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Management of Design Process
of
University-Industry Collaboration
-A Case Study of the Collaboration
between Honda and TUAD-

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1. Introduction

In recent years, along with the fact that design has been increasingly acknowledged as a significant management resource, there is a rise in companies working on a joint project with students of design universities to explore the possibility of more innovative product design and to promote the creativity of its design organization. Designs created by students with young sensibilities and creative ideas bring about the ideas and inspirations that can not be generated internally in companies. Because students often perform the task of design in different contexts with companies, there exist misfits between their designs with the real problem-solving ones of companies. In order to deal with these problems and to create good performances, students need to make some changes in the existing framework and methodology for their actions and adapt to the desirable designs of companies through "reflective practice". However, because it is not easy for students to achieve higher levels of learning by themselves, some external work becomes necessary in the collaboration process. This research questions "How to promote "reflective practice" by students to deal with the incompatibility in the collaboration process?" Through making a deep analysis of successful cases in Japan, this research aims to clarify some requirements of management for promoting reflective practice by students and generating the desirable collaboration process. In this study, "Design" mainly refers to the product design, and the collaboration between design universities and companies is called "University-Industry Collaboration in Design Field".

2. Examination of existing studies

2.1 Features of the design process

Fundamental problem of design is to achieve fitness between two entities: the form in request and its context, and to create the ensemble comprising the form and its context

(Alexander, 1964). According to Alexander (1964), context defines the problem presents a request to the form. In other words, the form in request as the solution for the problem is determined depending on how designers define its context. Therefore, designers need to define clearly the context. In this sense, defining the context is the core task of the design process. However, in the modern society, multiple elements that should be satisfied interact complexly and the design problems are reaching to insoluble levels of complexity. Alexander (1964) and Simon (1996) suggested that disassembling the design problem into semi-independent components is the effective way of dealing with the complexity. In this way, by repeating several times the cycle of capturing the "gap" between goal and reality as the problem, exploring acceptable alternatives, evaluating them, and finally expressing the form, designers can reach "satisfactory solutions". This analytical solution is useful in clarifying the structure of complex design problems. On the other hand, we must admit that there is a certain limitation of dealing with the unique design problems characterized by tacit knowledge features. Design act is basically to visualize an idea, a concept, a plan into a creative form (Walsh, 1996). When the designers perform these tasks, they interweave many kinds of knowledge and information complexly and internally (Dumas, 1995). Cognitive processes inside the designers are dynamic with many interacting factors and occur tacitly (Utterback, 2006).

This research points out the following three characteristics of the design process based on above-mentioned existing discussions. a) utilizing the various knowledge while using both logical and intuitive thinking, b) passing through complex cognitive processes, c) progressing in action-oriented and by trial and error. Such design process is the process to finally try to achieve fitness between the forms in requests and its context.

2.2 Management of design process

One of the basic principles in the design process is to achieve "consumer-centered product design" such as grasping the needs and knowledge of users efficiently, sharing them among organization members, and reflecting them to design rapidly (Lojacono and Zaccai, 2004). Norman (1988) also emphasized the importance of that designers have the same image (cognition) with users through the design (product) while doing research about the designs of tools used in daily life. The suggestion of Norman (1988)

implies that, from the viewpoint of creating good designs much more efficiently in an organization with several members, designers need to share not only the cognition and needs of users but also their knowledge and cognition among members through the design. However, it is not easy for designers to share cognition (image) among members because there are unique features reflected by sensitivity aspects that go beyond logical explanations.

