Different predispositions of design and scientific thinking

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Abstract
The important role of design in HCI is providing design thinking to support scientific thinking especially for generating novel ideas in the concept forming stage. However, why couldn't scientific thinking generate novel ideas by itself and need the assistance of design thinking in HCI research is an interesting problem. In this paper, we conduct two experiments for this problem. We assume representation is a reliable evidence for human thinking. By studying representations, we can understand process of human thinking. We propose a classification table as our coding schemes for analyzing representations. This classification is based on observation of Leonardo da Vinci's manuscripts and correlation between the former and Buchana's ideas. Finally, we assure the need of design thinking when dealing with a problem in terms of generating novel ideas. We also prove that those characteristics of design thinking that scientific thinking lacks can benefit searching for novelty such as reframing problems and inventing oriented problem solving. We finally propose the idea that the type of a problem is not rigid but a predisposition resulted from design or scientific thinking.

INTRODUCTION
After the discussion during 1980s, where researchers sought to recover the crucial role of design in the applied science fields but nothing had been dramatically changed so far [19], Human Computer Interaction (HCI) field originated from Computer Science is reconsidering this issue due to encountering many design behaviors in their research [4, 5, 6]. Some researchers indicate that design is used to service HCI research because more and more novel artifacts are produced by cooperating with designers as research targets, tools and even results [8, 9, 11]. Based on this, plenty of design knowledge related to human factor [1], aesthetic principle [7, 14] and design process [12] are needed and introduced to the field.

Others observed that the value of design in HCI is its novel ideas that are from diverse approaches and leads to surprising results. These results are hard to be achieved by conventional engineering process [13, 20]. Furthermore, in order to realize innovative ideas resulted from design, researcher has to give up original technological hypothesis and to develop new technologies to fulfill new requirements. Design in HCI, instead of providing specific knowledge, surface structure and appearance decoration, is further to envision innovative possibility and technological opportunity [21].

Basically, it is generally recognized that HCI research mostly relies on scientific thinking [2]; whereas, design mainly results from design thinking [19]. Thus, based on above, the important role of design in HCI is providing design thinking to support scientific thinking especially for generating novel ideas in the concept forming stage. However, why couldn't scientific thinking produce novel ideas by itself and need the assistance of design thinking in HCI research? This is the research problem of this paper. The objective of this research is, first of all, to assure whether scientific thinking does need the assistance of design thinking for novelty/creativity, and then to discover the key features resulting in the differences between design thinking and scientific thinking. Finally, we can identify the role of design in the HCI field.

ILL-STRUCTURED VS. WICKED

Based on Simon's idea, our everyday problem can be divided into two sets: well-structured and ill-structured. An ill-structured problem can be solvable when it is decomposed into well-structured problems. Those well structured problems have clear initial states and goals, and solutions for them are reliable knowledge [2, 19]. Rittel propose a parallel idea including tame and wicked. A tame problem is similar to well structured problem; whereas a wicked problem is different from an ill structured one. The difference is that a wicked problem couldn't be decomposed into tame problems. The way to solve a wicked problem is to formulate this problem continuously at different levels related to diverse domains. Once the problem is well formulated, the solution is conceived at the same time [15].

CATEGORY VS. PLACEMENT

Buchana adopts concepts of "placement" and "category" to further explain the difference between ill-defined and wicked. He mentioned "Categories have fixed meanings that are accepted within the framework of a theory or a philosophy, and serve as the basis for analyzing what already exists. Placements have boundaries to shape and constrain meaning, but are not rigidly fixed and determinate." In his opinion, Simon's method which decomposes an ill structured problem into well structured ones related to categories is to discover solutions in some sense already known. However, Rittel's method looking for placements for a wicked problem is much more like invention of solutions yet unknown. For him, treating a problem as wicked will conceive more creative solutions than as ill-defined [3].

REPRESENTATION VS. THINKING

Representation plays an important role in both design thinking and scientific thinking. There are many research results about the role of representation in design thinking. The famous concepts of "seeing-moving-seeing" [17], "seeing as" [10], "seeing that" [10], and "reflection in action" [18] indicate that the dialogue between representation and designer is essential for thinking. In detail, representation not only provides ways to visualize ambiguous ideas, it stimulates designers to generate more ideas by observing previous one. Some intuitions are also emerged during representing. On the other hand, scientific thinking relies on representation as well. For scientist and engineer, representation is much like the protocol of communicating knowledge with themselves and others. They generally reason ideas through predefined symbols which follow specific operational rules.

