Model of Meta-Reflection and In-Depth Analysis of Knowledge Creation Process in Design

Georgi V. Georgiev*
Japan Advanced Institute of Science and Technology, Japan
Yukari Nagai
Japan Advanced Institute of Science and Technology, Japan

ABSTRACT
The purpose of this research is to propose a model of meta-reflection and in-depth analysis of the knowledge creation process (KCP). We focus on observation of the KCP in research on creative design. The new method of meta-reflection is applied both to reflection on ‘research about design creativity’ and object of research—‘design creativity’. One result of the applied method of meta-reflection was that the analysis of KCP in research on design involved different tacit forms of knowledge and creativity and included a wide spectrum of knowledge processes and knowledge types. We identified the roots of creativity and imagination, which then stemmed into certain parts of research activities, such as development of hypotheses and theory proposition. We produced a model of meta-reflection (MMR) and an in-depth analysis of the KCP. This study is a step that provides understanding of the role that human creativity and imagination play in research.

Keywords: Knowledge creation, Knowledge science, Knowledge process analysis, Knowledge creation theory, In-depth analysis of knowledge, Reflection, Meta-reflection, Reflective verification, Creative design research, Creativity and imagination

INTRODUCTION
Knowledge is a subject of investigation in many studies on the processes involved in scientific research. However, the role of creativity and imagination in research environments is not yet understood from the point of view of knowledge processes and knowledge creation. This lack of understanding is the main motivation for undertaking this research. The purpose of this research is to propose a model of meta-reflection and in-depth analysis of knowledge creation processes (KCPs). We pay attention to possibilities for describing knowledge creation processes emerging in research projects. Moreover, this paper addresses the importance of meta-reflection on knowledge creation processes in research projects. We focus on observation of the KCP in case of research on creative design, particularly on the role that imagination plays there. The particular case we focused on is a research project about creative design, i.e. this is a case where creativity is an object of investigation in the research project and is an element involved in the knowledge creation process. Thus, the objectives of the work are to investigate the KCP in creative design, and to provide a new method based on meta-reflection.
This study is based on an approach consisting of reflective and meta-reflective verification and analysis of knowledge creation processes. The meta-reflective verification is supported by data that are collected from discussions, observations and document analysis of the research project under investigation. Our approach includes critical analysis and integration of a number of theories on knowledge creation. The approach chosen targets creativity in research projects and the role that imagination plays there. Our model is a result of this study (one paradigm of the approach employed is knowledge meta-reflection). Ultimately, the model of meta-reflection can lead to tools and methods to support creativity and imagination both in research and other academic activities.

The paper is organized as follows. The following section discusses knowledge creation processes and reflection. The section after the following discusses the analysis of the knowledge creation process. The paper further presents the aims and methods of the research. Section about research project on creative design extensively analyses the knowledge creation process in a case study. At the end of the paper, we present our model of meta-reflection, discuss its properties and conclude with the results of the study.

**KNOWLEDGE CREATION PROCESS**

In this paper, we understand the knowledge process as various kinds of knowledge-related work that are carried out in the context of the project under investigation. The knowledge creation process (KCP) is the process of making tacit knowledge explicit (Nonaka et al., 2000). Moreover, the dynamics of organizational knowledge creation are characterized by the knowledge creation spiral (Nonaka and Toyama, 2003). The spiral’s main characteristic is conversion between tacit and explicit knowledge—represented in a model with the basic steps of socialization, externalization, combination and internalization (SECI-model). These kinds of models of KCP help one to understand the nature of knowledge creation and manage the KCP effectively. To do this, it is particularly important to understand individuals’ reflection on the KCP.

**Definitions**

In our framework, we adopt the following definitions:

- **Reflection** – Critical and thoughtful consideration of knowledge processes (Schön, 1983, Rodgers, 2002). This consideration is facilitated by applied knowledge creation theories and fundamental concepts from those theories.
- **Meta-reflection** – Reflection included in the perspective of the knowledge process and its inherent reflection (reflected reflection).

Reflection and meta-reflection are the essential parts of the method used in this paper. Moreover, reflection is understood as inquiry into processes otherwise considered intuitive or creative (Schön, 1983). These processes might be placed within the framework of reflective ‘conversation with the situation’, which can partially account for cases such as scientific investigation or engineering design.

