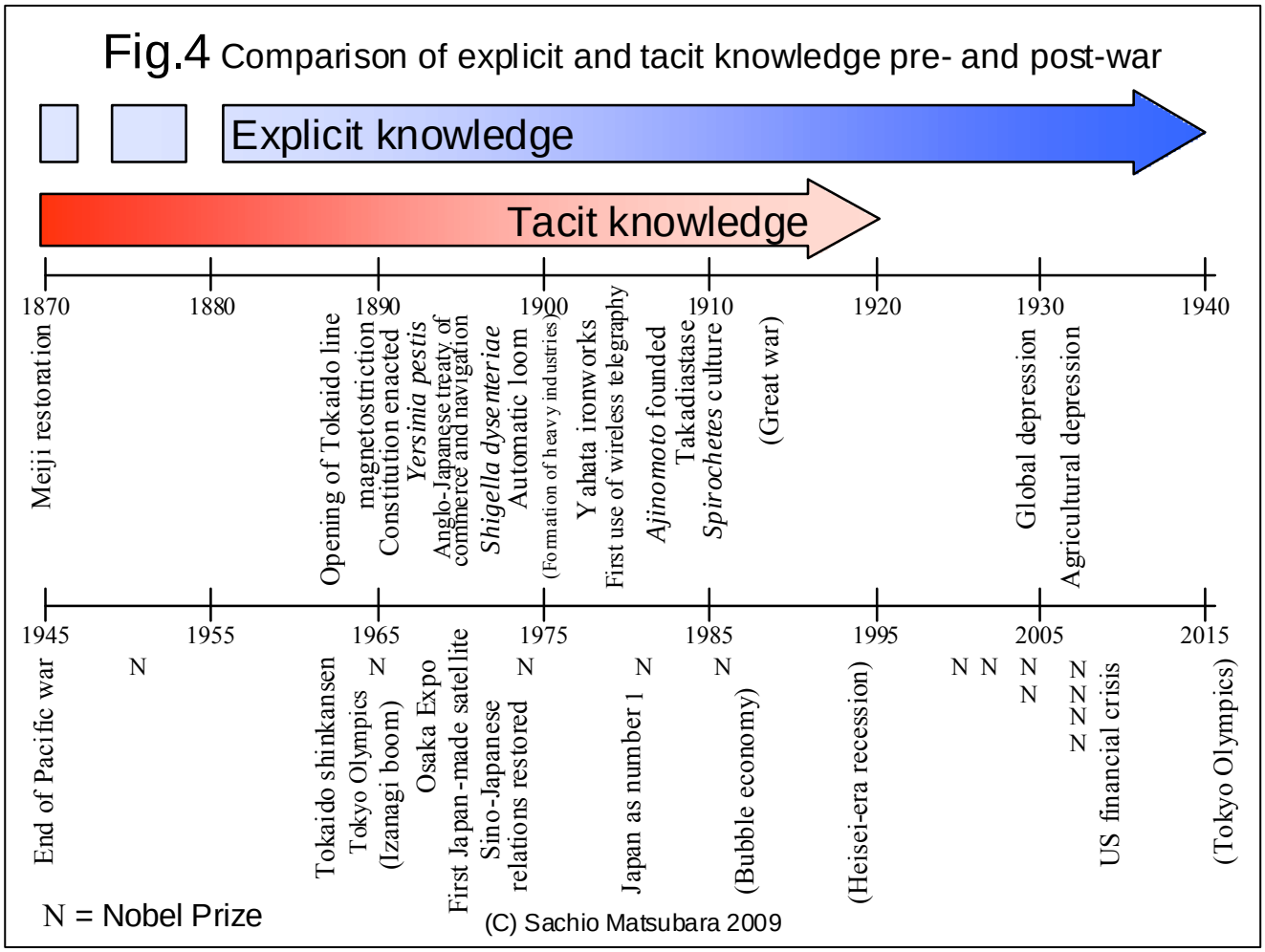


Fig.4 Comparison of explicit and tacit knowledge pre- and post-war

Although a US-style socio-education system was introduced after the war, Meiji era traditions also persisted and until recently Japan's education system was the best in the world. So why has there been deterioration recently?