ASSUMPTIONS

Based on these fundamental concepts described above, we propose three assumptions as bases for this research. First of all, representation is a reliable evidence for human thinking. By studying representations, we can understand process of human thinking. Second, a problem solver will acquire more novel answers by looking for placements rather than by finding categories. Last, reliable knowledge from categories is for solving an ill-structure problem; whereas, inventing ideas by placements is strategy for a wicked problem.

METHODOLOGY AND STEPS

This research is consisted of four parts. In part one, a classification table is proposed. This table is based on observation of Leonardo da Vinci's manuscripts and correlation between the former and Buchana's ideas. In part two, a hypothesis is suggested: what make design thinking and scientific thinking different are amount, order and composition of thinking elements. In part three, two experiments are conducted. Subject A in experiment one is with design background and subject B in experiment two is with science background. They are given an identical problem-solving task to deal with. The purpose of both experiments is to acquire representations of thinking. After these two experiments, the forth part of the method is to analyze the recorded results.

Classification Table

Leonardo da Vinci is recognized as an inventor equipping both design thinking and scientific thinking. After reviewing images from his manuscripts focusing on his inventions instead of art creations [16], we found that his representations can be generally recognized as three groups: text, symbol, and sketch. Text is written language, symbol is abstraction of idea, and sketch is visualization of image.

Text can be further divided into explanation and specification. Explanations are expressions of da Vinci's new ideas while specifications are about concepts borrowed from somewhere or his own previous solutions. Diagrams and formulas consisting of symbols are two common types representing abstract ideas and their relations. Diagrams are his own speculated relations; whereas, formulas are reliable relations. There are also two types of sketches; one called inference which is visualization of his invented idea, the other called reference recognized as something been existed such as plants, creatures, and artifacts.

Finally, we relate our previous subgroups of text, symbol, and sketch to Bachana's ideas of placement and category and create the table below. Obviously, explanation, diagram, and inference in the row of "Placement" match the idea of something not rigid; whereas, specification, formula, and reference for "Category" are about expressions of reliable knowledge (Table 1).

	Text	**Symbol**	**Sketch**
Placement	Explanation	Diagram	Inference
Category	Specification	Formula	Reference

Table 1. Classification of representations

Hypothesis

The major objective of this research is to discover the key features resulting in the difference between design thinking and scientific thinking in the early stage of solving a problem. Our hypothesis is that when a designer and an engineer deal with an identical problem, the amount, order and composition of thinking elements will be different. These

cause the different outcomes of design thinking and scientific thinking in terms of novelty/creativity.

Experiments

We conduct two experiments to collect representations of thinking elements. In order to compare design thinking and scientific thinking, we select two subjects, one is with design background, and the other is with science background, to approach the same problem. We assert that a designer mainly performs design thinking while an engineer mostly thinks scientifically, even though we believe that both design thinking and scientific thinking more or less coexist in their thinking processes as well.
We intentionally design a broad question instead of specifying it as a design or a scientific problem to focus on studying the problem solving strategies of subjects. Subjects are asked to generate ideas in any format. During the 35 minutes experiment, the subject is prohibited to be interrupted and a short interview is conducted after the experiment to assure the designer's real intentions and ideas. Detail specifications of these two experiments are listed below.

Experiment one: how does a designer solve a problem?

- Subject A: A 28 years old designer who has a Master of Architecture degree from National Tainan Art University and one year professional experience.
- Problem: How to improve long distance communication?
- Tools: A pencil and A3 format papers
- Process: Subject A is asked to generate ideas by only using provided tools. No specific amount of idea and format of representation are asked. The only thing required is to "record" their ideas visually during the process as complete as possible.
- Time: This research focus on comparing design thinking and scientific thinking in the concept forming stage, hence, we limit the duration of experiment within 35 minutes.
- Recording process: During the experiment, Subject A is recorded by video recorder. A digital camera is used to record the whole drawing process. After the experiment, Subject A is asked to briefly describe his thinking process in terms of intentions and ideas.