**KCP and Research on Creative Design**

Reflection is a popular technique for accessing self-consciousness (Schön, 1987). Reflection is a relevant approach to investigate one’s own knowledge creation process. Schön found that people who had high levels of creativity often reflected objectively on their own creative processes.
Moreover, it has been confirmed as a useful method for examining our understanding of the design process. The effectiveness of objective reflection has been reported in creative design research (Nagai et al., 2010) and is due to objective reflections help people noticing their mistakes or fixations from a meta-level viewpoint of their activities. Nagai et al. (2010) developed a methodology for internal observation of design thinking in creative design through the creative self-formation process, wherein a designer’s inner perspectives are integrated with an outer perspective. This is based on the idea that the method of inner observation is feasible when the occurrence of the self-forming process is later confirmed during the observing process. They identified the occurrence of motifs that stimulate the designer’s intrinsic motivation through a practical experiment.

Thus, we can observe that using objective reflection on the self when conducting creative activities can be beneficial. The creative dimension of scientific enquiry needs to be emphasized (Rust, 2004). The case of design is particularly suitable to the analysis of KCP in research. However, to make reflection as objective as possible, a very systematic approach to the analysis of KCP is needed.

**ANALYSIS OF KNOWLEDGE CREATION PROCESS**

**Systematic View to KCP**

Current work on knowledge processes and knowledge worker fields provides frameworks describing knowledge management. For example, Drucker (2000) provides a framework of organizational roles in subject areas, where knowledge is acted/communicated, including knowledge regarding science. The productivity and quality of the knowledge work and process are found to be critical for contributions and results.

Current work on the analysis of knowledge processes introduces a systematic approach to KCP. Nakamori & Wierzbicki (2010) introduced the i-System model with metrics such as intelligence, involvement, imagination, intervention and integration. The i-System model presents a systems approach to knowledge synthesis and construction, starting with a new systems thinking which should serve as the basic method of knowledge integration and support creativity.

In another approach (Tian et al., 2006), academic knowledge creation was analysed with a questionnaire-based survey to understand which aspects of academic knowledge creation enhance knowledge creation and research management.

**In-depth Analysis with KPA**

To analyse knowledge creation in the academic environment in-depth, models of knowledge creation should be systematized, schematized and applied to academic KCPs. Knowledge process analysis (KPA) (Sugiyama, 2008) is one such systematized approach, which focuses on a set of primitives to describe the complex processes involved in knowledge creation processes in small academic projects.

In order to improve the knowledge processes in the perspective of academic KCPs (thus, to conduct academic projects in shorter time, support the knowledge sharing and enhance the quality of the project outputs), we chose to elaborate on KPA approach as it systematises number of well-known theories of knowledge creation (Sugiyama, 2008). In this approach, a number of theoretical frameworks about knowledge creation are broken down into separate, fundamental
concepts (called primitives) which are used to systematically analyse the knowledge creation processes in academic projects. This is particularly useful for explorative reflection of own knowledge processes in a way similar to participatory (action) research (Coghlan & Brannick, 2010). In participatory (action) research, as a professional tries to make sense of reflection on knowledge processes, he or she also reflects on the understandings which have been implicit in the action which he or she surfaces, criticizes, restructures, and embodies in further action (Scrivener, 2000). According to Schön (1983), such reflection is central both to the practitioner’s ability to successfully complete projects and to their professional development.

Knowledge work involves logic and reasoning, tacit forms of knowledge (Polanyi, 1983) and creativity (Finke et al., 1992). It includes a wide spectrum of knowledge processes and types. KPA studies such knowledge work in scientific research projects (Sugiyama and Meyer, 2008). This is achieved by elaboration of various theories from the field of knowledge science and produces a knowledge creation model specific to scientific research projects. The main impetus for the development of KPA is found in analysis of the process of organizational knowledge creation in academic research projects (Sugiyama et al., 2003; Sugiyama, 2007). This analysis framework elaborates on various knowledge creation theories in an exploratory approach to academic research, aiming to improve future research projects and education (Sugiyama and Meyer, 2008). As a result, a work guide for further development and applications of KPA is proposed.

The KPA approach consists of the following tasks:

1. Extraction of primitives (fundamental concepts) from existing knowledge creation theories
2. Development of a work guide for reviewing the knowledge process in an exploratory way
3. Review of one’s own knowledge processes
4. Extending the work guide to other knowledge processes in various fields
5. Improvement of the work guide based upon experience of the cases
6. Implementation of tools for review of knowledge processes
7. Collection of cases using the tools
8. Seeking future improvements
9. Obtaining an integrated knowledge creation model applicable to scientific research projects

Previous work on KPA outlined this nine-step approach (Sugiyama and Meyer, 2008).

