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## The Knowledge Creation of Product Design: the Foundation of Green Product Design

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**Abstract:** The knowledge creation of product design is a 'dual-spiral' model. And it is made up of artistic knowledge, technical knowledge and social knowledge, while the social interaction between tacit (embodied) knowledge and explicit knowledge creates and extends new social and technical knowledge, and that between self-transcending knowledge and explicit knowledge creates and extends new artistic knowledge. There are both connections and differences between the two strands of knowledge, as well on the basis of different knowledge assets; these two kinds of knowledge promote the innovation and iteration of product design knowledge in different fields through the SECI process of knowledge conversion. The dual-spiral model about the creation of product design knowledge can inform knowledge creating spiral of green design (product) via 'Green Process' of knowledge assets and Bas, and the dual-SECI about the knowledge creation of product design, in order to promote the green design (product) knowledge's improvement and updating, as well provide Intellectual support for it.

**Key words:** *Knowledge Creation, Dual-Spiral Model, Green Product Design.*

### 1. Introduction

The constructivism takes the process of learning as the construction of knowledge, for learning is not just a process of absorbing new information, idea, and skills, but the new material is reconstructed by the mind (Joyce et al., 2009). It also considers students as the active constructors of the meaning, and for students do not translate the knowledge into their memory, but through the interaction of the outside world to construct individual understanding of the knowledge on the basis of existing experience, every person's knowledge is different from others' (Sang, 2005). Therefore, learning is neither a simple

process of information accumulation, nor that of information input, reserve or extract, but a process of the learners construct the meaning of knowledge while communicating, exchanging, or querying with others according to prior experience. In other words, the period of acquiring learning knowledge means the process of constructing new meaning of knowledge, namely, the process of knowledge creation (KC).

Since the beginning of the 1990s, a vast amount of research has been conducted on the themes of organizational learning and knowledge processes in the working community of the multi- and interdisciplinary field of knowledge management (KM) (Martin, 2008). There are various definitions of knowledge in academic circles (Eseryel et al., 2005), but KM is hard to define (Earl, 2001), so it still has no accurate definition of KM. And the academic circles is wildly believed that KC is a process linked to innovation and creativity as being fundamental for knowledge-based organizations to cope with increasing turbulence and the competitiveness of their operational environment (Nonaka & Takeuchi, 1995; Spender, 1996; Choo, 1998; Tsoukas & Mylonopoulos, 2004; Mehta, 2007; Suorsa & Huotari, 2014). Recent years, the KC is becoming a hot researching field, whose focal points includes the 'process of KC' (Nonaka, 1989; Cyr, & Choo, 2010; Anand et al., 2010; Ramírez et al., 2012); 'the role and function of technology in the processes of KC' (Salazar, 2010; Lopez-Nicolas, & Soto-Acosta, 2010); 'the way to manage the process of KC' (Kodama, 2005; Richtnér, & Åhlström, 2010); 'value creation in KC' (Li, Huang, & Tsai, 2009; Song, Seung, & Yoon, 2011); 'KC under the organization and culture context' (Lloria, 2007; Wang, & Yang, 2011); 'the relationship between KC and work practice & social network' (Alberts, 2007; Farshchi, & Brown, 2011); 'how to define KC and product development from innovation' (Aramburu, Josune, & Rivera, 2006; Schulze, & Hoegl, 2008); 'the interaction in KC' (Jakubik, 2008; Morner, & von Krogh, 2009; Tsoukas, 2009) and 'open innovation and KC' (Eserye, 2014) and so on. This article comes from the perspective of design discipline, with the support of SECI model of KC, to make a further study about 'the product design process', as well try to construct the model of product design knowledge creation, in order to make some theoretical contribution to the development of green product design.