Organizational design activity is strongly associated with knowledge that involves knowledge creating and sharing among members (Boujut and Blanco, 2003). If design is captured in terms of knowledge, we can regard design process as the problem-solving process through combining explicit knowledge and tacit knowledge. In the design process, tacit knowledge is particularly important (Utterback, 2006). Dumas (1995) pointed out that, in order to create good designs, cross-functional teams involving in the design need to go through a complex process of, such as, interweaving their knowledge to each other. Moreover, in order to create more creative designs, it is desirable that the knowledge interwoven is diverse and there is little relationship between pieces of knowledge (Finke, Ward and Smith, 1992). Utterback (2006) suggested developing a common language, face-to-face communication, and making use of visualized objects, as ways for designers to integrate and transfer tacit knowledge as well as to create ideal design. Bailetti, Callahan and McCluskey (1998) pointed out that the mutual coordination among interdependent members involving in the design development does affect the future performance of design output and that it is necessary for members to share the work and cognition through mutual coordination. That members in the design share the cognition of users through mutual coordination and interweave the tacit knowledge becomes the requirements in these organizational design processes. However, these existing studies have only discussed some management requirements of the design process for creating designs in one organization and do not fully answer the management matters in creating designs between organizations, which have different domains such as university-industry collaboration in design field.

Interpretation, understanding and deduction about perception and sensitivity of users are derived from self-reflection level and susceptible to individual differences such as culture, experience, education (Norman, 2004). Since tacit knowledge is also deeply rooted in an individual's actions, experiences, ideals, values or emotions, and it is too

personal to be formalized, it is difficult to communicate and share with others (Nonaka and Takeuchi, 1995). Moreover, designers have cognitive features in generating design concepts by combining own beliefs and aesthetic feelings to their experiences and the methodological framework they depend on (Ogawa and Tokosumi, 2000). Therefore, it is supposed to be more difficult for students and company designers to share cognition mutually and interweave the tacit knowledge. It is also difficult for students who usually design in the context stressing on originality and individuality to accurately recognize the context of designs in companies. As a result, there is a strong possibility that students can not create precisely the form in request in the contexts of companies, which leads to misfit between two sides. Moreover, it is supposed that existing framework and methodologies of students with little experience are too limited to create designs for companies. In this situation, modifying the design output produced by students is not enough, promoting students to learn to make some changes in the existing framework for their actions to define the context and create designs is also needed. This research suggests taking "reflective practice" into consideration as an important concept in order to achieve higher learning of students.

2.3 Reflective Practice

In this section, this research examines how students can achieve higher leaning and how the coordination between members in the university-industry collaboration process in design field can be achieved.

Shöne (1983) proposed "reflective practitioner" as those who finds the theory of practice while reflecting on unexpected experiences in the field and face the hard tasks that go beyond his or her fields, and he also pointed out the importance of "reflecting-in-action". Reflecting-in-action refers to generating a new situation through the dialogue with the situation that occurs in the course of activities. These reflective practice is based on the model of "theory-in-use" called "ModelⅡ" (Argyris and Shöne, 1974) . Theory-in-use is the "theory of action" that provides the actual practice of individual acts, apart from the "espoused theory" that is espoused subjectively. Argyris and Shöne (1974) has emphasized that, in order to deal with the difficult situation of problem-solving in practice, it is necessary to change from theory-in-use of ModelⅠ, of single-

loop learning that is a self-closing and one-way, to theory-in-use of Model Ⅱ, of double-loop learning that can be an open and denial to their own theories and the action.

In university-industry collaboration in design field, students who reflect in the difficult situation of unexperienced designs for companies, are the learners having the action world of Model Ⅱ in practice. Because practical inquiry is achieved through "body-mind" activity, learning activities as an inquiry need to be achieved in the interaction activities with others and in the appropriate commitments from outside (Dewye, 1933). In fact, the action world of Model Ⅱ is characterized by the mutual relationship based on interactivity, openness and cooperation (Argyris and Shöne, 1974). Argyris and Shöne (1974) suggested "personally caused experience" and "examining dilemmas" as basic requirements for moving to the action world of Model Ⅱ. It is supposed that, in order to achieve such a student's higher learning in the collaboration process, the following requirements need to work; a) Students can freely experience works with the absence of the expected outcomes; b) Students directly confront the gap between actions they thought effective and their achievements; c) Students learn through interaction with others. University teachers and company designers who generate a collaborative process need to manage from the viewpoint of generating effectively situations that students achieve reflective practice based on Model Ⅱ through creating a learning environment for above-mentioned requirements to work. However, how should university teachers and company designers deal with these problems? This research focuses on how university teachers and company designers can concretely deal with some problems in the collaboration process through making a deep analysis of a successful case in Japan. Finally, this research points out how university teachers and company designers should generate and manage the collaboration process.