Previously employed theories in the work guide for KPA are: Theory of tacit thought by Polanyi (Polanyi, 1983); equivalent transformation theory by Ichikawa (Ichikawa, 1970); knowledge management theory by Nonaka and colleagues (Nonaka et al., 2000; Nonaka and Toyama, 2003); non-explicit knowledge process support with model of knowledge categorization by Meyer and colleagues (Meyer and Spiekermann, 2006; Meyer and Sugiyama, 2007; Meyer, 2008); the KJ method by Kawakita (Kawakita, 1975); concept synthesis in creativity by Finke (Finke et al., 1992); and accidental discovery with serendipity by Roberts (Roberts, 1989).

The theory of tacit thought proposes a knowledge dichotomy between the explicit and the tacit. The equivalent transformation theory is a methodology for creative thought, elaborating fundamental concepts of equivalence discovery and equivalence transformation. Moreover, in this theory, two types of thought-flow are distinguished—an analogue route, characterized as intuitive, qualitative and imaginary and a digital route characterized as logical, quantitative and real. The knowledge management theory emphasizes the role of the tacit dimension of
knowledge, providing a convenient analytical framework for knowledge processes in dynamic organizational knowledge creation. The model of knowledge categorization is a two dimensional model, where the implicitness (the degree of consciousness) and tacitness (the degree of codifiability) are the axes. Based on findings from memory, cognition and knowledge science, this model elaborates on the basic concepts of the social network, the knowledge inventory, knowledge exchange, etc. Concept synthesis is characterized by the emergence of new properties in the synthesized concept in the mind during creative activities. The KJ method is a systematic, label-based method for organizing ideas and solving problems. Serendipity points out the importance of accidental discovery in science. These knowledge creation theories are utilized so as to explain certain aspects of research activity; however, they do not account for the entire process, especially for creativity and imagination involved in research.

This research adapts the approach outlined by KPA in a case study of a creative design research project. We intend to investigate what to appropriate from the research project’s existing fundamental concepts (primitives). Moreover we intend to add and test other candidate for the status of “primitive” from the domain of design studies, which is particularly relevant to creativity and imagination. This carried out to investigate the KCP in creative design research, and to provide a new method, that of meta-reflection.

Selection of Primitives for Analysis of Research on Creative Design

Sugiyama and Meyer (Sugiyama and Meyer, 2008; Sugiyama, 2007) synthesize the concepts from the aforementioned theories into factors influencing knowledge creation through tacit knowledge processes. The primitives used concern knowledge creation in general. We address the major shortcomings of KPA (Sugiyama and Meyer, 2008)—fail to identify creativity and imagination involved in KCP—by specifically targeting the creative activities in design. Creative activities in design differ from the general creativity, as design requires creative activity to specify exact concept of product.

By focusing on the primitives’ synthesis, the current study explores primitives from theories from studies on creative design. One candidate is the design insight model by Taura and Nagai (Taura and Nagai, 2008). The reasons behind the choice of this design theory can be better understood with the following clarifications:

- ‘Concept generation’ has been clarified as an important aspect of the process of creativity in design. Design studies have also addressed the roles of concept generation in the formation of ideas, related to the original design. The theory of “design insight” provides a model of the concept generation aspect, in opposite to the problem solving aspect, wherein the process begins even in the absence of a goal (Taura and Nagai, 2008).
- Design insight and “inner push of process” primitive express the intrinsic motivation: The theory of “design insight” expresses the driving force behind design as knowledge operating within inner processes.
- It relates to the inner criteria of the designers. This driving force ‘nudges’ the design process forward. The power of inner criteria was described as a ‘push’ of the design process (perspective, opposite to the problem-solving perspective) (Taura and Nagai, 2008).
- The push-type driving force refers to the force wherein the design process is moved forward (pushed) from within the person by something that is deeply rooted in the mind. On the basis of the design insight model, the problem-solving process is pulled towards the goal for a designer.
The “inner push of process” is a primitive, capable of representing process of generating creative idea involved in academic projects. Table 1 shows the primitives (fundamental concepts) formulated on the basis of the models and frameworks from other theories of knowledge creation. The omitted primitives are the KJ method by Kawakita (Kawakita, 1975) and the accidental discovery (serendipity) concept by Roberts (Roberts, 1989) as they analyse only a small number of research project cases and not applicable in our case study. Figure 1 provides a framework for in-depth analysis of the KCP. The relationships among the relevant primitives shown in Table 1 are illustrated in Figure 1. Only the primitives, relevant to the case of this research, are selected in the framework (compared to the set of primitives from Sugiyama and Meyer (2008)). Moreover, the discussed creative design-related primitives were added. This relationship diagram indicates possible insight from the viewpoint of related primitives in each of the nine steps. The arrows indicate the precedence relations of the eight steps of analysis. Precedence (from 1 to 7) is based on previous application of KPA (Sugiyama and Meyer, 2008). The new primitives from design theories are added and marked with asterisk. For example, the “inner push of process” based on design insight theory can be observed in connection with context (step 3). Moreover, concept synthesis, found in creative design, can be observed in connection with analogue and digital routes. The case study of this research follows these steps in a methodological way.