## **2. The Basic Constitution of SECI Model**

The SECI model of KC was proposed by Ikujiro Nonaka etc. in the early 1990s (Nonaka, 1989, 1990, 1991, 1994; Nonaka, & Takeuchi, 1995; Nonaka et al., 2000) which consists of three elements: 1) the SECI process, KC through the conversion of tacit and explicit knowledge; 2) 'ba': the shared context for KC; and 3) knowledge assets, the inputs, outputs and moderators of the KC process (Nonaka et al., 2000).

## 2.1 The SECI Process of KC

According to the taxonomy based view of an UK philosopher Michael Polanyi (1957, 1966), on the term of epistemology, knowledge can be divided into explicit knowledge and tacit knowledge. While new knowledge is created and extended by socialized interaction between explicit knowledge and tacit knowledge, and Takeuchi and Nonaka called it as 'knowledge conversion' (Nonaka, & Takeuchi, 1995).

Based on this assumption, Takeuchi and Nonaka proposed four forms of 'knowledge conversion': the 'Socialization' – from explicit knowledge to explicit knowledge, the 'Externalization' – from explicit knowledge to tacit knowledge, the 'Combination' – from tacit knowledge to tacit knowledge, and the 'Internalization' – from tacit knowledge to explicit knowledge, all of them formed the SECI model of KC. It should be noted that the four transitions between explicit knowledge and tacit knowledge can produce a spiral dynamic, not just a recycling one, and in the spiral process of KC, the interaction between explicit knowledge to tacit knowledge can be magnified or enhanced with knowledge transition (Takeuchi, & Konno, 2005). Actually, SECI is the spiral of creating knowledge.

## 2.2 'Ba': A Shared Place of KC

Depend on concrete time and space, knowledge was transferred with the change of the environment (Hayek, 1945). Knowledge doesn't stay in individual cognition layer, but the result of one's purposed action (Suchman, 1987). The creation of knowledge needs actual situation, as well the process of it needs a real place to transfer, in such a place, new knowledge is born by analysis and significant the information. Therefore, 'New knowledge cannot be created without place' (Casey, 1997). The concept of 'Ba' was originally proposed by the Japanese philosopher Kitaro Nishida (1921, 1970) and was further developed by Shimizu (1995). On that basis, Nonaka etc. defined 'Ba' as a shared space of KC for emerging relationships (Nonaka, & Takeuchi, 1995; Nonaka, & Konno, 1998). 'Ba' cannot only be physical place, but also virtual place such as e-mail and teleconference, as well the sharing situation of mental layer. 'Ba' exists for participants' interaction, in turn to form a place for participants to create new knowledge, in such a process, the participants take their own conditions into the 'Ba' to interact with others and their conditions, which can change the origin condition of the 'Ba', as well that of each individuals. According to different stages of the SECI process of KC, Nonaka and Konno classified the 'Ba' as four types: Originating Ba, Interacting Ba, Cyber Ba and Exercising Ba. Each Ba is corresponding to a form of knowledge conversion, which can provide necessarily sharing and interacting platform for knowledge spiral-up.

### 2.3 Knowledge Asset

The KC processes are based on knowledge assets, which were defined as 'firm-specific resources that are indispensable to create values for the firm, as well the inputs, outputs and moderating factors of the KC process' (Nonaka, Toyama, & Konno, 2000). For sake of better recognition of the creation, acquisition, development and utilize of knowledge assets. Nonaka classified it as four forms: Experiential Knowledge Assets, Conceptual Knowledge Assets, Systemic Knowledge Assets and Routine Knowledge Assets (Nonaka, Toyama, & Nagata, 2000). The four forms of knowledge assets are inseparably interconnected with the SECI process of KC.

The SECI process of KC, 'Ba' and knowledge assets, which made the dynamic model of KC jointly. Such a model was created by Nonaka etc. has become a classical one of KC field, and other KC models are expanded and replenished on the basis of this model (Yang, 2009).