4. Case

This case is about the university-industry collaboration activity between Power products R&D Center of Honda R&D Corporation (Honda) and Tohoku University of Art and Design (TUAD) from April to December in 2008. In this chapter, following the flow of joint projects, this research examines carefully which kind of problems arise between members in the collaboration process and how university teacher and Honda designers deal with these problems. The description of this case is mainly based on the

survey record of interviews by the author and secondary materials. Interviews for 4 persons involving in the collaboration activity were conducted four times from August 2008 to April 2009.

4.1 Background and purpose of the collaboration activity

Honda has been actively working on the joint project with students of design universities in Japan. The purpose is to promote consciousness and creativity of its own designers through participating in the joint project with students who design with free and young sensibility. Honda also aims to create good design outputs as a result of the collaboration activity. In this collaboration activity, Honda and TUAD worked on developing the design of "power products" such as tillers and mowers with a Honda small general-purpose engine, and finally aimed to complete the prototype models. Collaboration activity progressed through the ways that students tried to propose a design of power products, then university teacher and Honda designers provided some advice and guidance to student.

4.2 Process of collaboration activity

In going on with the collaboration activity, the problem that university teacher and Honda designers had to deal with firstly was that students did not have the basis for thinking and generating the idea of design concept, because they had no experience of designing actual products of the company and were not familiar with the power products such as tiller and mower. Therefore, students often failed to generate ideas in the stage of setting out the design concept. To deal with this problem, university teacher set up the opportunity for students to practically operate existing power products of Honda in the field constructed in the university for this project. Through experiencing the actual work with the products, students managed to understand the basic premises in design, such as the operation senses and the product structure ("What is the power products using general-purpose engines?", "What is making work easier?"). Through this understanding, students became to be able to point out the specific problems of existing tillers and mowers. For example, "The existing products are hard to bring to the field", "The operating display of the existing products is not refined and hard for novice users to understand", "The existing products are too difficult for users who don't have

so much power to operate", "The form of the existing products is less familiar". Through these experiences, students became to be able to start setting out the design concept and express the form basing on the problems they found in themselves.

In this collaboration process, university teacher and Honda designers did not set the goal of a specific output and made students design freely to make use of their superior sensitivity and perspective. And the image of design output was ambiguous in the earliest phase because Honda designers did not know what kind of characteristics and individuality students have. Then, Honda designers explored the concrete image of design while designing with students. Since the idea of students sometimes spread, Honda designers had to proceed the process in high ambiguous situations.

Honda designers also need to modify the design by students into the effective and practical one without losing the good sensibility of students, because the design by students with free-idea seemed to be physically unachievable from the viewpoint of Honda designers. Moreover, students seemed to be unskilled in communicating their intent, thought, materializing their ideas into concrete forms and expressing ideas into concepts appropriately. Therefore, it became difficult for them to share the basic concept and background of designs.

To deal with these situations, university teacher made students experience the actual process of growing crops in the field constructed in the university from spring to autumn: seeding-weeding-harvesting. Students then became to understand deeply the user's actions, for example, what function is required in what specific situation through using the existing products in many periods, situations, and purposes. Students found out new problems and the later focuses through these experiences. When it was necessary for design created by students to be modified or when students could not design as expected, university teacher promoted students to reflect their own premise of designing. University teacher also promoted students to realize their own mistakes and new value standards by not instructing the content concretely and directly but providing some questions for their students by using prototypes and sketches, making students verify the operation of products again in the field, and showing an example of reference designs. Students then became to be able to reflect their own designs, create ideas and set concepts with real problems through external works of university teacher. Honda designers also urged students to describe the concepts and forms designed on the basis