Table 1. Selection of primitives (fundamental concepts) and the new primitives from design theories.

<table>
<thead>
<tr>
<th>KC theories in KPA</th>
<th>Primitives (fundamental concepts)</th>
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<tbody>
<tr>
<td><strong>Knowledge Creation theory</strong></td>
<td><strong>Primitives (fundamental concepts)</strong></td>
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<tr>
<td>Tacit dimension (Polanyi, 1983)*</td>
<td>Tacit foreknowing</td>
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<td>Equivalent transformation theory (Ichikawa, 1970)*</td>
<td>Equivalent transformation</td>
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<td>Equivalent finding</td>
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<td></td>
<td>Analogue route and Digital route</td>
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<tr>
<td>Knowledge creation theory, SECI model of organizational dynamics (Nonaka and Toyama, 2003)*</td>
<td>Socialization</td>
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<td></td>
<td>Externalization</td>
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<td></td>
<td>Connection</td>
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<td>Internalization</td>
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<td></td>
<td>Ba (shared context)</td>
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<td></td>
<td>Knowledge leadership</td>
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<td></td>
<td>Knowledge assets</td>
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<tr>
<td>Non-explicit knowledge process support (Meyer and Sugiyama, 2007)*</td>
<td>Social network</td>
</tr>
<tr>
<td></td>
<td>Knowledge categorization</td>
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<td></td>
<td>Knowledge exchange</td>
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<tr>
<td>Creative cognition (Finke et al., 1992)*</td>
<td>Concept synthesis</td>
</tr>
<tr>
<td><strong>Design theory</strong></td>
<td><strong>Primitives (fundamental concepts)</strong></td>
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<tr>
<td>Design insight (Taura and Nagai, 2008)</td>
<td>Inner push of process</td>
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</table>

* Selected as relevant to the case of this research from Sugiyama and Meyer (2008).*
Figure 1. Relationship between relevant primitives describing knowledge creation and aspects of knowledge work. (* (asterisk) marks the creative design-related primitives added in comparison with Sugiyama and Meyer (2008)).
AIM AND METHOD

The aim of this study is simultaneously to investigate the KCP in research on creative design, and to provide a new method for the analysis of the KCP that is based on meta-reflection. The method of this study consists of:

- Reflective and meta-reflective verification and analysis of knowledge creation processes.
- The meta-reflective verification is supported by data that were collected from discussions, observations and document analysis of the research project under investigation. This approach includes critical analysis and the integration of a number of theories on knowledge creation.

The approach chosen targets creativity in research projects and the role that imagination plays therein. Meta-reflection built on and improves the existing knowledge process analysis (KPA) approach (Sugiyama and Meyer, 2008), to investigate knowledge creation in the case of creative design research. Knowledge process analysis is the basis of classification and integration of various theories from the field of knowledge science. Among the main elements of the KPA framework (Sugiyama and Meyer, 2008) – knowledge process modelling, synthesis of primitives and reflective verification – this research focuses on the latter, analyzing one’s own research process through reflective verification of various research events, knowledge flows, etc.

The intent of this paper is to produce a model that is based on the results of this study. The model is focused on knowledge meta-reflection. Along with this, it will contribute to the further development of an integrated theory of knowledge creation in academic projects.

The next section focuses on an extensive analysis of KCP in the case of a creative design research project.

RESEARCH PROJECT ON CREATIVE DESIGN

This paper carries out an in-depth analysis of KCP, as previously outlined. The project is analysed by the participants. The analysis targets creativity and imagination in design. We focus on the aforementioned reflection and meta-reflection applied to the following two levels:

- Research about creative design (e.g. reflection on ‘creativity and imagination in design’)
- Observation of the KCP in research (e.g. reflection on ‘research about design creativity’)

Further analysis is concerned both with studying the KCP on the basis of reflection on research in creative design, and (specifically) with certain parts of creative activities, such as development of research hypotheses and theory proposition.

Project

The theme of the research project on creative design is “An Approach to Design Focusing on the Structuring Process of Meaning” (Georgiev et al., 2010a, 2010b). The project investigated conceptual structures and propositions of creative design methodology in connection with the meanings of design. Figure 2 shows a schematic of this project.

