Four Types of Skills in Japanese Die and Mold Manufacturing and the Impact of New Technology on Skills：

Comparative Analysis on the Literature in Japan

Keiichiro ASAI

Introduction

Ogawa (1995) defined technology and skill as follows. 'Skill is a component of technology, and technology is a systematic means to achieve a goal. Technology further consists of two elements: engineering technology epitomized by machines and software, and technology based on skill. Skill, which is also called expertise, hunch or know-how, is acquired by individuals in order to achieve certain things and is difficult to articulate with language or figures.'

He also stated that skill would be engineered as technological innovation occurred, and would be eventually replaced by engineering. His idea on skill resembles what Polanyi termed 'tacit knowledge' (1980) or 'skill' (1985). In this article, we define that all explicit knowledge can be converted into tacit knowledge, and that tacit knowledge is classified according to whether or not it can be converted into explicit knowledge by using metaphor or analogy.[1]

Companies comprehend and evaluate skills in various ways. In this article, we attempt to categorize skills in a useful way. To this end, we reviewed a survey that started in 1993 on Japanese die and mold manufacturers and previous studies in business administration (discussions about tacit knowledge by Nonaka & Takeuchi, 1996; Architecture Theory by Fujimoto, 2006, and so on), labor economy (intellectual expertise by Koike, 2005; contextual skill by Hayashi, 1985) and cognitive psychology (routine expertise and adaptive expertise by Hatano & Inagaki, 1983, and Nomura, 1985).

Skill types

Hatano & Inagaki (1983, pp. 27-36) and Nomura (1989, pp. 149-150) categorized experts as 'routine experts' and 'adaptive experts' from the standpoint of cognitive psychology. Routine experts have acquired routine skill, a typical kind of skill, which they exercise under particular conditions (called 'area-specificity'). The first type, routine skill, is acquired by repeating the same work on a given task, in order to improve speed and accuracy. 'Routine experts', however, lack flexibility and adaptability to new tasks. 'Routine skill' is the lowest level of expertise or sub-expertise, forming a basis for all other types of skills. On the other hand, 'adaptive experts' can adapt themselves to changing situations by relying on their hunches and know-how. Moreover, they are capable of creating a new method and predicting the consequences when they execute it. We will therefore define the categories for this 'adaptive skill'.

In terms of the second type, we would like to mention a classical version of adaptive skill, known as craft skill. Since medieval times, there have been many societies where craftsmanship has developed. Among them is Japan, where there is a tradition to appreciate proficiency and sophistication in using tools, machines and equipment to their limits. Chuma called it 'craft skill' (2001).

The first example of this type of skill is copy modeling skill. This is required for processing the curved molds with copy milling machines, because it is necessary to have an understanding about the expansion/shrinkage rate of materials or their appropriate hardness in order to manufacture precise models. The second is to design the mold components. When the concept is designed to decide the structure of the entire mold, an assembly drawing is made. Then the mold is divided into components and drawings are made for each. The skill needed to design component drawings requires a certain amount of experience as a mold designer, and is greatly dependent on craftsmanship. The third is used to polish the processed mold components either by machine or by hand and finish it. This is a typical example of craft skill, for the process relies on humans' sense of touch using files and sandpapers to reach micron-level accuracy.

During the survey we conducted before 2000 (Company J, 1995; Company F and TM, 1996, and so on), we encountered several cases in which not only the field workers but the designers and numerical control (NC) data creators received training to acquire craft skill with files or general-purpose machines. In addition to these examples, we would like to mention 'Toyota Skill Development System' at Toyota Motors (Hachiro Taguchi, 1997 and Asai, 2006 b).[2] Details are described in Figure 1. In this system, with craft skill at the base, skill upgrades from C, B, A2, A1 to S as its width and height increases. Experience required to reach each grade is one year or longer for Grade C, five or longer for B, ten or longer for A2, 15 or longer for A1 and 25 or longer for S.[3] Notice that they have two classes in Grade S. Grade S skill shown in the solid line aims for directing overseas offices alone, which requires high leadership ability. This corresponds to 'contextual-integrated skill' which we discuss later in this article. On the other hand, Grade S skill shown in the broken line aims to train a limited number of workers to acquire highly sophisticated skills in a particular field.[4]

