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CONCEPTUAL PROCESS OF DESIGN THINKING ACCORDING TO CONTEMPORARY ACTIVITIES

Mohsen Faizi, Farhang Mozaffar & Mehdi Khakzand

Abstract: *In this paper, authors tackle three very important questions that need to be answered if a theory of design is to be constructed. The first is what designers do, Which we attempt to illustrate with the help of case studies and theories of design practice. The second question is what guides designers. Here, authors try to present some of the proposed normative positions about design, to show the similarities and differences between positions and a framework of how they can be categorized. The main (third) question is how the design thinking process can be represented drawing upon on a review of recent studies of design practice and designer's creativity.*

One approach to design thinking is to extract the features of the designers' strategic knowledge, for which comparative studies between expert designers and novices are useful. Also, controlled experimental studies may be adopted in order to understand the nature of the idea generation process.

Finally, the methods of research and representation of design thinking in order to gain a deeper understanding of the designers' creativity are proposed.

Keywords: *Conceptual process, Contemporary activities, Design creativity, Design Process Modeling, Design thinking*

1. Introduction

Exploring human creativity improves our understanding of the discovery and invention of new artifacts. It also contributes to an understanding of its role in productivity improvement and the enhancement of the quality of human life. For that purpose, an understanding of the nature of human creativity based upon evidence is required. The general goal of our research into design thinking is to contribute to the understanding of human creativity and the trivial aim of this research is to represent design thinking as process models. Furthermore, such modeling is developed in accordance with an educational remit.

2. Early Theoretical Positions

Early theories of design practice were strongly based on the prevailing theories of learning and cognition. The two cited by Rowe (1978) are associationism and behaviorism. Associationism asserts that the sole mechanism of human learning is the building of associations between concepts. In this view of cognition, problem-solving is seen as the mechanical process constructing a stream of associations. Behaviorism rejects the mentalistic attitude of associationism, instead it explains human behavior through observable physical patterns. The behaviorist aims to construct stimulus-response models, so that to give a certain stimulus a response which can be predicted with certainty. The behaviorist study of design and problem-solving activities lead to the construction of staged process models. These display the episodic nature of design indicated by studies of design practices. The three primary stages in the model are analysis, synthesis and evaluation. (Like Jones' model)

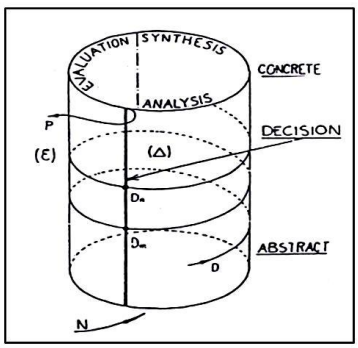

Fig. 1. Introduction of design process model- By Jones

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Mohsen Faizi is Associate professor, Dean of faculty, school of architecture and urban studies, Iran University of science and technology. mfaizi@iust.ac.ir

Farhang Mozaffar is assistant professor, school of architecture and urban studies, Iran University of science & technology and president of Isfahan Art University. f.mozaffari@iau.ac.ir

Mehdi Khakzand. Ph.D. in Architecture, Iran University of science and technology. mkhakzand@iust.ac.ir

3. Designing Results of a Process

In "Design in Mind," Bryan Lawson first declares that design consists of the, "creation of something new and original". A common definition of the word "creation" is "The divine act by which according to various religious and philosophical traditions the world was brought into existence". This definition is unsuitable for representing the act of designing.

The word "creation" is confusing because it could mean that the designers are able to produce without any material. This concept refers to the stereotype of the genius who magically finds his ideas without any basis in reality. The association of the word "creation" with the act of designing might be one of the reasons why analysts focused on the result of the design rather than on the design process.

We will see that designer's ideas are a result of a process where he will assemble and compose accumulated knowledge. For those reasons, the world "composition" seems to be more appropriate. Designers should be aware of why there is reluctance to try to make design processes explicit. Because processes and product are highly intermixed, making explicit ones process gives away some of their design secrets. Others may be able to replicate their designs by replicating their process. Or even more critically, the process may be analyzed and criticized.