The project objective was to investigate the factors of creative concept formation and propose an appropriate design and research method, based on the framework of “meaning elements”. The target was the concept formation process involved in early stage of design. A method aiding successful concept formation in the early stage of design, based on the structure of meanings, was proposed as result of the project (Georgiev et al., 2010a, 2010b).
The initial investigation regarding the evaluation of meanings as elements showed different possibilities for analysis. During this project, team members developed an original approach to the analysis of the structure of meaning (where the elements are the words) and of what the creative design object (artefact) represents to the user. Conceptual networks were used for the analysis of these structures, with similarity metric values in a semantic concept dictionary (database). This approach was further developed into a methodology for supporting designers in the conceptual phase of design, based on the exploration and evaluation of meaning elements.

![Diagram](image)

**Figure 2. Schematic for creative design research project.**

**Course of the Project**

Clarifying the time sequence of the project and the social network among related people is an important first step in our analysis. The time sequence (course of the project) and the social network are the most important dimensions of the project space (see Figure 1) (Meyer, 2008). The discussed project was a collaboration among different individuals with different roles over time, as shown in Figure 3. The participants involved and the duration of each participant’s activity are shown in the diagram, matched with the corresponding project phases and the modes of the SECI model (Nonaka et al., 2000). Also, the non participants and their activities are identified alongside the progress of the project. In this case, the identified phases are:

(I) Preparation,
(II) Basic ideas generation,
(III) Refocusing,
(IV) Socialization,
(V) Formalization of the research problem,
(VI) Explosion,
(VII) Focusing and specializing,
(VIII) Presentation and publication and
(IX) Advance to new research.

Four participants (A to D) from two research organizations and nine non-participants with smaller roles were related to each other in various ways. The first participant, A, is a PhD student who is supervised by B - leader of the project. Participants C and D are members of the same research team. The roles of the participants are relatively stable during the course of the experiment. Furthermore, the phases and SECI modes tend to be shorter as the project progresses. There is a specific phase of refocusing present in the course.

The key members are A, B and C: A’s tacit foreknowledge initiated the project and B and C’s formalization abilities clarified the research. This diagram clarifies the time sequence of the project and the social network among the involved persons as a basis for further analysis of knowledge processes. Significant academic events and discussions influenced the course of the project (for further reference, see Georgiev et al., 2010a, 2010b).

Social Network

The summary of the overall social network for the research project is shown in Figure 4. This is authors’ intuitive identification of an organizational and knowledge network among related people (Meyer, 2008). Note that Figure 4 emphasizes the viewpoint of participant A. We can recognize the importance of knowledge flows of declarative knowledge and hints/suggestions/criticism stemming from outside professionals. Hints and criticism affected the course and outcome of the project substantially. The social network and academic events were considered important for effective research.

Figure 3. Course of the project with phases and modes.
Figure 4. Summary of the social networks.

Context Analysis

The next stage of analysis describes the environment of the research project (according Nonaka’s theory (Nonaka & Toyama, 2003)), which is regarded as the most essential factor for a research project.

The contexts affecting A are as follows:

- Social Context: Understanding, enhancement and observation in the process of designing something are essential for the success of the designed products in any domain.
- Pressure: Participant A was compelled to accomplish his PhD research.
- PhD research subject: The subject is focused on establishing a new design methodology regarding meanings and their structuring in the conceptual design process.
- Stimulation: The academic background of A stimulates the ideas for the project. In later stages, a series of academic events stimulate the project.
- Hints: The concept of ‘structuring of meaning’ in the process of designing is essential to this research.
- Intuition: A graduated as an engineering design major, having technical and design intuition.
- Skills: Composition and design skills.
- Successful experience: Natural language-processing approach to the problem.

The individual and shared contexts (Sugiyama and Meyer, 2008) of other participants are as follows: B is a professor, supervisor of A. The expertise in design creativity, design research and concept synthesizing processes in design are the basis of the research topic. C is a professor, (external) supervisor of A. C’s knowledge and experience are the foundation of the ideas, course of the project, and original realizations of the research. D is an assistant professor whose experience is in research methods and cognitive science and who enriches the approach and methodology of the analysis.
Individual Knowledge and Knowledge Exchanges

Knowledge inventory (Meyer & Spiekermann, 2006; Meyer, 2008) has been proposed as a way to represent individuals’ knowledge and knowledge exchanges. In knowledge inventory, the individuals’ project relevant knowledge is represented on the basis of dimensional models of knowledge types (Nonaka et al., 2000; Nonaka and Toyama, 2003; Meyer, 2008).