Experiment two: how does an engineer solve a problem?

- Subject B: A 28 years old engineer who has a Master of Software Engineering degree from Carnegie Mellon University and has one year professional experience.
- Problem: The same as experiment one.
- Tools: The same as experiment one.
- Process: The same as experiment one.
- Time: The same as experiment one.

Analysis

The major analytical data of this research is the visual representations recorded from experiment one and two. Two coding schemes are adopted for analysis. One is T-Sy-Sk which is a macro perspective; whereas the other is TE-TS-SyD-SyF-SkI-SkR for a micro perspective. The macro one is to discuss the shift between representations while the

micro one is for detail comparison within a specific representation. The detail clarifications for coding symbols are as below (Table 2).

Coding schema	Clarification
T-Sy-Sk	T: text Sy: symbol Sk: sketch
TE-TS-SyD-SyF-SkI-SkR	TE: explanation TS: specification SyD: Diagram SyF: Formula SkI: inferential SkR: referential

Table 2. Clarification of coding schemes

Roughly, within the effective 33 minutes, subject A uses the initial 20 minutes for creating symbols along with texts, the next 10 minutes for drawing sketches as parts of symbols, the next 1 minutes for writing texts as part of symbols and the last minutes for drawing sketches as parts of symbols again. Subject B uses the initial 4 minutes for creating symbols along with texts, the next 4 minutes for only writing text, the next 20 minutes for drawing sketches belonged to diagrams and writing text as parts of symbols alternately, and the last 5 minutes for writing texts belonged to diagrams. The recorded drawings are as below (Figure 1, Figure 2).

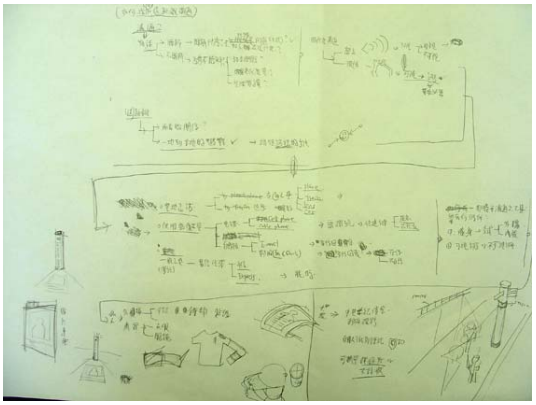

Figure 1. The result of experiment one

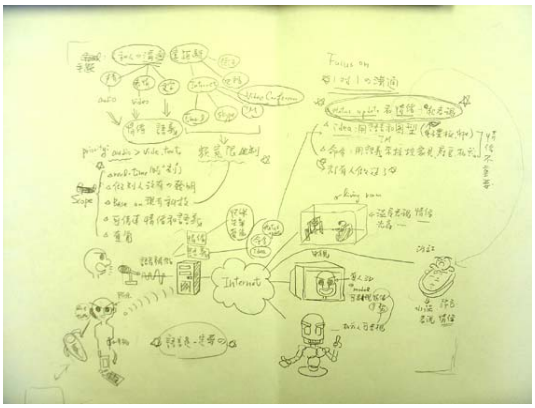

Figure 2. The result of experiment two

DISCUSSION

In the final coding results, we use two symbols, real dots and hollow dots, to distinguish different representational types happened at the same time. Real dot is for major activities and hollow dot is for minor activities. For example, in the initial 20 minutes of experiment one, subject A is making a big diagram (major) consisted of texts (minor). In

the following 10 minutes, subject A is drawing sketches (major) but these sketches are recognized to be part of a diagram (minor). When calculating amounts of times, we put equal weight for major and minor elements to enlarge the differences. Hence, the total amount will larger than 33 minutes.

Amount

We calculate the amount of time of making different representations and find out that, for placement, subject A spends 52 minutes while subject B spends 30 minutes. For category, subject A spends 12 minutes while subject B spends 25minutes. It is clear that subject A with design thinking does spend more time on placement than subject B with scientific thinking, although both of them spend more time on placement than category. The amount of time subject A spending on placement is far more than on category, while subject B spends almost equal amount of time on both placement and category (Table 3).