To some the discussion of design process removes some of the mysticism and the art of design. But quite the opposite, discussions of process will inevitably lead to the refinement of processes and allow attention to be given to the creative modification and enhancement of processes, for both social and for individual and creative ends. (Eastman, 1999)

4. The Importance of Design Thinking

Design can be applied and needs to be applied to essentially everything in our world. "The purpose of design is to bring together different things in order to deliver value. If there is no value; there is no design. If the only value is the self-indulgence of the designer, then there is no design either. Design is the opposite of complacency and being too happy with things the way they are.

Creativity feeds into design. A design may be a new way of putting well-known things together. A design may also involve new concepts. Design can be applied to everything we do, thinking or feeling. We may seek to design new types of capital; we may seek to design a better form of democracy; we may seek to redesign the legal system. Anything can be designed or redesigned. Design is very much more than just problem-solving."

5. Classifications of Researches About Design Thinking

Research trends in design thinking were surveyed by Cross, Dorst and Roozenburg (1992) drawing upon a number of key events in the design research community. Oxman (1995) classified various types of research in design thinking as follows:

- Design methodology
- Design as problem solving
- Design cognition
- Design psychological aspects of mental activities
- AI (Artificial Intelligence) in design
- Computational models, methods, systems and technology
- Collaboration: the social and educational perspective of design

Oxman (1995) also divided the methods of research into soft approaches and hard approaches. 'Soft' methods refer to techniques that employ conventional observation, such as classical 'thinking aloud' methods and 'interaction analysis' which are adopted in the ethnographic studies. 'Hard' methods refer to techniques that employ formal methods; for example, task analysis and information processes identified from 'thinking aloud' protocols.

6. Design Process Modeling Research

Design process research conducted in the 1960s and 1970s is typified by the work performed by Archer (1963), who modeled the design thinking process of professional designers, and also by Alexander (1962), who proposed a model for design thinking process related to construction and urban planning with a high degree of abstraction. However, these were actually models for understanding the entire structure of design behavior, rather than representing the creative thinking process of the individual designer in particular. In respect of the creative thinking process, Lawson (1993) investigated designers in the 1980s, taking construction design as an example.

Lawson and others (1980) have been developing their methodologies in order to gather verbalizations by designers. Of particular note is the research by Candy and Edmonds (1994) that considered the creative process of designers who had attained exceptional design solutions. These studies have focused on outstanding designers in their fields who are unquestionably capable of creative ideas and artifacts that can be turned into Innovative products (as Debono says, 2000). Although they represented a spectrum of different domains and cultures, they exhibited similar ways of thinking and working. The model has shown below represent three stages in the creative process each with a number of relevant sub-activities. The contributing elements are types of knowledge that are applied in design. The process model of creative work was extended into a model of creative knowledge work, illustrates the activities and contributing knowledge that comprise Creative Knowledge Work. The contributors to the activities are expressed as different types of design knowledge.

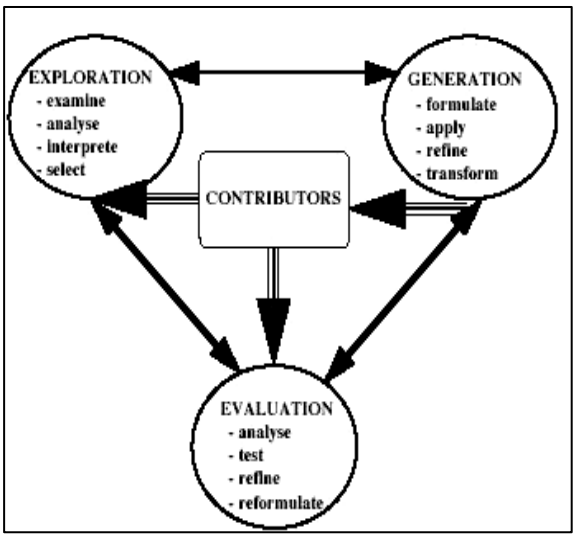

Fig. 2. Creative activities with contributors, By: Yukari NAGAI, Linda CANDY, Ernest EDMONDS