The explicit and non-explicit knowledge of participants A and B is the basis of the research processes (Table 2; cf. Figure 4). Knowledge exchange occurred mainly between A and B, where B is the project leader and coordinator. The explicit and non-explicit knowledge of participants A and B is the basis of the research processes. Participant C has explicit knowledge about interdisciplinary design aspects, creative thought, cognitive models, concept creation and computational simulation. Participant D has explicit knowledge about cognitive science, human cognition, experimental studies and analogical reasoning.

Regarding the knowledge of A, the important aspects are individual context in visual communication design (reflected in the basic ideas and framework of the research), technical senses and analysis of concept networks. As for participant B, the most important aspects are: expertise in design thinking, concept synthesizing processes and design creativity.

Table 2. Individuals’ knowledge.

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<tr>
<th>Individual</th>
<th>Explicit knowledge</th>
<th>Implicit knowledge</th>
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<tr>
<td></td>
<td>Declarative knowledge</td>
<td>Conscious access to structural knowledge</td>
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<tr>
<td>A</td>
<td>Visual communication design</td>
<td>Understanding the design process in visual communication design</td>
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<tr>
<td></td>
<td>Analysis of language and networks of concepts, Design research approaches</td>
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<td></td>
<td>Equivalent transformation thinking</td>
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<tr>
<td>B</td>
<td>General design theory, Design creativity, Thinking process in design, Creative design, Concept synthesizing process</td>
<td>Design knowledge</td>
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<td></td>
<td>Language analysis</td>
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<td>Analysis of design process</td>
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<td></td>
<td>Emergence features, designers training expertise</td>
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<tr>
<th>Individual</th>
<th>Explicit knowledge</th>
<th>Implicit knowledge</th>
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<tr>
<td></td>
<td>Acquired skills and procedural knowledge</td>
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<td>Unconscious access to declarative knowledge</td>
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<td>Emergence features, designers training expertise</td>
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The most essential knowledge exchanges and participants’ behaviours are as follows (cf. Figure 3 and the section clarifying the research project):

- Basic ideas about design process (from A to B): Based on his explicit knowledge of visual communication design, A proposed layering structure of two-dimensional design meanings. This resulted in extensive discussions between A and B (later C and D); and development of an analysis method (Georgiev et al., 2010a).

- Creative design research viewpoint, Concept dictionary tools (from B to A): Framework how concepts are transferred into shapes resulted from discussions between B and A. The interpretation and aid of the structure of meanings in conceptual design resulted from gained understanding of creative design research viewpoint.

- Theoretical approach, Method of analysis (from C to A and B): Methodological approach was developed on the basis of C’s expertise and discussions with A and B (Georgiev et al., 2010a, 2010b). The research was refocused as a result.

- Use of language networks (from D to A and B): Discussions between D and A led to elaboration of analysis methods based on concept dictionaries and concept similarities (Georgiev et al., 2010b). This was the fundamental for developing the tools aiding and evaluating the structure of meanings.

The knowledge exchanges provide information of how individuals’ explicit knowledge contributed to the thought-flow.

**Thought-flow Map**

As the final step of analysis (see Figure 1), the representation of the total thought-flow map is shown in Figure 5 in the form of analogue and digital routes, following the method of Ichikawa (Ichikawa, 1970). In the map, the relationships among members, research activities and basic primitives are presented. From the map, we can recognize the concrete experiences that are referred to by different primitives.

The routes elaborate on different knowledge creation primitives from the KPA. The newly-added primitive from the domain of design research (intrinsic motivation or inner push of process) is clearly expressed in several phases. For example, the “inner push” primitive is clear in the second half of the digital route.
Further technical details of the work are omitted due to the size limitations of this paper.

**Summary of the Processes**

From the process summary, we can gain the following insights into the case study’s development (see Figure 5):

- Tacit foreknowledge of the meaning of design objects (digital route) is connected with A’s individual knowledge and context (understanding of visual communication design). At this stage, C’s individual knowledge and two surveys helped A to transform his own knowledge into an ‘evaluation of meanings’ of the design object.
- In the next step, in the form of socialization (as part of the SECI model, cf. Figure 3), A’s basic ideas about the design process were transformed into a framework about how the ‘evaluation of meaning’ can be connected with the design process (concepts transformed into shapes). Here, B’s individual knowledge and knowledge leadership played a critical role.
- Furthermore, in the case of externalization (SECI model), elaborating on C’s individual knowledge and D’s individual knowledge led to the development of an original analysis method using similarity measures (of pairs of concepts) with a concept dictionary. Tacit foreknowledge, equivalence finding and concept synthesis were involved in this process.
- Next, in the case of connections (SECI model; cf. Figure 3 & 5), the understanding of concepts and meanings gained was transformed into a ‘methodology for structuring meaning elements’. C’s individual knowledge, B’s individual knowledge and both C’s
and B’s knowledge leadership helped make this connection. A’s “inner push of process” (design insight) is present at this step.