	Subject A	Subject B
TE	11	5
TS	10	13
SyD	32	23
SyF	0	0
SkI	9	2
SkR	2	12

	Subject A	Subject B
Placement	52	30
Category	12	25

Table 3. The statistics of experiments

Order

When looking at these two coding results of T-Sy-Sk, we generally find that the orders of generating different representations are different between design thinking and scientific thinking. However, after taking out 5^{th} to 8^{th} and 28^{th} to 32^{nd} minute activities of subject B, the patterns of subject A and subject B are actually similar. In detail, they both draw symbols with texts before sketches as part of symbols. The reason for taking out parts of subject B's data is that these data are just duplications in different representations. For example, during 5^{th} to 8^{th} subject B summarizes what he did in previous four minutes in text format (Figure 3).

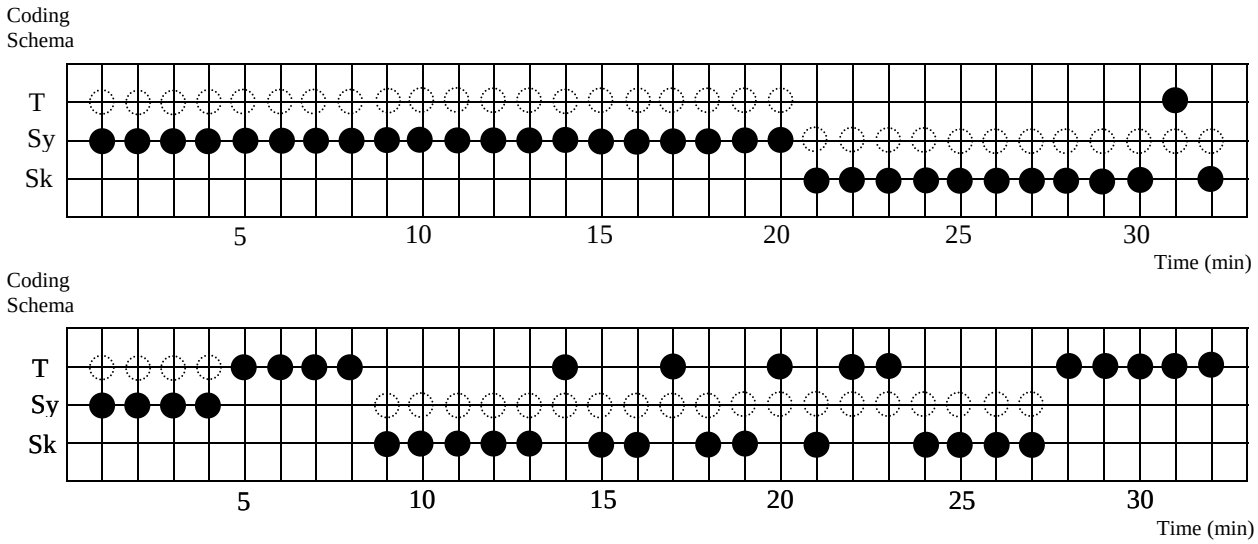

Figure 3. The result of coding with T-Sy-Sk.

Composition

When comparing 1st to 20th minute of subject A and 1st to 4th minute of subject B, neglecting the difference of duration, we find out that subject B misses the part of SyD+TE while subject A and B both have SyD+TS. During 21st to 32nd minute of subject A and 9th to 27th minute of subject B, Subject A has more SkI+SyD while subject B has more SkR+SyD. However, subject A has less TS+SyD than subject while both of them have the same amount of TE+SyD (Figure 4).