The third type is 'intellectual skill'. Chuma (2006) defined it as the ability to detect the cause of a problem in the production process quickly and efficiently. To explain this kind of skill, Koike (2001) examined the experts in an assembly and adjustment division. In order to improve the ease of use or to prevent faults, they sometimes advise the concept designers on amendments to the structure of the die and mold in the manufacturing process. This ability is an example of intellectual skill. Even if mold components are accurate enough at the assembly process, there can be a jagged line called a burr on the edge of the molded material at the trial phase. The ability to identify and modify the cause of the fault at the trial phase is also an intellectual skill. Another example is NC data creation skill. This is required when modeling a mold configuration with NC direct milling processing (or copy model-less processing) machines which design models based on product drawings on a computer, not on copy models.

The fourth type relates to what Hayashi (1999) called 'contextual skill'. Workers who have a certain amount of experience and contextual knowledge exploit this skill effectively, especially when skills are not standardized or normalized enough. He depicted this unstandardized skill by giving an example of workers' experience and knowledge about the relations between one process and another. When the workers' technique and skill overlap, the organization gets a redundant structure. As a result, members with contextual skill cooperate to produce new knowledge to handle tasks more efficiently.[5] While the contextual skill he defined is limited to two processes adjacent to each other, the definition in this article is not necessarily so.[6]

In this article, we define integrated skill as the ability to understand a wide range of the manufacturing process and to direct modifications if necessary. It is, ultimately, to coordinate the entire production process of die and mold and is more advanced than the other three. It corresponds to the previously described Grade S skill in the bold line of Figure 1.

However, as the segmentation of processes or specialization has progressed over the past decade, Japanese organizations today do not necessarily have workers who have integrated skill. In such cases where there is no person with integrated skill, one who has several contextual skills covers the void. In other cases, even with a training program to cultivate integrated skill, the ability does not necessarily reach the required level. In order to include these skills, we here define the fourth type as contextual-integrated skill.

We show the relations between contextual and integrated skills in Figure 2. Notice that it does not indicate any relations regarding to routine, craft or intellectual skills. However, the interviews we carried out previously demonstrated that both contextual and integrated experts had acquired (all of) those three skills as well.

Meanwhile, Fujimoto suggested in 'Architecture Theory (idea for product-process

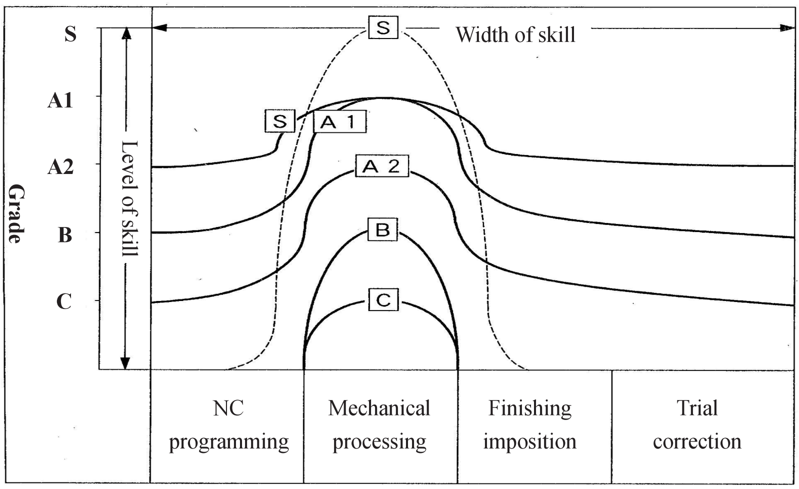

Figure 1. Toyota's 'Skill Development System' in the company's die and mold manufacturing department. Originated from Hachiro Taguchi (1997) p. 46 and interpolated by the author.