### 3 The Construction of Product Design Knowledge

Product design mainly takes goods as its carrier to integrate its style, function, colors, surface finishing and material from points of people, machine (products), and environment and so on. The process of product development integrates a series of design activities which including initial conception of products' appearance, analysis and positioning of market, market development, technology implementation, researching and development of product planning and design administration to ensure effective implementation of plans (Otto & Wood, 2005) . Therefore, product design is a compound creating activities with integrating much different knowledge in the field of science, art, society and so on, as well asks the designers to possess versatile talents' knowledge and skill: scientists' knowledge, inventors' talent, speeches' eloquence, diplomats' communicating ability and artists' presentation skill.

Combine with the knowledge characteristic of product design, we have concluded the main knowledge structure of product design (see figure.1), which mainly consists of social knowledge, artistic knowledge and technical knowledge. The social part is the background knowledge of product design, which is mainly severed for the decision of product design. For only sufficiently learn the political, economical and cultural setting of design target (products) and severing targets (customers), as well apply relevance knowledge flexibly, can the designers put forward efficiently design schemes. The artistic branch is one of the core knowledge of product design which is mainly severed for design expression and thought of different products. It holds the balance of designers' aesthetic building and taste promoting. Under the aesthetic view, the main purpose of grasping design knowledge and art is to reveal design innovation with the form of artistic by different impressing

ways. The technical part is mainly severed for realization and innovation of product design, for transferring design concept into valid products cannot do without the support of technical knowledge about structure, material and processing technique. Therefore, the social, artistic, and technical knowledge of product design respectively dominant the design decision, artistic taste and design style, as well the reveal of above innovation.

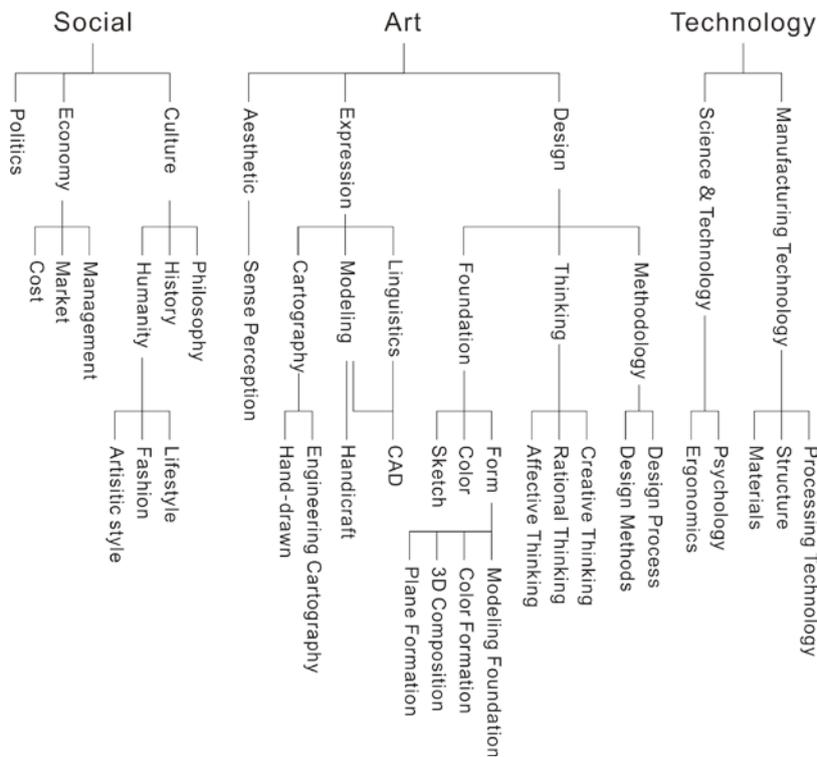


Figure.1 The Main Knowledge Structure of the Product Design (Li, 2012)

Product design is a complicated systems engineering with closely linking different kinds of knowledge to form an inseparable knowledge structure, and the absence of any knowledge will destroy the completeness of the design works, as well reduce the designers' working level. It must be emphasized that the bound and proportion between each knowledge is comparatively vague, for some knowledge cannot be divided into a certain field, but to apply dialectical thoughts to understand such a knowledge structure.