of practical experience in words as much as possible. Students became to be able to explain the basis of concepts and forms more clearly and objectively because they designed to meet the needs of real problems and experiences. After constructing the basis of designing for students, Honda designers tried to find the key elements in the design created by students through observing carefully sketches and prototypes. However, another problem arose when students themselves were unaware of the important points or elements of their own design. When Honda designers observed carefully sketches and prototypes proposed by students, they verified empirically some potentials of the design by creating a movable object as a prototype. And they verified the designs that students had wished to express by explicitly conveying key elements to students through the prototype. Through these interactions, students knew a substantial element of the original designs they wished to express. They also understood empirically the important way of thinking in designing real designs in company and gradually learned how they should design with their own view through facing directly the way of thinking and viewing of Honda designers.

Finally, in the stage of completing the actual models based on the concepts set by students, Honda designers visited university every week and created models with students. In this stage, Honda designers and students gradually revised them to the complete state through discussing with each other through the visualized objects in front of them. Therefore, Honda designers and students recognized directly the differences in their ways of thinking and focuses and gradually filled the gap in their images.

3.3 Results

Students made presentations about the final design output at the final presentation, and their proposal were also praised by Honda designers. For example, through the experience of growing crops in the field, students identified users' problems while working with operating tillers, and created the design to solve the specific problems. It was found that users need tillers with different functions suitable for each scene of the growing crops. For example, when students cultivated the soil of field, large tillers were used. But when they had to cut off the weeds growing together with the crops the field, the large tillers became impossible in this situation because they could not enter and move between ridges and ridges. Large tillers were also difficult for students who don't

have strong power to operate. On the other hand, the operation of small tillers was easy and they could enter and move between ridges and ridges. However, the rotors of small tillers were not able to enter the deep soil due to its lack of weight. Therefore, students were not able to mow the weeds. Thus, each type of product was required for each work, but it was difficult for personal users to buy every products. Therefore, students proposed designing with various functions upon finding out these problems. Students gave the ideas of designing the tiller with high-operating handles and equipped a water tank to add the necessary weight to the tiller in case of need. Users can also cultivate the crops comfortably by draining water from the tank when they don't need weight for tiller students made the work more easily and made it possible to do many works with a single machine through these ideas. Both of the ideas and form of this design were praised highly from all sections in Honda.

Honda also has recognized the achievement of promoting the creativity of the organization. Honda designers often design in the realistic and severe constraints. However, they often re-captured their own creativity through facing directly the rich and pure idea of students in the collaboration activity. Honda designers thought over the deep and fundamental problems of design in order to share the idea with students in the collaboration process. Therefore, the collaboration activity served as a good opportunity for Honda designers to reflect and reaffirm the way of their routine works, and come to realize again what the design should be. As mentioned above, the collaboration activity provided Honda designers with stimulations and promoted them to make some changes in their way of thinking and awareness of design. Therefore, it worked as the opportunity for them not only to explore new possibilities of design but also to promote the organization's creativity.

4. Analysis

4.1 Generating of process of University-Industry Collaboration in Design Field

As discussed in the case above, the significant problems in the collaboration process are: firstly, designs produced by students were physically impossible to be developed into prototype model practically; secondly, students were not able to express the concepts and forms accurately because the basic ideas themselves were also vague for

students, therefore they and Honda designers were not able to share a specific image and understanding of the output.