- Last, in the case of internalization (SECI model), the findings were tested in the conceptual design process, applying the aforementioned methodology to the conceptual design process. Tacit foreknowledge, equivalence finding and A’s individual context were involved here.

Different steps reflected the analogue route equivalence transformation and the digital route equivalence transformation. Both routes show complex structure, and were, therefore, difficult to summarize. The analogue route expresses the basic ideas and their refocusing at a later stage, leading to the original analysis method and method for support. The digital route, on the other hand, shows the importance of individual context and knowledge. Moreover, it elaborates on various knowledge creation primitives from the KPA. The newly added primitive (from the domain of design theory) is expressed in particular phases. It is possible that an investigation at the micro level of the digital route will reveal more of these primitives.

**Meta-reflection and In-depth Analysis of KCP**

Critical analysis on both object of research and its reflection revealed that the primitives related to creativity and imagination are as follows (cf. Figure 5):

- Inner push on the analogue route: In connection with meaning hypothesis formulation
- Concept synthesis on the analogue route: In connection with method of support
- Concept synthesis on the digital route (beginning): In connection with transformation of individual knowledge into research framework
- Concept synthesis on the digital route (middle): In connection with imagination of exploration of meanings in design
- Inner push on the digital route: In connection with ‘structure of meaning elements’ theory proposition

**Model of Meta-reflection**

The in-depth analysis provided is concerned with studying the KCP on the basis of reflection on research in creative design, referring to certain parts of creative activities, such as the development of research hypotheses and theory proposition. We applied meta-reflection to both reflection on ‘research about design creativity’ and object of research—‘creativity and imagination’. As a result of the applied in-depth analysis and meta-reflection, the analysed KCP of research into design involved different tacit forms of knowledge and creativity, and included a wide spectrum of knowledge processes and knowledge types.

Meta-reflection—critical analysis on both object of research and its reflection—played an indispensable role in the analysis. To be specific, allowed observations on the creativity and imagination process of the academic project; moreover, it allowed identifying the roots of creativity and imagination—concept synthesis and inner push of process (intrinsic motivation)—which then stemmed into critical formulations and propositions of the project (cf. Figure 5). We produced a model of meta-reflection (MMR) and an in-depth analysis of the KCP (Figure 6).
The paradigm for the approach used is knowledge meta-reflection. The object of reflection is process (creative design), and our research is on this object (knowledge creation). Moreover, the consequent meta-reflection both on the knowledge creation process (KCP) and the object of knowledge (creative design) permitted in-depth analysis of the KCP. The identified components during meta-reflection of knowledge are essential for our understanding of knowledge creation, especially regarding the creativity and imagination involved in work related to scientific knowledge.

The measurable and valuable outcome of this analysis is the model of meta-reflection (MMR) of knowledge creation processes in research. The proposed model is expected to improve methods for the analysis of KCP in the area of research.

DISCUSSION

Findings
From the aforementioned analysis of experimental results we found:
1. Reflection related findings:
   - KCP in the research project is complex and largely non-systematized
   - The object of knowledge (creative design) affects the research approach and creativity and imagination applied to research on creative design
2. Meta-reflection and in-depth analysis related findings:
   - Imagination and creativity appear at critical points in the course of the research project
   - An intuitive connection exists between the area of experience (design) and approach used (e.g. concept synthesis and “inner push of process” or intrinsic motivation). In other

Figure 6. Model of meta-reflection (MMR) of the knowledge creation process in research.
words, the participant’s previous experience and tacit knowledge in the design area affects some steps of the knowledge creation process (e.g. approach to the research problem)

The framework of KPA (Sugiyama and Meyer, 2008) was applied in an academic research project, along with primitive (theory) from the domain of design studies. This application is focused on meta-reflection and contributes to integrated knowledge creation theory in research and academic environments. Application of KPA in the creative design case shows improved meta-reflective analysis of the activities. This improvement can be seen in the identified roots of creativity and imagination of the project (concept synthesis, inner push of process), contributing to critical formulations and propositions of the project. Moreover we refined the primitives’ list and addressed one shortcoming of previous studies—fail to identify creativity and imagination involved in KCP (cf. Table 1, cf. Figure 5).