#### 4 The Process of Product Design KC

##### 4.1 The Explicit Knowledge and Tacit Knowledge of Product Design

In the knowledge hierarchy of product design, the artistic branch is the specific knowledge of a designer, as well the core knowledge among whole knowledge hierarchy, which mainly consists of tacit knowledge such as aesthetic purport, design thinking, design process and experience that cannot be voiced by words, and acquiring of such knowledge needs the

designers to keep experiencing design thinking, weighing design process, accumulating design experience and digesting design methods to problems in practice. For instance, there is no existing knowledge can tell us adopt what style, color, materials and surface finishing process to meet use requirements of different space and consumption psychology of different customers. Therefore, many teachers from the design major think it hard to pass on 'design' is mostly because the tacit knowledge mainly constitutes the knowledge hierarchy of product design.

Compare with artistic knowledge, social knowledge and technical knowledge have less tacit part, for such knowledge can acquire from some information source as books and magazines, newspapers, reports, technical specifications and so on. But in the process of product design, how to internalize of these kinds of knowledge and use them to lower production cost, as well improve product function in order to work out the product meet the market and customers' acquirements, still needs the designers to master many kinds of tacit knowledge.

All in all, the tacit knowledge occupies the majority of that of product design, which is the critical factor of design and innovate, while the explicit knowledge plays a necessarily supporting role, the two are complimentary, and not a single one can be omitted. In order to further clarify the relation between explicit knowledge and tacit knowledge, we need to know the concept of 'tacit-embodied knowledge' and 'self-transcending' knowledge.

#### **4.2 Two Kinds of Tacit Knowledge in Product Design Knowledge**

Scharmer (1999) considers the tacit knowledge has two forms: 'tacit-embodied knowledge' and 'tacit-not-yet-embodied knowledge', the former is the tacit one that we usually talk about, and the latter is often named as 'self-transcending knowledge'. Self-transcending knowledge is the ability to sense and presence the emerging opportunities, to see the coming-into-being of the new and usually associated with artists, not business managers (Scharmer, 2001). Which is also the ability to sense the presence of potential, to see what does not yet exist (intuition and hunches) (Uotila, & Melkas, 2008). In other words, self-transcending knowledge is the knowledge about the highest future possibility (Kaiser, & Fordinal, 2010). For an analogy, there may be three ways to view the painter and his works: appreciate painters' completed works, observe the painter and his works while he is creating or observe the painter's mediating state before his creation. Every perspective provides a distinctive working style of the artists. For a completed works can explicit the artist's work. Observing an artist while he is creating can insight the chance that he bring tacit knowledge to the works, and observing the painter's mediating state can infer and grasp his self-transcending knowledge, just as Michelangelo talked about his famous works:

the David, when he perceived its emerging body, he said, 'David has been in those stone, I just take away those parts don't belong to David.' Which shows that the ability of David rather than of stones (owning self-transcending knowledge or not) is the critical evaluating factor to distinct common artists and famous artists. As the core of design knowledge, the artistic knowledge decides the value and status of self-transcending knowledge in design knowledge. Therefore, many researchers classified the 'design' among the self-transcending knowledge (Scharmer, 2001; Feghali, & El-Den, 2008).

The difference among the explicit knowledge, the tacit-embodied knowledge and the self-transcending knowledge, from the perspective of epistemology, the distinction among the three can be seen in table 1. The explicit knowledge is based on observing experience and catching knowledge about things, whose data form points to the external reality that has been observed, as well it is the aim of KC and the base of organizational competitiveness. But the tacit-embodied knowledge is based on behavior experience, the present source of knowledge creation and on behalf of present organizational competitiveness and catching that knowledge of current things, whose data form points to setting reality. While self-transcending knowledge is based on aesthetic experience and catching that knowledge about current things' origin, whose data form points to unsetting reality, while it is the real source of KC and on behalf of the future competitiveness of the organization.