These problems are supposed to arise due to the fact that students initially fail to accurately define the context of design. Because students defined the context incorrectly, the adaptive form was then created wrongly. As a result, misfit as a whole occurred. Normally, students usually stress on individuality and originality in university, which differed much from the real contexts of companies. Therefore, it is limited for students to define accurately the context for the design of real companies with the existing framework. In order to create good designs, university teachers and company designers need to promote students to make some changes in the existing framework itself for their action to define accurately the context. In the case above, university teacher and Honda designers observed carefully and grasped the cognitive process of students through their design, and they provided properly some external commitments for students. When students failed to design, university teacher and Honda designers committed much more actively into the cognitive process of students, figured out how to deal with the situation and developed new some external works. Students then became capable of making some changes in the design by reflecting the premise to the design through those some external works. After university teacher and Honda designers also extracted what was meaningful and important in the design by students without losing their unique and superior characteristics of students, they shared it with students. Thus, in the collaboration process, students need to achieve high learning to make some changes in the existing framework so as to define contexts accurately. University teachers and company designers also need to consider and modify repeatedly the way of dealing with students in these situations. As mentioned above, the process of university-industry collaboration in design field is supposed to be generated through the process of making efforts of changing gradually the existing situations into preferred ones while all members reflect repeatedly.

4.2 Management requirements for promoting Reflective Practice by students

4.2.1 Acquiring knowledge about users through the direct experiences

Students don’t have the basis of designing the actual products in companies. Therefore, before beginning to set out concept, it is important for university teachers

and company designers to promote students to acquire knowledge about users. Because acquiring the rich knowledge about users is the central element of recognizing the context presenting the request to the form. In the design process, it is necessary to reflect quickly a user's knowledge to design (Lojacono and Zaccai, 2004), and tacit knowledge is particularly important for designers to create a better design (Utterback, 2006). Students can not understand about users because it is impossible for university teachers and company designers to communicate enough tacit knowledge about users to students only through the means of words. Tacit knowledge can be acquired by generating experience actively (Polany, 1966). Therefore, the direct experience is supposed to be the best way of promoting students to acquire knowledge about users. In the case, students acquired some knowledge about user's cognition through operating existing products actually in the field, and they became capable of expressing the objective concept and form of design based on the knowledge. Students also became to be able to reflect the premise and basis of their own design upon discovering the new problems in their experiencing the task of growing crops. To students, experiencing directly about the products to design means placing themselves into the context of design and touching on it. Therefore, direct experience is very useful for students to acquire tacit knowledge about users efficiently. The direct experience also enables students to establish the basis of achieving reflective practice.

4.2.2 Do not instruct and guide students to modify directly

When students cannot create desirable designs and it is necessary to modify their designs, it is important not to lose the good characteristics of designs of students, because if university teachers and company designers modify directly designs created by students, there are dangers of losing pure elements of designs created by students and becoming unable to achieve the original purpose to make use of good features of student's design. Therefore, in the collaboration process, it is necessary to create the opportunities that students can create and verify designs freely.

In this situation, it is particularly important for students to create ideas freely and to confront the dilemma that the action appeared to be effective results become ineffective ones. The arising of these unexpected or unintended results and the situation of experiencing surprise and confusion are essential for reflective practice (Shöne, 1987).

However, learners need some appropriate external commitment to achieve inquiry by themselves (Dewye, 1933). In order to promote students facing some severe problems to reflect to make some changes by reflective practice to the existing framework for their actions, it is necessary for university teachers, who are familiar with the characteristics and personality of designs of students, to grasp accurately cognitive process of students through observing carefully the design output produced by students. It is also necessary for university teachers as a learning supporter to provide useful feedback required to reflections for students. The important point in this situation is to support learning based on Model Ⅱ. In this case, university teachers did not give specific instruction for students to create designs. University teachers provided some questions to their students by using prototypes and sketches, and made students verify the function of products again in the field, and showed an example of reference designs. University teachers also promoted students to consider the reason why they can't design well by themselves and to reflect their own premise to design. Argyris and Shöne (1974) emphasized the role of "instructors" to support the reflective practice by learners. They pointed out the risk of the forced intervention by instructors such as transmitting contents of learning to learners in one-way direction in the situations that learners can not reflect effectively. Such learning is based on the way of Model Ⅰ and it prevents students from learning openly. In this situation, it is also very important to support students psychologically. When students feel disappointed with their own incompetence, university teachers need to regard it as a positive sign and need to consider not making students feel guilt even if students feel sad. Because the essence of reflective practice based on Model Ⅱ is learning from the non-effective actions themselves (Argyris and Shöne, 1974). Students is supposed to recognize that their premise is not useful to define the context itself with some external works from university teachers, to reflect to reconstruct the new framework for their actions, and finally to become able to define the context accurately.