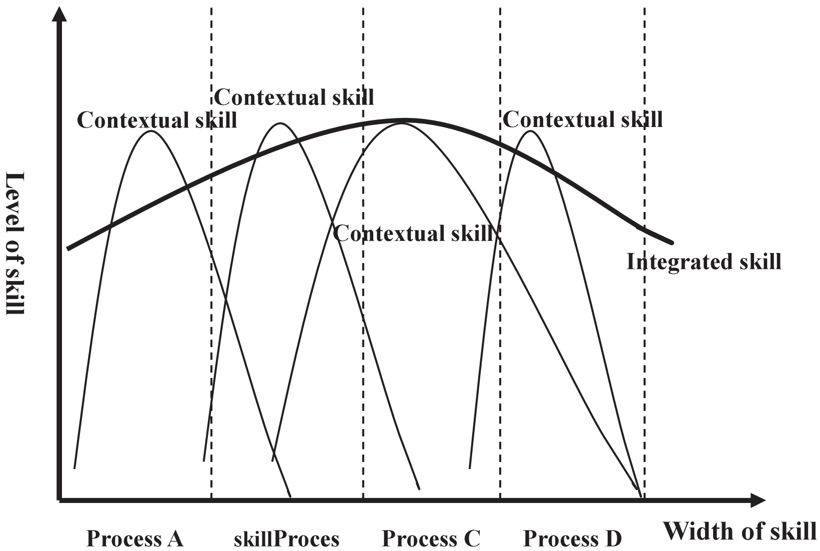

Figure 2. Relations between contextual skills and integrated skills.

architecture)' (2006, p. 309)[7] that Japan needed abilities in relation to 'subtlety in mutual adjustment of component design', 'cooperation between development and production' and 'close communication in the field'. He pointed out 'the organizational capability of integration' as one example of the competitive advances that Japan's manufacturers[8] had. We consider this ability to organize products, processes, experts and divisions to be synonymous with the contextual-integrated skill that we defined above.[9]

We present here two examples of this type of skill : concept designing skill and computeraided engineering (CAE) analysis skill. The former makes the process of creating NC data smoother by taking into account the structure of the mold and the injection molding technique. The latter is necessary when using 3-dimensional solid data to evaluate whether the calculated results are consistent with the phenomena. To obtain the right results, it is essential to simplify the configuration and condition depending on the purpose so as to minimize the calculation size. The skill needed for this CAE analysis is to have an understanding of the whole die and mold process, which covers several technological fields, including the configuration, forming mechanism, characteristics of resin materials, and so on, as well as the know-how for modification at the trial phase. This skill corresponds to our definition of contextual-integrated skill, because routine or intellectual skills are not sufficient enough to judge the simulation results effectively in order to set the condition for the following simulation.

These are the definitions of four types of skills (routine, craft, intellectual, and contextual-integrated) required for die and mold manufacturing in Japan.

Changes in skill

From the 1980s to the early 1990s, labor sociologists argued if skill would be replaced by technological innovation, or new skill would be required, or both changes would occur simultaneously. However, they have not yet agreed on one single idea (Yamashita, 1995, p. 123). Penn mentioned the changes in skill caused by technological innovation and pointed out that, since the 1970s, there has been a controversy over 'degrading thesis' and 'upgrading thesis' among British and American sociologists (1984, p. 35).

Braverman was one of the advocates of 'degrading thesis' (1974). He elaborated on this by writing that the purpose of technological innovation was to reduce dependency on workers' skills. On the one hand, low-level workers would have limited discretion on routine work that no longer required skill. On the other hand, certain workers who have specialized skill or administrative skill would exclusively hold authority and responsibility.

Spenner advocated 'upgrading theory' (1983). He wrote, 'Unskilled labor work remains because the cycle of technological change is incomplete, so this kind of work will be automated as the cycle of change is completed. If the automation advances further, the range of personal autonomy, skill and decision-making will expand. As a consequence, for example, organizations will tend to be decentralized.'

Attewell analyzed the discussions over changes in technology and skill comprehensively and realistically, based on the previous studies and investigation. Excerpts from his work were published in 1992.

Braverman thought that skill would diminish as technology changed, and depicted this as 'de-skilling'. In contrast, some argued that new skill would emerge (Penn, et al. (1985) called this upgrading-skill.). According to Attewell, these changes are two different subjects existing only theoretically and occurring separately, but in reality they happen simultaneously. He further wrote about the idea that only a certain portion of skill would diminish due to technological changes, whereas the essential skills would continue to be required. He also mentioned that some skills were reshaped. He cited 'cognitive capacity' and 'knowledge at the workplace' as examples of these kinds of skill.

As far as we have reviewed, there has not been any nomenclature in the previous studies that indicates these kinds of skills. However, we consider that they are of a type which continues to be necessary through technological innovation, and that they relate to the concept of 're-skilling' advocated by Zuboff (1988). In Japan, some companies train their workers to obtain conventional skills which are no longer needed in current manufacturing. This is because there are cases where the workers need these old skills when they deal with problems. This is generally accepted as re-skilling in Japan, but Zuboff did not mention it.