Epistemology	Explicit knowledge	Tacit-embodied knowledge	Self-transcending knowledge
Type of knowledge	Knowledge about things	Knowledge about doing things	Knowing about thought-origins for doing things
Experience type	Observation experience	Action experience	Aesthetic experience
Data	External reality	Enacted reality	Not-yet-enacted reality
Role of knowledge	Basis of competitiveness	Current competitiveness	Future competitiveness
Relationship of knowledge innovation	Purpose of innovation	Current thought-origins of innovation	Real thought-origins of innovation

Table 1 Difference between the three Types of Knowledge (Drucker, 1993; Scharmer, 1999; Johannessen, et al., 1999)

### 4.3 The Creating Process of Self-transcending Knowledge

In the article 'Named Organizing around not-yet Embodied Knowledge', Scharmer takes the case of AHC company to illustrate the creating process of self-transcending knowledge, 'In such a case, the AHC company builds the common process about organizing and making strategies of self-transcending knowledge on the following three core: sharing regular practice, reflection and volition formation. On the basis of such three points, the core principles of high performance network and group base are interweaved and combined

with these following three process: transferring allocating work to sharing experience, abstract discussion to sharing reflection and targeted negotiation to the formation of collective will (Scharmer, 1999).’ According to Takeuchi and Nonaka’s SECI model, Scharmer considers the above creating process of self-transcending knowledge can be included as interaction between self-transcending knowledge and explicit knowledge. With the same sequence of SECI knowledge transferring, such a process starts from ‘Socialization’, which is to familiar with the natural and proper fields, namely from self-transcending knowledge to the sharing and transfer of self-transcending knowledge, then goes into the field of ‘Externalization’, it is a critical step of self-transcending knowledge’s creation to transfer self-transcending knowledge to explicit knowledge. The next step is ‘Combination’ field, which transfers the explicit knowledge to be an advanced one in order to realize systematize of explicit knowledge. Lastly, finishing the transformation from explicit knowledge to self-transcending knowledge in the field of ‘Internalization’ in order to develop the ‘S’E’C’I’ process of self-transcending knowledge creation.

#### **4.4 Dual-SECI Model of Product Design Knowledge Conversion**

For the creation of artistic knowledge is mainly based on aesthetic experience or pure experience (Nishida, 1992), as well the thought-origins knowledge that points to unset reality. On contrary, design thinking, design process, design experience, especially the design ‘inspiration’ we usually referred, have high percent of self-transcending knowledge – a kind of knowledge cannot be master easily. Therefore, acquiring such kind of knowledge needs the designers or students keep experiencing design thinking, weighing design process, accumulating design experience and absorbing the design methods of solving problems in theory, especially in designing practices. All of this shows that the creation of artistic knowledge is a process from ‘self-transcending knowledge’ to explicit knowledge which can be expressed by the ‘S’E’C’I’ model. Compared with the artistic knowledge, the tacit knowledge in technical knowledge and social knowledge is mainly ‘tacit-embodied knowledge’, whose creating process comes from the interaction between tacit-embodied knowledge and explicit knowledge. And the model of product design KC is also the result of such a process, which is a dual-SECI model.