4.2.3 Interaction through visualized objects

The last requirement is to promote reflective practice by students more effectively by the interaction among members through the visualized objects. Visualized objects refer to the idea sketches and the prototypes such as rough models and mock-ups created in

each phases in the design process. “Visualizing” in the design process is to convert ideas and concepts into explicit and concrete objects and to externalize tacit knowledge into the concrete forms (Carlile, 2002). Therefore, visualized objects work as a common language, a cognitive mediation and a communication tool, and help to share images and cognitions among members (Star, 1989). In addition, visualized objects stimulate creativity of members because they concentrate on the essential part and help to generate various experiments (Schrage, 2000). Moreover, visualized objects improve the efficiency of the design process by summarizing the idea quickly into forms (Utterback, 2006).

These functions of the visualized objects are supposed to be useful from viewpoints of promoting reflective practice by students to make some changes to the existing framework for defining contexts. Visualized objects are the objects externalized the cognitive process and ideas of designers (Carlile, 2002) and make the cognitive process externalized and observable. Thus, university teachers and company designers become able to examine the appropriate way and timing to involve in the cognitive process of students by grasping the situations of cognition of students through visualized objects. These direct feedbacks through the object can be “valid information” or “directly observable date” needed for reflective practice. Students become able to reflect critically on their own framework for actions and premise. University teachers and company designers also become able to find the important point in designs by students unconsciously and implicitly and to extract the essential elements of the designs through observing carefully the intermediary and incomplete objects. Students can recognize the way of thinking and perceiving of company designers by figuring out clearly the important elements through visualized objects. Students are supposed to become able to reflect their own actions and way of thinking with comparing to company designer’s one through recognizing these difference from company designers’ ones.

Visualized objects can also help to achieve fitness between the defined contexts and the forms. When designers carry out design activity, it is useful to fill the “gap” between the desirable output and the current situation of design through grasping the gap (Alexander, 1964; Simon, 1996). Visualized objects show the gap as an existing entity in front of members. In this situation, it is also necessary for all members to show the gap between the both sides and modify it through discussion with using movable

visualized objects. By recognizing and modifying these gaps repeatedly, the gap in interpretation of design for each members supposed to be decrease gradually. Finally, it becomes to be able to increase the level of fitness between the forms and its context.

5. Conclusion

Through deeply analyzing a successful case in Japan about the process of university-industry collaboration in design field, which has not been clarified in existing studies. The research pointed out that there are two misfits arising in the collaboration process; a) the misfit between the context for design of real companies and the context defined by students; b) the misfit between the defined context and the forms created by students. This research also pointed out that, in order to create good design without losing the characteristics of students, it is necessary not to modify the design output created by students but to promote students to make some changes in the existing framework for their actions. And this research suggested taking reflective practice into consideration as an important concept in order to achieve such higher learning and pointed out some requirements of management to promote that. Misfits arising in the collaboration process are a serious problem for achieving purpose. On the other hand, from the viewpoint of reflective practice, misfits also provide important opportunities for students to learn. Therefore, in the collaboration process, it is important how to deal with the situation problems arising rather than how to prevent problems from arising. It is necessary for all members not to have Model Ⅰ attitude to try to eliminate or modify the problems but to have Model Ⅱ attitude being open to dilemma to regard the problems as crucial opportunities.