customs and etiquette) are examples of this. The Edo government well understood the advantages and disadvantages of indiscriminately introducing explicit knowledge from abroad, and while implementing a policy

of isolation, through its antennae at the Dutch trading post at Dejima, it identified and absorbed the best of foreign knowledge. Carefully selected high-quality information became widely disseminated through publication. Because the explicit knowledge had been closely examined, such knowledge and publications were esteemed by the common people. The Edo rulers also well understood that if truly important things are easily expressed and conveyed in writing, it becomes difficult to re-instill tacit knowledge. In this way, the Edo era saw the formation of a stable society which lasted a long time.

This 50 years theory of tacit knowledge most clearly appears during periods of great change, such as the Meiji Restoration and end of the Pacific war when social systems and culture were suddenly interrupted. There are, however, exceptions to this hypothesis. The 50 years theory does not apply in situations where a family, business, village, cultural organization or the like deliberately preserves its family precepts, business style, technological traditions or traditional practices without being swayed by social change. Many such exceptions can be found in businesses engaged in Japan's fields of pioneering expert technologies. These businesses well understand the importance of tacit knowledge, and while faithfully preserving family values and company principles through the generations, they also actively introduce new techniques. These businesses not only introduce new explicit knowledge, they also visit cutting edge manufacturing sites to see things for themselves, feel the air on their skin. They find new methods of manufacture that keep what should be kept and change what should be changed. [7]

In Fig. 4, the distribution of Nobel Prize winners along the lower level is unrelated to economic and social conditions. This is probably because rather like the high-skill businesses mentioned above, the university research laboratory has maintained an experience-based training system which emphasizes values such as rigorous training in the basics, community, and trial and error without being swayed by social change.

6. Discussion

6.1 Positioning of the SECI model

Professor Nonaka Ikujiro of Hitotsubashi University has proposed the "SECI model" in order to explain the processes of transformation and transmission of tacit and explicit knowledge in knowledge-creating companies which showed superior performance during Japan's high-growth period. By positioning the SECI model within the currents of manufacturing described above, it is possible to represent the best practice of Japanese companies which made ample use of both explicit and tacit knowledge in the rapid growth era.

6.2 Daniel Pink's 'conceptual age'

Daniel Pink was employed as aide to the US Secretary of Labor during the 1980s when the Clinton administration managed to revive the economy. He now works as a freelance journalist, and his book "A Whole New Mind: Why Right-brainers Will Rule the Future" was number one business bestseller in the US in 2005. The following is the outline of Pink's keynote lecture at AUTM 2009.

In modern business, left-brain thinking alone is insufficient—right-brain thinking is also necessary.

- Left-brain thinking: Logical, analytical, linear thinking
- Right-brain thinking: Intuitive, instinctive, inclusive, holistic thinking
- The 20th century was the information age in which the direct and logical thinking style of programmers, lawyers and MBA holders was useful. The next age is the 'conceptual age', in which social and economic development will depend on creativity, empathy and an all-embracing vision.
- In the 'conceptual age', a new holistic thinking is required, and many people with this sort of 'kansei' or intuition will be active in two or more specialist fields (mathematician and designer, pastor and pediatrician, pianist and management consultant, etc.) and will have the ability to solve difficult problems.

The Japanese apprenticeship system shares Pink's emphasis on diversity of experience, since in the ha stage of Shuhari it is considered important for the journeyman (Gesellenwanderungen in the German Meister system) to build up a range of experience under different masters.

In addition, the terms 'tacit knowledge' and 'explicit knowledge' used in this paper are equivalent to Pink's 'right brain' and 'left brain'. The knowledge creation cycle in Fig. 1 shows the importance of cyclical movement through the domains of both explicit and tacit knowledge, and similarly Pink points out that while right-brain thinking is important, the use of left- and right-brain thinking together is also important.

Pink also points out the importance of holistic understanding, and it may be meaningful to take an overview of the currents of manufacturing mentioned above.

6.3 TRIZ and empiricism ~History repeats itself~

In recent years, there have been many examples where technological innovation which can not be realized even by cutting-edge scientific means have been realized based upon the skill of craftsmen.