### **5 The Extending of SECI Model: Building a Dual-spiral KC Model**

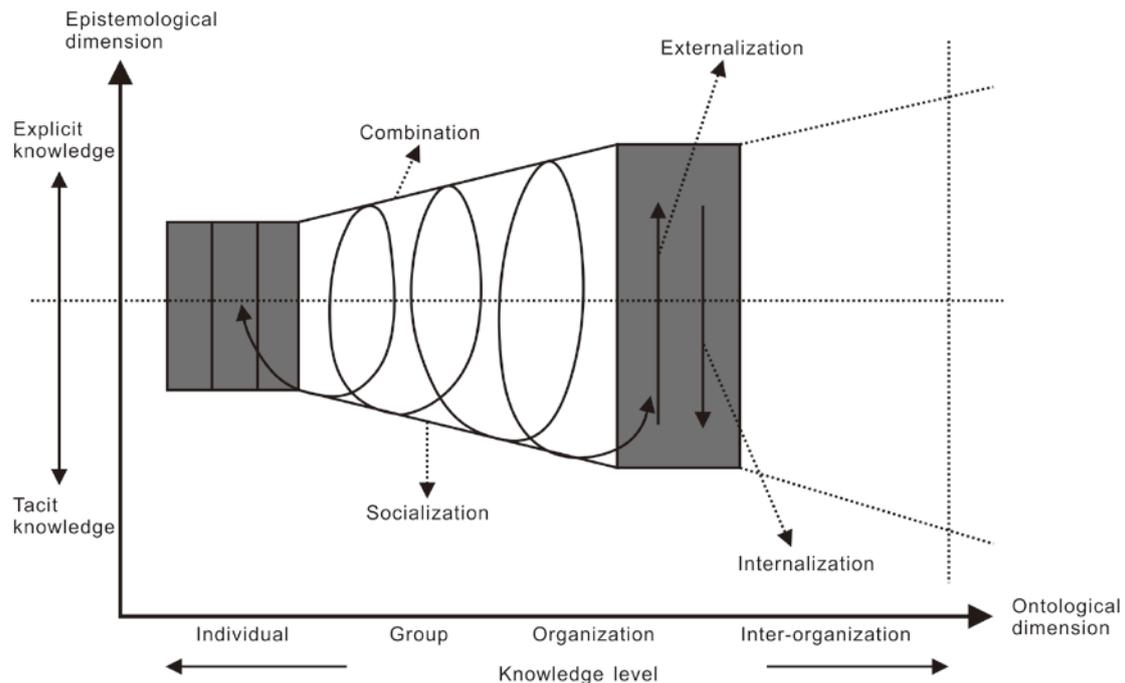


Figure.2 Spiral of Organizational Knowledge Creation (Nonaka, & Takeuchi, 1995)

Takeuchi and Nonaka's SECI spiral model of knowledge pays special emphasis on its two dimensions: epistemological dimension and ontological dimension. The base of the epistemology is the division of explicit and tacit knowledge, while the ontology is mainly considering subjects of different levels that create knowledge. Combine with the process, the spiral model of KC from organization can be seen in figure 2. In the spiral process of organizational KC, tacit knowledge continually change to be explicit one through SECI process, such a spirally rising process can synchronize on different subject levels, so as to facilitate the creation and formation of new organizational knowledge. On the base of such model theory and two kinds of concept about tacit knowledge, as well combine with product design knowledge's own characteristics, we put forward the dual-spiral model about the KC of product design (see figure 3).

The dual-spiral model is also based on the above two dimensions. On the part of the epistemology, explicit and tacit knowledge still as the based division, the only difference is the tacit knowledge included tacit-embodied knowledge and self-transcending knowledge. On the part of the ontology, which pays attention to those subjects of different levels who has relation with the product design KC.