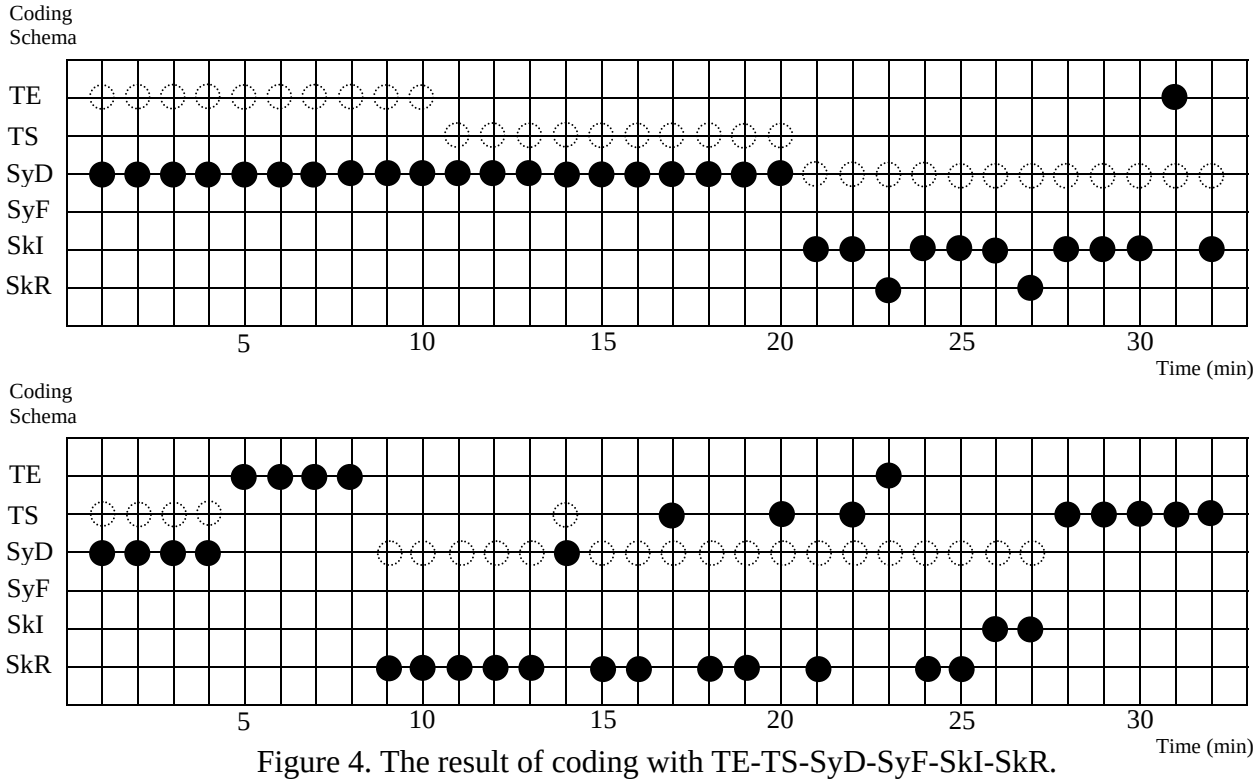

Figure 4. The result of coding with TE-TS-SyD-SyF-SkI-SkR.

CONCLUSION

After only discussing data without attaching any meanings on them, we are going to derive some phenomena for predispositions of design thinking and scientific thinking when subjects approaching an identical problem.

Design thinking can assist scientific think for novelty

Based on the analysis of amount, design thinking refers less reliable knowledge and creating more its own ideas; whereas, scientific thinking refers similar amounts of knowledge from both sources. It shows that scientific thinking also generates novel ideas based on Buchana's idea. However, design thinking does have stronger predisposition of generating novel ideas than scientific thinking. Hence, involving design thinking in HCI research process does equip assistance of novelty.

Abstraction goes before visualization for both design and scientific thinking

Based on the analysis of order, when tackling a problem, both subjects use text diagrams before sketches. This predisposition exists in both design and scientific thinking. It indicates that both subjects deal with abstract meanings before visual appearances when approaching a problem. Although mostly relying on visual feedbacks to generate ideas, design thinking still relies on dealing with abstract meaning and relations before considering the potential forms when approaching a new problem.

Design thinking provides a function of reframing problem

Based on the analysis of composition, scientific thinking misses the part of SyD+TE while design thinking spends almost 10 minutes for it. In Detail, during these 10 minutes, designer reframes problem by asking questions continuously. These questions are organized into a diagram to check whether some other questions miss. Without this part, scientific thinking directly specifies strategies for this problem by using SyD+TS during 1^{st} to 4^{th} minute and explains these strategies during 5^{th} to 8^{th} minutes. Design thinking has the characteristic of reframing problems which can assist scientific thinking.

Design thinking is more about inventing ideas than scientific thinking

Again, based on composition analysis, design thinking has more SyD+SkI than scientific thinking. It indicates that a designer is capable of refer something irrelevant from other domain to create new ideas. On the contrary, scientific thinking generates more SyD+SkR than design thinking. In other words, an engineer always refers to some existing products as possible solutions for the problem. Design thinking is about invention yet known ideas while scientific thinking is integrating known concepts.