On the basis of the discussions described above, we classify skills according to the changes caused by technological innovation, or introduction of new technology, as follows. 'Diminished skill' is one degraded or eliminated by technological innovation, which Braverman depicted as 'deskilling'. 'Emerged skill'[10] is a newly introduced skill, which Penn, et al. called 'upgrading skill' (1985). 'Retained skill' continues to be required or reshaped by innovation and relates to 're-skilling' (Zuboff, 1988). We propose to use this classification as a tool to evaluate a company's strategy when it introduces new technology.

These three patterns of changes in skill take different courses as technology innovates. We previously discussed (Asai, 2009) the changes of skills influenced by three major technologies that had been introduced into Japanese die-and-mold industry: copy milling machine processing, NC direct milling processing, and 3-dimensional solid data (figure 3).

When copy milling machine processing was introduced in the beginning of the 1950s, a new skill became necessary to manufacture precise copy models considering the characteristics of material (emerged skill). Later in the late 1980s and 90s, NC direct milling processing (copy model-less processing) was introduced. This replaced copy modeling skill (diminished skill) with a skill to create number control programs, or NC data, that work for machine tools (emerged skill). In the mid 2000s, simulation analysis skill using CAE was newly required as 3-dimensional solid data was introduced (emerged skill). Meanwhile, NC data creation skill is still necessary up to this day (retained skill). It has been 3-dimensional during the time of NC direct milling processing following the introduction of 3-dimensional solid data. However, it is even more relevant today, because more sophisticated designing is

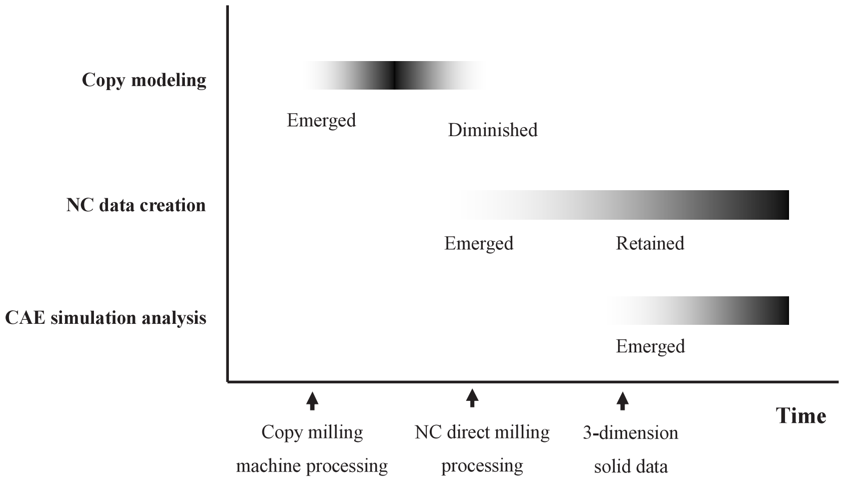

Figure 3. Changes in skills caused by the introduction of technologies.

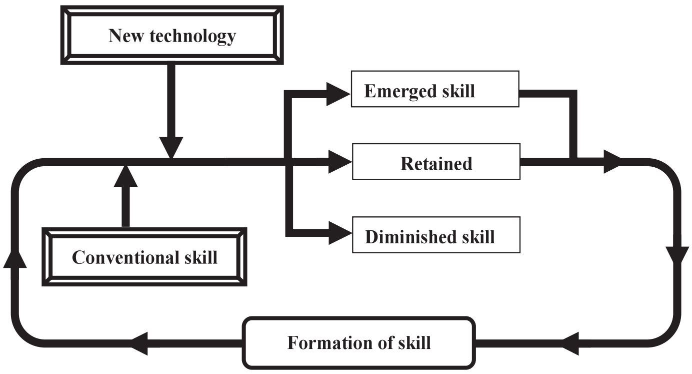

Figure 4. Relations between new technology and skills.

needed in order to reduce the burden on following processes by taking into account the processing methods, tool shape, rotation number, and feeding speed. As the amount of data increases, the machining time and accuracy are more dependent on how small and efficient the data are.