While Finke, Word and Smith (1992) have focused on the creative cognitive structure, taking creative thinking used in scientific discovery and inventions within range, their studies are focused on artificial shape expression and consequently are strongly related to design thinking. The Geneplore Model of Finke (1992) and others represents creative thought as working through a conscious 'Pre-Inventive Structure' state. Creative thinking refers to a model for trial and error looping which acts as the intermediary to target restrictions created between the generated pre-inventive structure, the pre-inventive search and interpretation.

Thus, sequential thought processes as a target search domain in thinking are considered to be the repetition of partial structuring between the problem and solution domains. The 'reflection-in-action' is a theory which places value on a need for artistry in professional education by Schon (1987).

Donald Schon thinks he could analyze the "Reflexion in action" in "The Design studio." He tries to understand the "design thinking" by analyzing the discussion between a teacher and a student. Schon identifies what he calls the "language of design". He also tries to access the designer's thinking by analyzing how one can teach how to design at a design studio. Those texts confirm that designers are not creators and that they have acquired as various knowledge's as possible to compose.

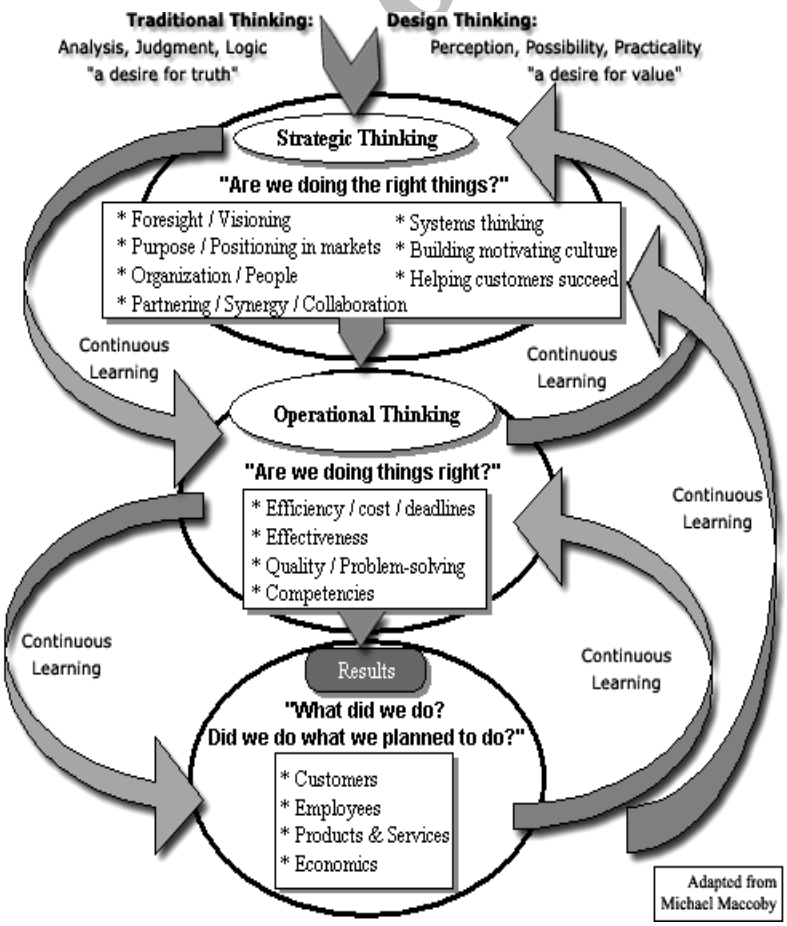

Fig3. Relation between operational and strategic thinking

7. Impact on Strategic and Operational Thinking and the Effects on Design

Solving instructional design problems requires being able to think strategically, as well as operationally. DeBono (2000) has adapted an illustration originally developed by Michael Maccoby[2], which highlights the different aims of strategic and operational levels of thinking. Maccoby's original graphic has two important messages: First, to illustrate the difference between strategic and operational thinking tasks, and Second, to show how continuous learning is an integrating process uniting strategic and operational workflows. To these messages we add one more: that strategic thinking and operational thinking become more effective and complete when our thinking enables us to express both "a desire for truth" and "a desire for value."