Ill structured and wicked are predispositions not definitions

Whether a problem is ill structure or wicked depends the way a problem solver treats it. In other words, a problem couldn't be defined as ill structured or wicked until the problem solver decides what strategies to adopt. These strategies are the sources of solutions. Where are they from, categories or placements? Even though the problem solver assures sources of solution, we still can't assert a problem is ill structure or wicked due to both strategies are more or less involve in both type of thinking. Ill structured problem or wicked problem is a predisposition not a definition.

In this paper, we conduct two experiments to assure the need of design thinking when dealing with a problem in terms of generating novel ideas. We also prove that those characteristics of design thinking that scientific thinking lacks can benefit searching for novelty. We finally propose the idea that the type of a problem is not rigid but a predisposition resulted from design or scientific thinking.

However, this research is basically a protocol analysis and the reliability of coding schemes and results need to be further tested by adopting advanced methodologies. Also, the representability of our subjects should be further challenged. These are limitations of this research and also goals for our future study.

Reference

1. Alonso, M.B., D.V. Keyson, and C.C.M. Hummels. Squeeze, rock, and roll; can tangible interaction with affective products support stress reduction? *Proc. TEI2008*, ACM Press (2008), 105-108.
2. An Introduction to Science: Scientific Thinking and the Scientific Method. http://www.freeinquiry.com/intro-to-sci.html.
3. Buchanan, R. Wicked Problem in Design Thinking. *Design Issues 17, 4* (1999), 3-23.
4. Coyne, R. *Designing Information Technology in the Postmodern Age*. MIT Press, Cambridge MA, 1995.
5. Fallman, D. Design-oriented Human-Computer Interaction. *Proc.CHI2003*, ACM Press (2003), 225-232.
6. Fallman, D. Why Research-Oriented Design Isn't Design-Oriented Research. *Proc. NordiCHI2005*, Umera Institute of Design Press (2005).
7. Fogarty, J., Forlizzi, J. and Hudson, S.E. Aesthetic information collages: generating decorative displays that contain information. *Proc. UIST2001*, ACM Press (2001), 141-150.
8. Gaver, W.W., et al. The drift table: designing for ludic engagement. *Proc.CHI2004*, ACM Press (2004), 885-900.
9. Gemperle, F., et al. The Hug: a new form for communication. *Proc. DUX2003*, ACM Press (2003), 1-4.
10. Goldschmidt, G. Visual displays for design: imagery, analogy and databases of visual images, *Visual Databases in Architecture: Recent Advances in Design and Decision making* (1995), 53-76.
11. Hurst, A., et al., The sense lounger: establishing a ubicomp beachhead in elders' homes. *Proc. CHI2005*, ACM Press (2005), 1467-1470.
12. Lim, Y.-K., et al., Interaction gestalt and the design of aesthetic interactions. *Proc. DPPI2007*, ACM Press (2007), 239-254.
13. Lowgren, J. Applying design methodology to software development. Proc. DIS1995, ACM Press (1995), 87-95.
14. Peterson, M.G., et al. Aesthetic Interaction: a pragmatist's aesthetics of interactive systems. *Proc. DIS2004*, ACM Press (2004), 269-276.
15. Rittel, H.W.J., Webber, M.M. Dilemmas in a General Theory of Planning. *Policy Sciences 4, 2* (1973), 155-166.
16. Rosheim, M.E. *Leonardo's Lost Robots*. Springer, Berlin, Germany, 2006.
17. Schon, D.A., Wiggins, G. Kinds of seeing and their structures in designing. *Design Study 13*, (1992), 135-156.
18. Schon, D.A. *The reflective Practitioner: How professionals think in action.* Temple Smith, London, 1983.

19. Simon, H. A. *The Science of Artificial*. MIT Press, MA, USA, 1996.
20. Wolf, T.V., et al. Dispelling "design" as the black art of CHI. *Proc. CHI2006*, ACM Press (2006), 521-530.
21. Zimmerman, J., J. Forlizzi, and S. Evenson, Research through design as a method for interaction design research in HCI. *Proc. CHI2007*, ACM Press (2007), 493-502.