The scientific revolution in Western Europe in the 17th century was brought by intellectuals who shifted the emphasis from documents to experience, and the question arises whether present-day craftsmen are not in the same situation where they enter the field of scientific technology.

The following is an excerpt from "The Cultural Revolution in Europe in the 16th Century" (Yamamoto Yoshitaka 2007). [8]

"While after the 19th century it became common to apply scientific results to technology, the scientific revolution in Western Europe in the 17th century was brought by document-oriented intellectuals who studied the concept of empiricism proposed by craftsmen in the 16th century."

In the 21st century as well, if a spiral relation is constructed between TRIZ and the training system of engineers which is based on empiricism, the appropriate balance between explicit knowledge and tacit knowledge as it existed in the 17th century can be restored, and it might be possible to develop TRIZ further.

6.4 Transmission (*Densho*) and dialectics

Traditional craftsmanship in Japan takes place in the context of 'transmission'—the passing down of knowledge from master to apprentice. In this system, only the best information which has stood the test of time is selected and passed on. In contrast, the more recent Western-style manufacturing has been dominated by the dialectic approach of dialogic discussion. In the dialectic world, valid argument is sometimes defeated by sophistry, and in order to rectify this, Plato introduced the Theory of Ideas. In the field of natural sciences, dialectics functions correctly since its object of study, nature itself, embodies the Ideas, whereas in fields such as social sciences and humanities, dialectics can produce conclusions wide of the mark when applied without a consideration of Ideas [9]. This is also why corporate philosophy is considered important in business management. In order to cultivate an abundance of tacit knowledge, we must pass through both the world of transmission and the world of dialectic.

6.5 The importance of trial and error

In the Japanese apprentice system, 'watching' is regarded as more important than 'reading' or 'listening'. Things taught in books or the spoken word are soon forgotten, whereas watching and then struggling to emulate them through trial and error serves to instill an accumulation of tacit knowledge. Because the teacher shows only the final outcome, the learner must figure out by themselves the processes leading up to that outcome. Because no answer is immediately forthcoming, the apprentice works up a hunger for knowledge and comes to know the pleasure of thinking for oneself. This process may even furnish the apprentice with greater insight and creativity than the teacher. In Pink's six lessons for developing and refining intuition, he also points out the importance of trial and error.

6.6 Kondratiev waves

Kondratiev waves are 50- to 60-year business cycles discovered by the Russian economist Nikolai Dmitriyevich Kondratiev after analyzing long-term time series data on wholesale price indexes, bond prices, wages, import/export values and coal and steel production in the UK, France and America in the 1920s. Near the turning point at the end stage of the wave, there is economic depression, historical structural changes such as revolution, and phase shifts in human society. Although the existence of Kondratiev waves as an economic reality is known, the mechanisms that generate these waves have not yet been clarified.

The most popular theory is Joseph Schumpeter's 'creative destruction by the entrepreneurial spirit', in which 'the appearance of genius entrepreneurs and the acceleration of technological innovation brings about creative destruction'. It is not, however, explained why genius entrepreneurs appear and epoch-making technological change arises in 50- to 60-year cycles.

I will now consider the Kondratiev wave from the perspective of explicit and tacit knowledge. As indicated above, in periods of social upheaval and economic depression, people build up tacit knowledge through experience of a good deal of failure. This newly acquired tacit knowledge is then immediately utilized in the form of measures to gain control of social disorder. As stated in the 50 years theory of tacit knowledge, people with the tacit knowledge to overcome such periods of social upheaval will presently disappear from society. Under the new social system created by those with tacit knowledge from the previous generation, the next generation will enjoy stable economic growth and the tacit knowledge sought during social upheaval will no longer be necessary. Because it is then possible to achieve stable growth through learning explicit knowledge alone, social and education systems too emphasize efficiency and so become biased towards explicit knowledge, while the importance of tacit knowledge is forgotten. With the bias towards explicit knowledge and weakening of tacit knowledge, the ability to respond appropriately to various social changes is lost, inviting the possibility of social disorder and reappearance of social upheaval.