The relations between new technology and skill are shown in Figure 4.[11]

Conclusion : new technology and changes in four types of skills

In this article, we analyzed and demonstrated how the Japanese die-and-mold industry has dealt with three major technologies that had been introduced from the aspect of types and changes of skills. Table 1 shows the specific examples.

Routine skill is constantly replaced by new machines and software as a result of

Table 1. Introduction of three major technologies and changes in four types of skills. Asai, 2009.

<table>
<tr><th></th><th>Copy milling machine processing</th><th>NC direct milling processing</th><th>3-dimensional solid data</th></tr>
<tr><td>Routin</td><td>Retained</td><td>Retained</td><td>Retained</td></tr>
<tr><td rowspan="2">Craft</td><td rowspan="2">Copy modeling
-emerged</td><td rowspan="2">Copy modeling
-diminished</td><td>Components designing
-diminished</td></tr>
<tr><td>Polishing and finishing
-diminished</td></tr>
<tr><td rowspan="2">Intellectual</td><td rowspan="2">Trial and modification
-retained</td><td>Trial and modification
-retained</td><td>Trial and modification
-retained</td></tr>
<tr><td>NC data creation
-emerged</td><td>NC data creation
-retained</td></tr>
<tr><td>Contextual-integrated</td><td>Trial and modification
-retained</td><td>Concept designing
-emerged</td><td>CAE analysis
-emerged</td></tr>
</table>

technological innovation. However, because it is the base for all other types of skills, it will be retained in the future, and organizations will have to devote a certain amount of man-hours for it. As new technologies have continuously been introduced, there has been a remarkable tendency to be less dependent on craftsmanship. Copy modeling skill, which emerged as the introduction of copy milling machines, diminished as NC direct milling processing appeared. The same change happened to mold components designing skill and polishing-finishing skill, when 3-dimensional solid data was introduced. Intellectual skill, on the other hand, is retained in order to detect and solve problems, which arise due to whatever new equipment has been installed. Modification skill, used to correct distortions or to match molds at the trial stage, for example, has become even more sophisticated as the number of molds has increased. The fourth type, contextual-integrated skill, is becoming increasingly valuable because the specialization of labor demands the ability to oversee several or all processes in the entire procedure.

Hachiro Taguchi wrote that workers who have contextual-integrated skill should ideally constitute 30 percent of the workforce (1994, pp. 76-77).[12] Since copy milling machines appeared, various other kinds of technology have been introduced and have caused the segmentation of the die and mold manufacturing process. Eventually it became difficult to acquire contextual-integral skill from experience, so it is necessary to develop human resources systematically. One can see an example of this attempt in Toyota's 'Skill Development System' (Hachiro Taguchi, 1997) and Mazda's 'Densho Dojo' (Advanced Technical Skills Training Course) (Segawa, 1997).[13]

As we had pointed out in 1996, it is extremely important for small-and-medium-sized enterprises to know how to invest in machines, equipment and software with a limited budget.

In order to make a wise investment, contextual-integrated skill is essential to comprehend the whole process.

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References

Asai, K. (1995). Kanagata sanngyo-ni okeru kigyou kyousouryoku-no gensen (Competitive Edge in Mold Industry). *Keizai Kagaku (The Economic Science)*, 43-1 : 1-22 (in Japanese).

Asai, K. (1996). Gijutsu-kakushin jidai-no ginou keisei; Knagata sanngyo-wo chuushin-ni (Technological Innovation and Skill Formation in the Die & Mold Industry). *Shokou-Kinyuu*, 46-10 : 20-37 (in Japanese).

Asai, K. (2007). Chuugoku purasuchikku kanagata meekaa-ni okeru gijutsu kakusin-no doonyuu-to sukiru (The introduction of technological innovation and skills in Chinese mold manufacturing). *Nihon Keiei Gakkaishi (Journal of Business Management)*, 20 : 130-139 (in Japanese).

Asai, K. (2008). Kanagata sangyoo-ni okeru gijutsu kakushin-to sukiru-no hen'yoo : San jigen soriddo deeta-no katsuyoo-o chuushin-ni (Innovation and skill change in mold and die industry : focusing on the utilization of 3D solid data). *Nihon Chuushoo Kigyoo Gakkai Ronshuu*, 27 : 86-99 (in Japanese).