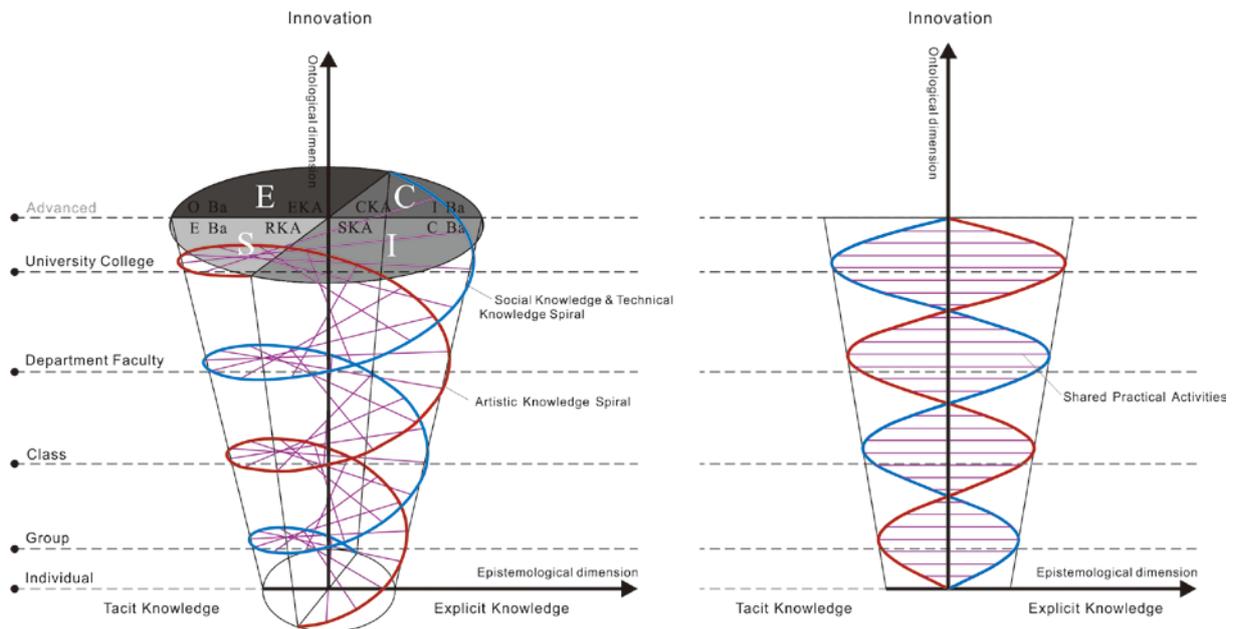


Figure.3 Dual-Spiral Model of Product Design Knowledge Creation

In the dual-spiral model, the blue spiral line reflects SECI knowledge's creating spiral from the social interaction between explicit and tacit knowledge, which is also on behalf of the creating spiral of social knowledge and technical knowledge. While the red spiral line means S'E'C'I' knowledge's creating spiral from the social interaction between self-transcending knowledge and explicit knowledge, which is also on behalf of creating spiral of artistic knowledge. The connected line between dual spiral lines is the bond of two spirals, which connects them in the sharing activities of knowledge 'Ba' with different layers. Besides, two spirals revolve around the same axis which points to the aim of spiral rising – Knowledge Creation.

## 6 Green Product Design under the Model of Product Design KC

Green design (also called sustainable design, eco-design) is the philosophy of designing physical objects, the built environment, and services to comply with the principles of social, economic, and ecological sustainability (McLennan, 2004). It is imperative that designers consider environmental factors in addition to technological and market-derived requirements, from the early stage of conceptual design and through all product development (Russo, & Rizzi, 2014).

Green design consists of a set of coordinated activities aimed at developing products and processes with less environmental impact. Four levels of green design can be identified (Brezet et al., 1997):

*Level 1 - Product improvement: a progressive and incremental improvement of the product, i.e., a re-styling. For example, one can decrease the materials consumption or replace a type of fastener with another.*

Level 2 - Product redesign: a new product is redesigned on the basis of an existing one.

Level 3 - New product concept: it is an innovation rupture; technical functions, which fulfill product functionality, are changed.

Level 4 - New production system: it occurs when innovation in the productive system is required.

As far as the knowledge structure of 'green product design' concerned, it more strongly emphasis on social knowledge and technical knowledge, especially the latter, but not artistic knowledge. As the application of knowledge, it stresses on the promoting effect of designers' sense of responsibility and technical creation on green design.