References

- Alexander, C. (1964) *Notes on the Synthesis of form*, ARCHITECTURAL RECORD
- Argyris, C. and Shöne, D. A. (1974) *Theory in Practice*, Jossey Bass Classics.
- Bailetti, A., Callahan, J. and McCluskey, S. (1998) Coordination at Different Stages of the Product Design Process, *R&D Management*, vol.28, no.4, pp 237-248.
- Boujut, J. F. and Blanco, E. (2003) Intermediary Objects as a Means to Foster Co-operation in engineering Design, *Computer Supported Cooperative Work*, vol.12, pp 205-219.
- Carlile, P. R. (2002) A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development, *Organization Science*, vol.13, no.4, pp 442-455.
- Dewye, J. (1933) *How We Think: a restatement of the relation of reflective thinking to the educative process*, Boston: D.C.Heath.
- Dumas, A. (1995) Commentary Reflections on Design and the Third Way, *Graham, P (edi): Mary Parker Follett, Prophet of Management*, the President and Fellows of Harvard College, pp 205-211.
- Eastman, C. (1970) "On the analysis of intuitive design process," *G. T. Moore(edi.): Emerging methods in environmental design and planning*, MIT Press.
- Finke, R. A, Ward, T. B. and Smith, S. M. (1992) *Creative Cognition: Theory, Research, and Applications*, The MIT Press.
- Hirasawa, T., Kweon, K. and S. Learmount. (2008) "On the dilemma of scientific rigor or practical relevance in management: Revisiting the practice of Dr. Nishibori as a reflective practitioner," *European Group for Organization Studies*: Proceeding.
- Ivory, C., A. Thwaites and R. Vaughan. (2003) "Shifting the Goal Posts for Design Management in Capital Goods Projects: Design for Maintainability," *R&D Management*, Vol.33, No.5, pp.527-539.
- Lojacono, G. and Zaccai, G. (2004) The Evolution of the Design-Inspired Enterprise, *Sloan Management Review*, vol.45, no.3, pp 75-80.
- Nonaka, I. and Takeuchi, H. (1995) *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford University Press.
- Norman, D. A. (1988) *The psychology of everyday things*, Basic Books.
- Norman, D. A. (1993) *THINGS THAT MAKES US SMART: Defending Human Attributes in the Age of the Machine*, Addison-Wesley Publishing Co.

- Norman, D. A. (2004) *EMOTIONAL DESIGN: Why We Love (or Hate) Every Things*, Basic Books.
- Ogawa, Y. and Tokosumi, A. (2000) Cognitive Process of Making Creative Design: A Methodology for Design Activities, Based on the Designer's Belief System, *Bulletin of JSSD*, pp 356-357.
- Polanyi, M. (1966) *The Tacit Dimension*, London: Routledge and Kegan Paul.
- Schrage, M. (2000) *Serious Play: how the world's best companies Simulate to innovate*, Harvard Business School Press.
- Shöne, D. A. (1983) *The Reflective Practitioner: How Professionals Think in Action*, Basic Books.
- Shöne, D. A. (1987) *Educating the Reflective Practitioner*, JOSSEY-BASS.
- Simon, H. A. (1996) *The Sciences of the Artificial: Third edition*, The MIT Press.
- Star, S. L. (1989) The Structure of Ill-Structured Solutions: Heterogeneous Problem Solving, Boundary Objects and Heterogeneous Distributed Problem Solving, *M. Huhns and L. Gasser (eds): Distributed Artificial Intelligence*, Morgan Kaufmann Publishers Inc., San Metlo Park, CA, Chap.2, pp 37-54.
-
- Utterback, J. M. (2006) *DESIGN-INSPIRED-INNOVATION*, World Scientific Publishing.
- Vinck, D. and Jeantet, A. (1995) Mediating and Commissioning Objects in the Sociotechnical Process of Product Design: A Conceptual Approach, *D. MacLean, P. Saviotti and D. Vinck (eds): Management and New Technology: Design, Networks and Strategy*, COST Social Science Series, Bruxelles, pp 111-129.