In this sense, the Kondratiev wave can be applied to the changes in Japanese society after the Meiji Restoration and after the Pacific war. However, while the Kondratiev wave has a period of 50 to 60 years, in the case of Japan, the period was slightly longer at 70 years.

The Kondratiev wave cannot be applied to Japan in the Edo era. Why is this?

From the beginning of rule by the Edo bakufu (1603), Japan's rulers regarded the kind of long-term periodic change described by Kondratiev as the most important problem. The Edo bakufu was aware of the importance of cultivating tacit knowledge to prevent a repeat of the war and social upheaval of the past, and they aimed to build a system for nurturing human resources so that in the spheres of economics, society and culture tacit knowledge would be re-instilled in each generation. Another example of this is Shuhari in disciplines such as traditional manufacturing.

In Shuhari, the cyclic process of 'growth, destruction, and creation' described by Kondratiev is incorporated in a training program for a single individual. In the Edo era, the ideal was that by the time an individual was recognized as a fully fledged member of society, they would be a competent person equipped with both explicit and tacit knowledge. It is likely that the Edo era was able to last for 260 years because it was able continuously to turn out such competent people.

Within Shuhari, a cyclic process corresponding to a Kondratiev wave was incorporated into a training system that developed the talents of individuals and when this system functioned properly, it was able to support over a long period a society of stable growth untouched by Kondratiev waves.

6.7 Collective knowledge – the third knowledge

In the Shuhari process, a spiral of explicit and tacit knowledge arises in a single individual, but such a spiral also occurs in a community. It is rare in an actual organization to find individuals rich in intuition and combining explicit and tacit knowledge, while in every organization there are always personnel who are outstanding in just tacit or explicit knowledge. If these individuals can cooperate and work together, knowledge spirals can also be manifested at the group level. Such knowledge spirals can also be found in the 'QC circle' activities which underpinned Japan's high-growth era. In Japan, there is the ancient proverb 'out of the counsel of three comes wisdom', and this could similarly be understood as teaching the importance of pooling together in a group the tacit and explicit knowledge of various different minds. The communal living of the apprentice with master and senior pupils was also an extremely important element of the Shuhari system [10].

Japan's traditional personnel training system included the merging of two levels of knowledge: the spirals of knowledge within the individual and in the group. It is likely that out of this process is born the 'third knowledge' which expresses itself in moments of inspiration.