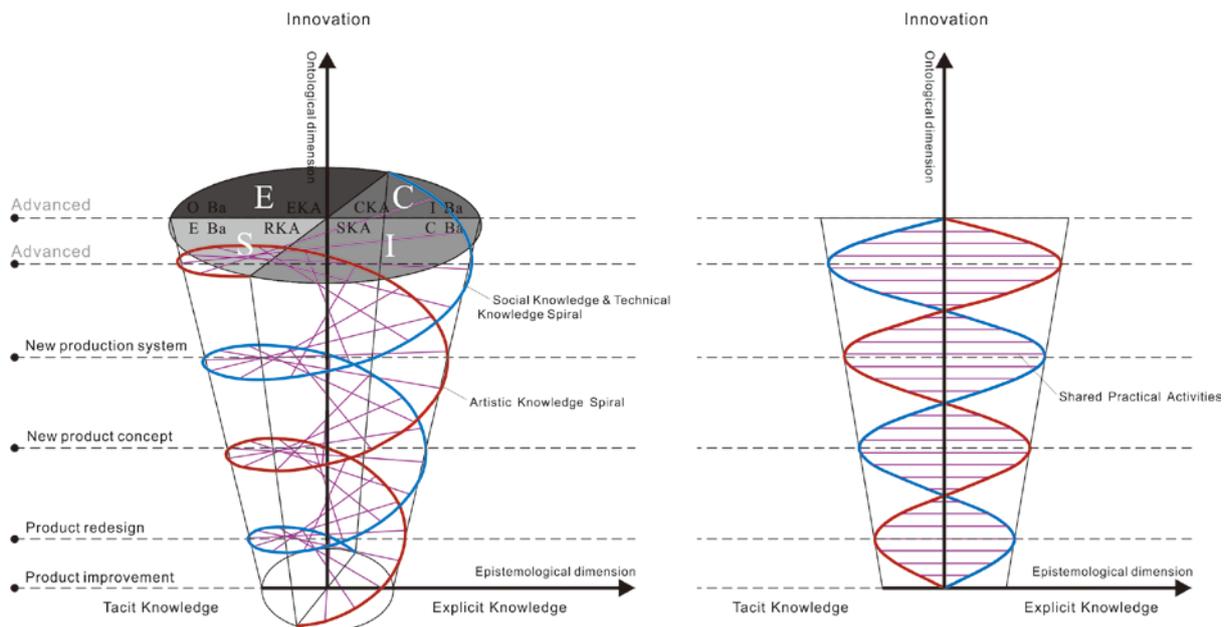


Figure.4 the Model of Green Product Design Knowledge Creation

In different Bas from the process of KC about product design, through understanding of information, old knowledge gets further meaning of 'green' to produce new one with 'the concept of sustainable design'. Such new knowledge will take necessary sharing and interaction in Cyber Ba, Exercising Ba, Cyber Ba and Exercising Ba in order to inform knowledge spiral of green product design. Meanwhile, providing necessary dynamic foundation and moderating variable for the spiral creation about green design knowledge through constant accumulating of green knowledge to inform knowledge assets with 'the concept of sustainable design' in different stages of KC.

According to the dynamic model of product design KC, the creating model of design knowledge about green product can be named as a spiral one which based on green knowledge assets and produce in 'different green-knowledge-orientated' Bas. It also has two dimensions: the epistemological one from tacit knowledge to explicit knowledge, the ontological one about green design in different layers.

## 7 Conclusions

The creation model of product design knowledge is a spiral one of KC, the social interaction between (embodied) tacit knowledge and explicit knowledge has extended new social and technical knowledge, while that between explicit knowledge and self-transcending knowledge has created new artistic knowledge, there is connection and also difference between such two knowledge spiral, simultaneously, on the basis of knowledge assets, they jointly promote the innovation and updating of product design knowledge through SECI of knowledge conversion in different knowledge Bas. This article considers that spiral model of product design KC can provide intellectual support for green (product) design from 'green processing' and dual-SECI of KC about product design to knowledge creating spiral of green product design in knowledge assets and Bas.

Knowledge innovation belongs to one researching branch of knowledge management, whose study mainly concentrates on the field of economy and management, while there are few ones in that of art. Although this article put forward the concept of knowledge creating spiral model about product design, it still need improvement and abundance from the perspective of practice, as well interdisciplinary and multidisciplinary research in order to get further supplement for it from the field such as economy and management.

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