It is a common observation that some individuals are excellent at an operational level, but never excel at a strategic level of thinking. Ideally both Traditional Thinking (analytical) and Design Thinking (creative vision) will be applied in both strategic and operational thinking tasks. However, it is clear that a one-sided, "analytic only" mode of thinking will be genuinely incapable of dealing with the range of thinking tasks that the strategic level requires. Strategic thinking, especially, demands both the analysis-judgment and possibility-value frames of thinking. Several methods were implemented to access the designer's mind. According to Nigel Cross (1993), in "Research in Design thinking", the following techniques were used for this purpose: interviewing designers, observing, studding protocol, making test controls or by simulating the phenomena.

Creativity in design may be classified according to subjects and regional differences as shown in the following.

(A) Designer's own creativity,

(B) Creativity supported by cooperative behavior of multiple designers,

(C) Creativity for the item designed in terms of social meaning.

In this paper, the authors describe the research on (A) and (B).

In "Design thinking", Bryan Lawson reports the same kind of method. According to him, several techniques were employed to understand the design process: "observing the designer at work", conducting "laboratory experiments", or asking "the designers to tell us what they do". These researches enable designers to identify several methods the designer implements to generate solutions.

The first step of a methodology consists of formulating an interpretation of the problem. While designing, one has to make choices among infinity of solutions. A strategy consists of imposing additional constraints that will result from the interpretation of the program. A self imposed constraint that Nigel Cross (1991) did not mention is the style.

He reports that the designers will "exercise considerable freedom in changing the problems, goals and constraints to take advantage of opportunities that emerge in the developing design solutions, and partly to avoid being obliged to change the original concept."

We could wonder if the designer's methodologies are logical. Ellen Do (2002) is skeptical with the idea that the design solutions can be analyzed by debating. The analysis method consists of a breakdown: the problem is divided into several subsets. Each part is resolved separately and then the whole is being reassembled. This technique can be implemented to study complicate objects that can be modeled as a tree, which means the object is composed by several subsets that are independent themselves. The various issues in design are interconnected, and a solution that will resolve a question could engender other problems. All the subsets of the problem are interconnected.

8. Practical Studies of Design

Rowe (1987) presents some case studies at the start of his book, taken from very different building projects with different architects in each case. The details of these case studies although interesting are not as important as the questions about the design process which they raise and the observations which can be made.

Rowe shows that the design proceeds as a sequence of episodes. Each episode focusing on a different aspect of the problem. Sometimes the level of focus can result in the intentional "blinding" to certain problems. Blinding allows the designer a certain amount of freedom to explore possibilities without the hindrance of considering all the constraints on the solution. Blinding also results in backtracking which is where a designer must retreat to an earlier point in the development of a solution because the current solution proves impractical.

9. Design Research Methodology

There are many methodologies for studying the individual designer's thinking process. In this section, we consider two main forms of empirical data: verbal data and visual-spatial data. In research into design thinking conducted recently in the cognitive psychological area, much of this work has utilized the 'Think Aloud Method'.

In this design area, a method for obtaining subjects' protocols has been employed in response to requests from usability tests in user interface design and other areas. According to Erickson, the purpose of the Think-Aloud Method is to collect subjects' short-term memory thoughts in the form of words: this method requires the subjects to practice verbalizing their thoughts in advance. The method is based on the idea that thoughts are in principle formed by means of

[2]- http://www.maccoby.com

language. Therefore, the Think aloud Method uses only spoken language information as data to learn about the content of thought. However, for a more complete picture, there is a need to capture, not only
verbal expression, but also the subject's gestures, attitudes, emotions and so forth in order to comprehend the full dimensions of the design thinking process.
Another form of research is to use methods for creating Visual-Spatial thought data. Drawing can be said to link verbal search domains to visual-spatial search domains through a process for converting 'language' to 'shapes.' The following is a summary of research that focused attention on these areas. Goldschmidt (1994) observed the design process of architects, and then analyzed the relationship between drawings and protocol.
Goldschmidt's research used speech data as the key to understanding drawing, revealing the importance of the visio-spatial aspect in the design thought process.