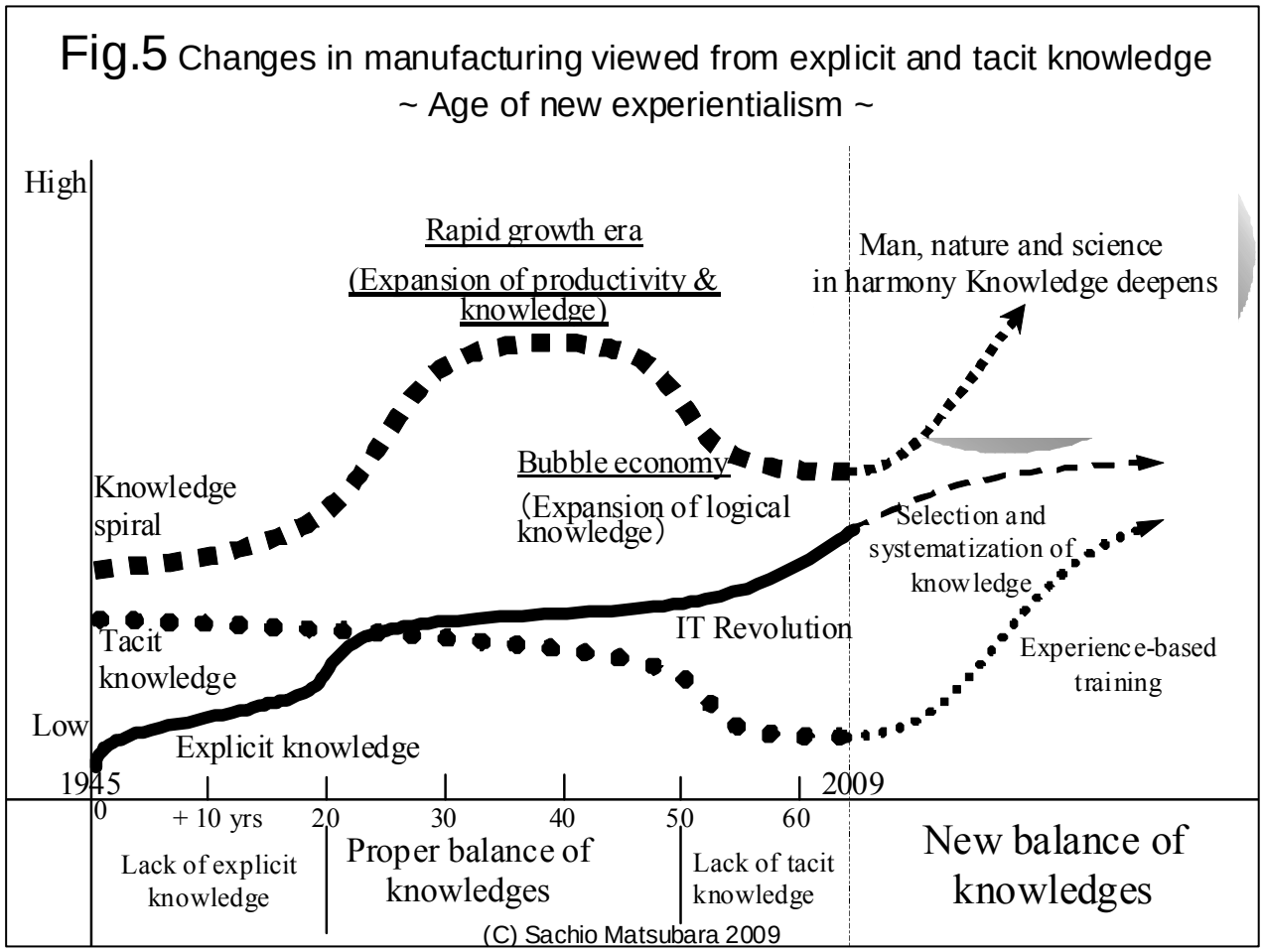
6.8 New experientialism

Fig. 5 presents a schematic view of the correlation between explicit and tacit knowledge in the changes in manufacturing described above. The theory that tacit knowledge persists for 50 years has been stated above, but new explicit knowledge and new socio-educational systems are also expected to require about 20 years to penetrate and have an impact on society. Fig. 4 shows that economic growth in Japan took off around 1965, after the 1964 Tokyo Olympics and 20 years after the end of the Pacific war. This is about 10 years after those junior school children who entered the new socio-education system at the end of the war as 10 year olds entered society as young adults, and in their 30s their influence on society was just beginning to emerge.

During the first 20 years of the post-war period, there was insufficient explicit knowledge for the knowledge spiral to arise. Similarly in the Meiji period, it was 27 years after the Meiji Restoration that Western style civil law—which amounted to a legal infrastructure for economic activity—was implemented. Between 20 and 50 years after the Pacific war there was an abundance of both explicit and tacit knowledge and thus knowledge spiraled, leading to a period of rapid growth. At around the 50-year period, the previous generation's tacit knowledge dissipates and the knowledge spiral declines; however, with production continuing to increase, we enter the bubble economy. Explicit knowledge in the form of linear and logical knowledge predominates and continues to expand.

For the future, it will be necessary to restore a balance of knowledge by reconsidering the experiential training system that has persisted in some high-skill businesses and university research departments, and also by carefully examining the burgeoning information driven by the IT revolution and systematizing the highly differentiated technological know-how.