Asai, K. (2009). Gijutsukakushin-to sukiru-no henyou; Kanagata sangyoo-ni okeru rekishitekihennsen karano kentou (Innovation and skill change : historical analysis in mold and die industry) Dissertation of Hiroshima university (in Japanese).

Asanuma, B (1997). *Nihon-no kigyousosiki kakushin tekiou no mekanizumu*. Tokyo : Toyou Keizai Shinpousha (in Japanese).

Attewell, P. (1992). Skill and occupational changes in U. S. manufacturing. In P. Adler (Eds.), *Technology and the future of work* (pp. 46-88). New York : Oxford University Press.

Braverman, H. (1974) *Labor and Monopoly Capital : The Degradation of Work in the Twentieth Century*, New York, Monthly Review Press.

Chuma, H. (2001). Inobeeshon-to jukuren (Innovation and skill). In H. Chuma (Ed.) *Inobeeshon manejimento nyuumon (Introductory innovation management)*, (pp. 245-283), Tokyo : Nihon Keizai Shinbunsha (in Japanese).

Chuma, H. (2006). Inobeeshon to jukuren (Innovation and skill). In Itami, H., Okazaki, T., Numagami, T., & Fujimoto, T. (Eds.), *Nihon-no kigyoo shisutemu, dai 4 kan, Senryaku-to inobeeshon (Japanese corporate system, vol. 4, Strategy and innovation)* (pp. 133-158). Tokyo : Yuuhikaku (in Japanese).

Fujimoto, T. (2006). Soshiki nooryoku-to seihin aakitekucha (Organizational capabilities and product architecture). In Itami, H., Okazaki, T., Numagami, T., & Fujimoto, T. (Eds.), *Nihon-no* *kigyoo shisutemu, dai 3 kan, Soshiki nooryoku, chishiki, jinzai (Japanese corporate system, vol. 3, organizational capabilities, knowledge, human resources)* (pp. 303-331). Tokyo: Yuuhikaku (in Japanese).

Htano, G and Inagaki, k (1983). Two Courses of Expertise" Research and Clinical Center for Child Development (pp. 27-36). Faculty of Education, Hokkaido University (in Japanese).

Hayashi, H. (1999). Nihongata jinzai ikusei shisutemu-no yuukousei-to kadai: nikkei meekaa shingapooru mareeshia kogaisha-ni okeru jirei kenkyuu (Effectiveness and problem of Japanese human resource development system: case studies of subsidiaries of Japanese manufacturers in Singapore and Malaysia). *Nanzan Keizai Kenkyu*, 14 (1/2), 345-375 (in Japanese).

Ishida, et al. (1997). *Nippon-no reen seisan houshiki (Japanese lean production system).* Tokyo: Chuoukeizaisha.

Koike, K. (2001). Monodzukuri ginoo-to kyoosooryoku (Manufacturing skill and competitiveness). *Hitotsubashi Business Review*, 49 (1): 16-27 (in Japanese).

Koike, K. (2006). Monodzukuri-no ginoo (Skill of manufacturing). In Itami, H., Okazaki, T., Numagami, T., & Fujimoto, T. (Eds.), *Nihon-no kigyoo shisutemu, dai 4 kan, Senryaku-to inobeeshon (Japanese corporate system, vol. 4, Strategy and innovation)* (pp. 110-132). Tokyo: Yuuhikaku (in Japanese).

Nomura, Y (1989). *Chi-no taitoku (Mastery of the knowledge),* Tokyo: Fukumura Shuppan (in Japanese).

Nonaka, I. & Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation.* New York: Oxford University Press.

Ogawa, E. (1995). Gijutsu kakushin jidaini ginou-no imi-wo kangaeru (Innovation and meaning of skillI). *Yagoto*, 11: 100-103 (in Japanese).

Penn, R. (1984). *Skilled Workers in the Class Structure,* New York: Cambridge University Press.

Penn, R., Scattergood, H. (1985) "De-skilling or Enskilling ? : An Empirical Investigation of Recent Theories of the Labor Process."*British Journal of sociology*, vol36-4, pp. 611-630.

Polanyi, M. (1958). *Personal Knowledge: Towards a post-*critical philosophy. Chicago: The University of Chicago Press.