10. Approaches to Designers Thinking Modes

Many recent studies concerning the creative thought process have applied methods that have (stochastically) analyzed chronological data of extrinsic factors expressed in the thought process, and judged the outcomes based on the analysis of results but it is not enough.
This research focuses on understanding the structure of the design creativity. According to this research, the design thought process is considered to be a process of expressing a design objective provided verbally as a visual-spatial type image and gaining design solutions.
Based on design results, the paper discovered that there are different search processes corresponding to a variety of phases in the thinking process whereby different searches are initiated according to the relationship between them and the method used to depict the conceptual sketches and at what stage the semantic structure of words are set.
We learned that the design solution details change significantly according to the sampling method used for key words in this process. The following steps describe the tests conducted for realtime tracking of the design thought process through a more detailed observation. A structure of the design thought process is expressed as a conceptual model based on results analysis and a comprehensive examination.
The separation of thoughts between subjects (design target itself) in the design target expression and predicates (state required for design target) could be presumed at the initial step in the thought process. Then, the basic function of design target (subject) and the shape that expresses the required conditions (predicate) were integrated, and in a post-process, the shape obtained from the integration of the subject and predicate was worked out through the drawing.
The search mode is expressed in the design thought channel model. The creative thought process for design enables the process to continue while enabling search mode switching to be predicted according to the stage. There is the linguistic interpretation stage for the target expression, where a search to link the predicate expression to the shape image is performed, irrespective of the main design target as the subject.
A 'Semantic Generation Search', which generates the meaning of design targets expressed by subject and predicate, is performed as a visible shape at the stage where certain predicate shape images are acquired. The Semantic Generation Search carries with it a very significant meaning because the shape expression also indicates functions. Therefore, drawings become cautious, while the conceptual sketch frequency here, often expressed in the Interpretive Search and Reminder Search, is reduced. The 'Pre-Drawing Behavior' mentioned below often emerges in contrast.
The goal for future research is to understand the creative thought processes of designers through even greater numbers of dimensions which will certainly require idea for new test methods and research on how to interpret them.

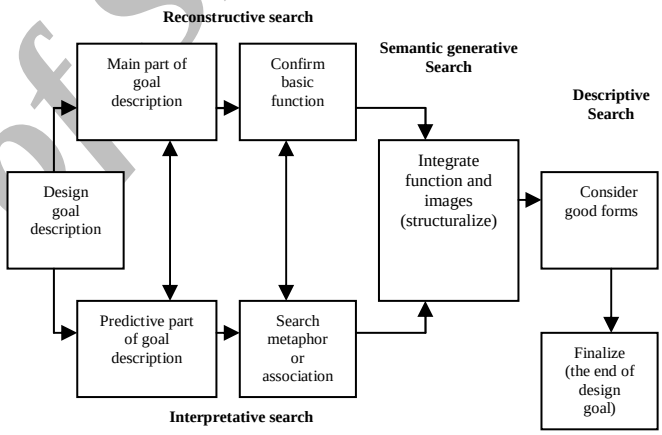

Fig. 4. Creative thinking process in design, By: Yukari NAGAI

To recognize the relationships between drawing symbols (at different stages) using technology, an experiment was conducted by the authors of this article, with 15 designers and architects all of whom are the faculty members of board in the Faculty of Architecture and Urban Development at the Iran University of Science and technology. Results are shown in the following tables. This experiment was conducted through a questionnaire.
Diagrams concerning the answers provided for question 4 (How much do architects use computers in each of the following cases, before the main stage of design during conceptual design) reveal how much architects use computers before entering the main stage of design, i.e. the conceptual design stage. Answerers believed that designers make most use of computers before starting designing and sketching. So computers play the greatest role at this stage and help architects to present their ideas the best way possible. In the next stage (i.e. before starting to design), computers can be

of great help in showing functions. Instructors have also judged their influence as very high. Answerers believed that the skill of drawing diagrams by computers at the stage of conceptual design is high. It is interesting that they have evaluated the help of computers in drawing sketches as low or even nothing and diagrams show that computers are of little help in drawing sketches.