In the wake of environmental problems and the like, contemporary society seeks new concepts to replace the notion of scientific and technological omnipotence. In the rapid growth period, the synergistic effect of explicit and tacit knowledge brought about an expansion of knowledge and material prosperity, but from now on society must cultivate new tacit knowledge by emphasizing quality over quantity of explicit knowledge and reconsidering



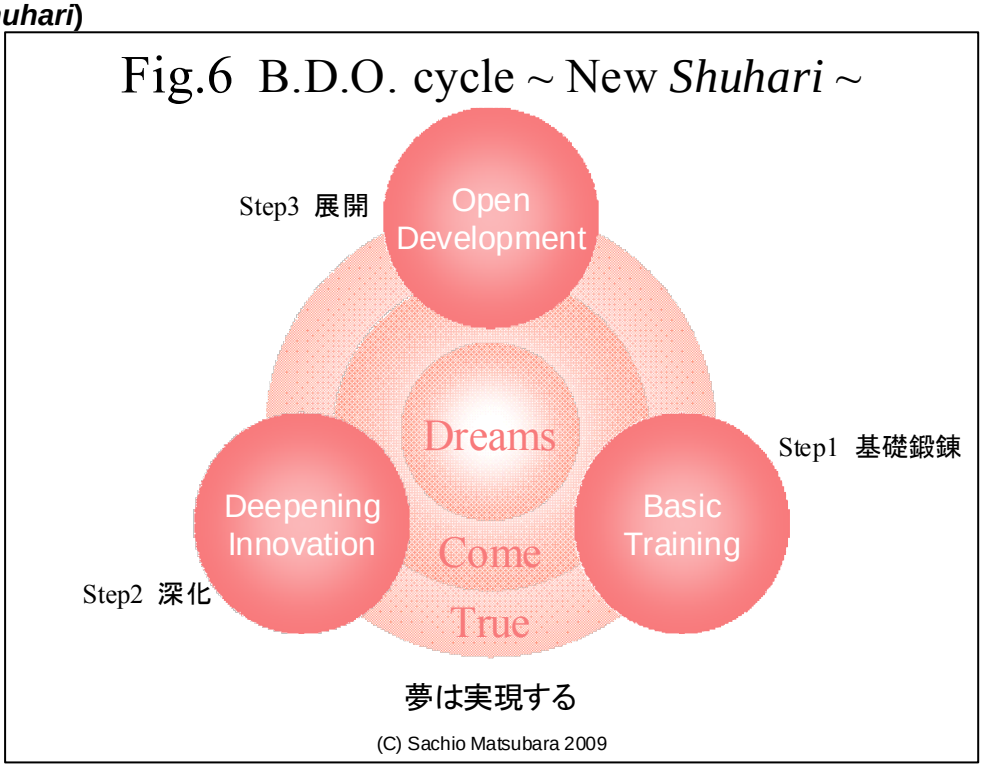
experiential training systems. A merging of these two knowledge types not only expands knowledge, it also deepens that knowledge, and promises to generate a new approach to manufacturing in which humans, nature and science are in harmony.

6.9 B.D.O. cycle(New *Shuhari*)

In Fig. 6, each process of the aforementioned 6-step creation cycle is simplified to the following three steps: Basic Training, Deepening Innovation, and Open Development.

Although it is desirable that in the case of long-term training programs the order B→D→O is followed, where the training programs must be completed within short-term, the program can be structured in such a way that a transition from deepening to open development was performed from the very beginning. It is thought that placing the open development stage after the deepening and the basic training is effective from the point of view of creativity development and cultivation of human resources.

Tacit knowledge is cultivated through Step1 and 2, and enjoyment of work and dreams will be derived from B.D.O cycle.



7. Summary

Below are my proposals for an ideal of manufacturing in the future.

- Utilize both explicit and tacit knowledge.
- In order to cultivate an abundance of tacit knowledge, reconsider experientialist training methods that enable mastery of techniques through rigorous training in the basics, communal living, and trial and error.
- Emphasize the quality of information. Systematize knowledge by scrutinizing information. For this purpose, TRIZ is expected to play great role as advanced models.

I would like to end with a quote from Basil H. Chamberlain (1850 - 1935) who came to Japan at the beginning of the Meiji period. "Only a people with its roots firmly planted in the past can be expected to flower and bear fruit in the future."

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Publications

Shin tokkyo nyuumon : yoku wakaru chiteki zaisanken no mamorikata / ikashikata [New patents primer - how to protect and use intellectual property]. Co-authored (2002, Chukei Publishing Co. Ltd.)

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