This can be considered a successful application of the approach of meta-reflection we discussed. Thus, the overall results show the capability of KPA to promote the building of integrated knowledge creation theories for scientific projects.

The focus was not only on the roles of various traditional knowledge creation theories (Sugiyama and Meyer, 2008), but also on the fact that an essential part of the processes can be explained in terms of design theories. The particular primitives are concept synthesis (Finke, 1992) and “inner push of process” or intrinsic motivation (Taura & Nagai, 2008). These primitives are regarded as playing an important role in design creativity. Thus, we argue that creativity plays a special role in the scientific knowledge creation process.

One may need more empirical demonstrations in such analysis of own knowledge creation processes. However, such concerns about empirical demonstrations are universal for the research on reflection of own knowledge processes (Nagai et al., 2010).

Creativity and Imagination

The involvement of primitives connected with creativity (Figure 5) can be explained as follows:

- Inner push and imagination contribute to transformation of implicit knowledge; and help to put the individual context to use
- Concept synthesis (and creativity) is important and often appears in hypothesis formulation and theory proposition.

Compared to the work of Sugiyama and Meyer (2008), the originality of this study lies in the focus on creativity and imagination involved in academic projects by elaborating on primitives capable of representing it, such as “inner push of process” based on the theory of “design insight” and the intrinsic motivation (Taura and Nagai, 2008). Focus on such primitives is a key point in understanding the creative knowledge creation.

What is achieved by this research? We recognized the effectiveness of adopting meta-reflection in the identification of the elements of KCP, particularly, creative and imaginative turns in the course of the research. It is possible to evaluate the effectiveness only qualitatively. We identified concept synthesis, inner push of process (intrinsic motivation) as involved in critical formulations and propositions of the project—a view missing from previous studies (Sugiyama and Meyer, 2008).

This study found that meta-reflection was likely to provide an effective paradigm for analysis and improvement of the knowledge creation process. The model of meta-reflection (MMR) was proposed as a result, providing a basis for methods and tools for analysis and improvement of the KCP in the area of research.
Compared to other frameworks of knowledge process analysis, this research applies a systematic, break-down approach to the KCP in research. The added primitive related to design creativity makes a difference, specifically, in the identification of creative and imaginative turns in the course of the research. The research limitations of this study are connected to the empirical ability to generalize, as this paper relies on a single case study.

**Implications**

The proposed model and possible tools that could be developed based on the model will help to conduct a project in a shorter time and manage it effectively, allowing identification of the knowledge creation “elements”, and their proper “utilization”. Such tool for knowledge sharing between collaborators (especially between experienced and younger collaborators) would enhance the quality of the academic project outputs. One implication for practice is the need to recognize the influence of knowledge creation processes at different points in the course of research. The value of our analysis is in identification of the connections between knowledge creation processes and creativity/imagination, i.e. individual creativity/imagination in knowledge creation processes in research. It also suggests strategies for the implementation of analysis of KCP, so as to make research more effective. Moreover, the reported research produced valuable insight into the way in which creativity and imagination defined the direction of research and the understanding of knowledge processes. This study provides better understanding of the role that human knowledge creation processes play in creative design and models reflections on it. It is evidence of the special purpose of the MMR for future investigations into creative design. Effective application of the KPA/MMR approach and conscious knowledge creation processes will provide benefits for future research projects.

Future work will include meta-reflection and in-depth analysis of additional research cases and implementation of the findings to knowledge creation processes in research.

**CONCLUSION**

This article proposes meta-reflection as a qualitative analysis tool for the knowledge creation process (KCP) in research projects. The meta-reflection approach is build upon knowledge process analysis (KPA) theory, adding primitive relevant to creative design. KPA elaborates knowledge creation primitives (fundamental concepts) from various theories of knowledge creation that have been proposed in the last few decades. This case study of research project on creative design is a case where creativity is involved at the level of research knowledge creation and research objectives. Our insight into what promotes and what hinders successful knowledge creation was deepened. Moreover, the importance of creativity and imagination in research projects can be seen from this case. This case study contributes to the development of the knowledge creation model with specific applications to scientific projects by proposing a model of meta-reflection (MMR). The value of this study is in the identification of the connections between knowledge creation processes, theory proposition, hypothesis formulation and creativity/imagination in research. However, so as to improve the framework of meta-reflection, the knowledge process analysis method should be used to investigate additional case studies of academic projects. With the help
of this kind of academic knowledge creation meta-reflection model we expect more in-depth analysis and improvements to future projects.

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REFERENCES