Tab. 1. Answers to question 4 (Mozaffar & Khakzand, 2007)

Question 4	Very low	Low	Medium	High	Very high
Drawing diagrams	1	1	0	10	4
Drawing sketches	6	2	0	5	1
Presenting functions	0	2	0	5	8
Presentation and rondo	0	1	0	4	10

In the answer to question 5 (How much do designers use media and the following tools in the design process), according to the diagrams below, concerning how much designers and architects use tools and media, it can be generally concluded that paper and pencil are still of great importance (which proves Lawson's idea). The use of hand has the highest position in design and architects make the best use of it in conveying concepts and ideas.

The results of this experiment showed that architect use paper and pencil quite a lot in the design process. After manual skill (i.e. the use of paper and pencil), the second important tool in media for architects are the "visual referents." Concerning visual referents, it has been proven that architects make a great use of them in making judgments to reach a conclusion. The next important uses of computers and software are colors and sketching tools. The instructors have also judged it high. (Mozaffar & Khakzand, 2007)

Tab. 2. Answers to question 5 (Mozaffar & Khakzand, 2007)

Question 5	Very low	Low	Medium	High	Very high
Paper and pen	0	0	0	6	9
Visual referents	0	1	0	9	4
Computer and software	2	4	0	6	3
Colors and other rondo tools	2	4	1	6	2

11. Discussion

Our approach, supporting creative design with shape based reminding, should be considered in the context of related studies of drawing, visual reasoning, and the role of metaphor and analogy in design.

Many designers tell stories about the role of analogy in design ideation. Denise Scott Brown quoted in Lawson's "Design in Mind" says: "Analogy is there all the time in our thinking".

Anthony Antoniadis says "We all perform metaphoric acts whenever we... attempt to 'see' a subject (concept or object) as if it were something else.... in the hope that by comparison or through extension we can illuminate our contemplated subject in a new way...." Broadbent (1973) describes Le Corbusier spending his lifetime "building up a store of analogies," his years of traveling and "his years of sketching being particularly fruitful" so "when faced with any design problem, an analogy pops out at precisely the right moment. He also suggests "we all have our stores of analogies, not perhaps as rich as Le Corbusier's but valuable nevertheless because they are personal."

Moreover, several books emphasize the importance of drawing and visual thinking in the creative design process. They provide examples of how architects develop designs through visual analogies and they suggest employing analogies while drawing, to inspire design. William Gordon's Semitics, a method for enabling creativity, identifies four types of analogy including symbolic, direct, personal and fantasy. Paul Laseau (1980) in his influential book, "Graphic Thinking for Architects and Designers" encourages designers to use analogy for discovery. He suggests that sources of analogies may be physical, organic, and cultural and he provides example drawings to illustrate Gordon's four types of analogy.

For example, by symbolic analogy, a pitcher is like a house, both are containers. By direct analogy, a house with shade and air movement is like a tree. A house sited below the crest of a hill where a person might choose a place to rest is a personal analogy. A house that opens and closes like a tulip is a fantasy analogy. Drawing plays an important role in design thinking. For example, Michael Graves in "The Necessity for Drawing" argues that drawing is central in architectural design and he identifies various functions that drawing fulfills. Graves explains that a "referential sketch....is a shorthand reference ... which has the power to develop into a more fully elaborated composition when remembered and combined with other themes.... [It] is a metaphorical base which may be used, transformed, or otherwise engaged in a later composition." Robert Oxman (1995) points out, "In sketching, we frequently see the designer referencing an analogy as a form of 'stepping outside of the limitations of the design task environment'."