Polanyi, M. (1966). *The Tacit Dimension.* London: Routledge & Kegan Paul Ltd.

Segawa, M. (1997). Mazda tsuuring sentaa-ni okeru ginou kyouiku-to jinzai ikusei (HRD in Mazda tooling center). *Katagjijutu (Die & Mold Technology).* 12-12: 57-65 (in Japanese).

Spenner, K. (1983). Deciphering Prometheus: Temporal Change in the Skill Level of Work, *American Sociological Review.* 48:. 824-837.

Spenner, K. (1990) "Skill", *Work and Occupations.* 17-4:. 399-421.

Taguchi, H (1994). Korekara-no kata ginousha (What is the die & mold craft-master). *Katagjijutu (Die & Mold Technology).* 9-12: 73-77 (in Japanese).

Taguchi, H (1997). Toyota jidousha-ni okeru kataginousha kyouiku (HRD of die & mold craft-master in Toyota motor cooperation). *Katagjijutu (Die & Mold Technology).* 12-12: 13-17 (in Japanese).

Zuboff, S. (1988). *In the age of the smart machine : The future of work and power.* New York : Basic Books.

Notes

1 Explicit knowledge is knowledge that has been verbalized or schematized. Machines and software are good examples of it. (Nonaka, Takeuchi, 1996, p. 89)

2 The company's training system in the die-and-mold department was promoted in the early 1990s by Hachiro Taguchi as chairperson. He is known as a 'contemporary master craftsman' certified by the Japanese Ministry of Health, Labour and Welfare.

3 According to the description of the system for maintenance mechanics by Ishida, et al. (1997, pp. 214–224), it requires 15 years or longer to reach Grade S. This indicates that it takes a longer time to acquire skills in the die-and-mold department.

4 To apply the types defined in this article, the company's system is described as follows. Grade C corresponds to routine skill, B to craft skill, A1, A2 and S in a broken line to intellectual skill and S in a solid line to contextual-integrated skill.

5 Most holders of contextual-integrated skill are now in administrative positions, so they are also required to have project management skill and communications skill.

6 Asanuma used the term 'contextual skill' to describe contextual ability between corporations with no organizational boundaries (1997). In terms of relations of skills, its meaning is similar to what Hayashi defined (1999).

7 Fujimoto gave two basic types as examples of architecture. The first is 'integral type'. In this type, relations between the function of a product and the structure of its components are intricate. In order to create the best performance out of a product, one has to adjust the components' design closely to the architect's components and their interfaces from product to product. The second is 'modular type'. In this type, function and structure correspond with one another, and thus the interface is standardized. One can bring separately-designed components together and manufacture a proper product. Die-and-mold industry is considered to be the former, because it is generally performed in a one-piece flow production which requires integration between divisions of product design and die and mold design.

8 The term manufacturing here means the industry of integral architecture.

9 'Adjustment skill for change' described by Koike and others is not categorized according to the characteristic of skill itself, but considered being based on a specific work that requires skill. For this reason, we omitted it in this article.

10 The term 'newly-introduced skill' would represent this type of skill more properly. However, we use 'emerged skill' in this article. Zuboff had written about this idea (1988).

11 Among the skills that are no longer necessary in die and mold manufacturing due to technological innovation, some are determined to be transfered in order to deal with coming innovations. This is discussed in Asai, 2005 b p. 3.

12 Hachiro Taguchi defined the required qualifications as follows. The first is to have acquired

basic skills including programming, processing and finishing. The second is to have mastered practical skill by mastering all the processes in charge and having experienced the adjacent processes. Finally, the third is to have acquired specialized or related knowledge. It takes about five years to train workers to acquire basic skill and about 15 years for practical skill.

13 As advancing innovations in technology hollowed out skill and development overseas advanced, cultivation of human resources with multiple skills has become increasingly important. In response to this, the 'Toyota Skill Development System' started in 1991, aiming to train each individual worker systematically to acquire specialized knowledge, basic skill and practical skill. A detailed discussion of this can be found in Hachiro Taguchi (1997). Mazda has also implemented countermeasures against the hollowing out of skill caused by technological innovation and the adverse effects of specialization. They aim at cultivating applied skill and improving ability by basic skill training at 'Densho Dojo'. See Segawa (1997) for details. Both indicate that it is necessary to develop a consistent ratio of experts who have craft-oriented skills.