Oxman sees the designer sketching to explore an analogy, thereby restating the design problem before returning to develop the design.

Design research studies also support these designers' introspective observations on visual thinking in design process. For example, in "Design Thinking" Peter Rowe (1987) discusses analogy in design, saying "...initial design ideas appropriated from outside the immediate context of a specific problem are often highly influential in the making of design proposals." He identifies several kinds of analogies or as he puts it, 'solution images' that designers use as heuristics to constrain design problem spaces. Closest to this work is Rowe's 'literal analogy', which "involves borrowing known or found formgiving constructs as a point of departure for structuring a design problem." However,

Rowe merely identifies various types of analogy and gives examples, but does not suggest how analogy functions in design thinking.
Research on visual thinking also sheds light on how drawing facilitates design development. Schön, for example, sees designing as a ‘conversation' between the designer and the materials of design (the sketch, the drawing) in which a designer engages in various 'kinds of seeing'. The designer sees the visual marks she has made on paper, sees that these marks have some qualities or characteristics has previously learned to recognize, and may see the form of the marks as one or another gestalt. In another example, Laseau (1980) says "the graphic thinking sketches which architects have used provide evidence for analogy-taking in their Design process. Often these sketches are small in order to pursue many different analogies on the same piece of paper...This permits the designer to work loosely and entertain all sorts of ideas; original trains of thought are recorded and can be returned to at will. Combining images derived from sketches can also generate further variations."

12. Conclusion

Authors presented a convincing argument for the further study of design methods both in practice and the theory. However, to conduct a meaningful study of the design process, the paper suggest (like Rowe, 1987) that it is first necessary to investigate the normative positions which guide the production of content.
Only then can studies and theories of design thinking be appreciated fully. The concepts of what is "good" design must be separated from what are the "right" kinds of design practices. Otherwise, any arguments will become circular and meaningless when "good" becomes defined in terms of what is "right".
In research into design thinking as a dynamic cognitive process, the paper points towards some important new trends.
Thus, research into creative cognition and studies of cooperative creativity and computational systems for enhancing human creativity were cited.
Furthermore, the result of some experiments described the thinking of an individual in detail. We can conduct the experiment for observing the conversion process, after defining a design as the conversion process from language to a form, in order to catch an individual thinking process. The knowledge of that research was expressed as a thinking process model.
The representation of design thinking is indispensable to the design of creativity support computational systems.

- Referential Interpretation

Referential interpretation is introspective in its evaluation of architecture, interested in its own constituent elements. With a goal of creating its own language with which meaningful interpretation and expression can be conducted.

- Meaningful Interpretation

Referential interpretation faces several problems if it is to satisfy the requirement that, buildings be generally understandable. An obvious one stemming from the work on formal languages within architecture is the private nature of the resulting language.
Presented with a complex system such as a building, understanding of the whole can only be reached through understanding of the parts, but the full meaning of the parts cannot be understood with reference and some understanding of the whole. This paradox in the understanding of architecture is one which is evident in the public disillusionment with many examples of modern architecture. Though this is not a new phenomenon, it has been observed that it often takes time for new developments in the language of architecture to be fully understood and appreciated.
Architecture often develops a life of it's own outside of its original intentions. Each spectator brings his own interpretation to the work, which asks the question of whether there is any lasting meaning? Of course each spectator within a society also shares a common cultural background. Architecture must allow for the interpretations which will be devised for its products, once they are placed in its cultural setting.
Architecture is therefore susceptible to changes in culture, society and technology. It must respond to these changes without severing links with its historical legacy. The use of language itself is subject to discoveries outside the bounds of architecture. One example is the development of the concepts of hyperspaces and virtual realities which provide new avenues for investigation into the use of language in architecture. Science often has a deep effect upon the way we view the world, architecture must adapt to these changing approaches in order to remain relevant.
It appears to be essential to communicate with universities, active in the field of Design in order to achieve efficient results in Design thinking process.

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