

# A STUDY ON THE ROLES OF THE THINKING STYLES IN THE DESIGN BEHAVIOURS

Shyi-Jeng Tsai, Pei-Fen Chang, Hsiu-Fen Lin, and Je-Liang Yeh

National Central University, Taiwan

## ABSTRACT

The aim of the research is to find out whether the behaviours of *novice* designers are in association with their thinking styles, and which roles the thinking styles play in design. Based on the Sternberg's mental self-government theory for thinking styles, the study focused on the following thinking styles: *legislative-executive-judicial*, *global-local*, *internal-external* and *liberal-conservative*. 26 students from the course "product design methods and practice" at National Central University, Taiwan, are all novices in design and participated the research as subjects of experiments. Before conducting the experimental tests, the students were asked to take the questionnaire tests to identify their spatial ability and thinking style. The relation between thinking style and design behaviour were investigated through two experiments, "group-effect test" and "solo-test". Two issues were discussed in the tests – How will designers be influenced by external resources while in individual design work? And what will be the performance of the designers having different thinking styles while facing to the same task? In each test the students must solve the problem using sketch in a given scene. From the analysis results of the tests, the prognoses on the characteristic design behaviours of the designers with the different thinking styles before test were verified. We also find that some working behaviours of designers can be indeed explained based on the Sternberg's theory.

*Keywords: Product Design, Thinking Styles, Sternberg's Mental Self-Government Theory, Design Behaviours*

## 1 INTRODUCTION

Through several years of experiences in teaching creativity, design and implementation at the university, we observed common learning difficulties to students. Due to insufficient capability in conceptualization and implementation, students encounter setbacks in realizing their creative ideas. The setbacks depressed their ambitious creativity and even kept them from multi facet problem solving attempt [1].

From the point of view of learning, the students as novices are generally not taught in which situations and rules may be violated, and they lack a coherent sense of the overall task. They judge their performance mainly by how well they follow learned rules. There are three key principles characterize novices' knowledge [2]:

- Novices tend to solve problems guided by literal and superficial principles.
- Novices' undifferentiated rule-following patterns reflect lack of a coherent understanding of the overall task.
- Novices are unable to separate relevant from irrelevant information with respect to the task at hand.

In order to overcome this hurdle, we should try to develop new teaching strategies addressing such common learning difficulties.

From the point of the procedural view, students with different learning styles will solve problems with different ways. Furthermore the different members of a design team, who have different competencies, responsibilities and interests, will judge the object of task also differently. One of the influence factors on the differences mentioned above is the "thinking style" of designers. This raises then a question – which roles does the thinking style play in their behaviour during designing products?

Thinking styles are the preferred ways of thinking, but not the abilities for problem solving. People may be identical in the abilities and yet have very different styles during solving problems. However,

someone may succeed and the other may fail in doing the same thing, although they have the same abilities. The key point for success is how to find compatibility between the thinking styles and the abilities [3]. Sternberg has established a concrete framework for thinking styles based on the mental self-government theory [3]. The framework is applied in many fields, especially in the educational research, to observe the human behaviours and to judge their performance. In the field of design, Hilton has used the framework to study the relation of thinking styles and the motivation of students of design degree [4]. As the authors know there is however no literature on the role of such thinking styles in design behaviours. In contrast, Dörner, Pahl [5] and Ehrlenspiel [6] opened a new research topic – human behaviours in design. Since then there are many contributions on this new research topic that can offer us to understand how designers perform in designing [7], [8], [9]. Because the relation between thinking styles and design behaviours is very complicated, we focused our attention on the roles of the thinking styles in the design behaviours of novices, not experts. The category of thinking styles developed by Sternberg was used in the research. Beyond it, the behaviours of student (novices) were observed through experiments in our study, because our interest is how to devise personalized teaching strategies and learning activities or sequences for our students.

## 2 THEORY ON THINKING STYLES

### 2.1 Sternberg's theory of mental self-government on the thinking styles

The idea of Sternberg's theory of mental self-government comes from the form of government. As the governments in the world are not coincidental, people think and do things also in different ways. Based on the theory, Sternberg classifies 13 different thinking styles according to the categories *function*, *form*, *level*, *scope* and *leaning*. He had also developed a stylistic self-assessment correspondingly. The brief outline on the Sternberg's thinking styles are listed in Table 1.

### 2.2 Prediction of the designer's behaviours based on the thinking styles

From the points of view of knowledge, methodology and creativity, Pahl & Beitz summarize the characteristics of good problem solvers (designers) in [5]. Based on those observations from psychological studies, we may predict how the designers with the different thinking styles mentioned below solve their problems.

- *Legislative* designers like to create their own rules and have thus a tendency of creative thinking. However, they may not solve a complicate problem effectively, when they have not enough knowledge for solving or analyzing the problem. In contrast to *legislative* designers, designers with *executive* style desire to follow the existing and structured rules, they have therefore the sufficient knowledge to solve problems. Of course they lack motivation to apply creativity to solve some problems with ambiguous conditions. Designers with *judicial* style prefer to analyze and evaluate creative ideas in a design team. They can give good suggestions for task in a team.
- Most designers with *hierarchic* style can solve problems systematically. This style meets the requirement of the modern design methodology. *Monarchic* designers tend to focus on the thing or the problem that they are dealing with. They may also solve problems creatively. It is not suitable, however, to assign *oligarchic* designers to solve a complicate and ambiguous problem, because they can not decide the priorities of the objectives of the task. The designers with *anarchic* style are perhaps the worst to formulate and understand the task or the problem, but they can also do their best by trial and error.
- Designers with *global* style can analyze the problem with an overall view and give suitable and effective solving strategies. However, an ideal problem solving behaviour also needs the *local* thinking style to take care of the details of conceptualizing and implementing.
- Under consideration of the individual design works, there is no difference between *internal* and *external* designers. The *external* designers, however, tend to integrate the ideas or concepts of other people into their solution. Designers with an *internal* style, on the other hand, perform as introverted and are persistent to change their ideas.
- The designers with *conservative* style tend to solve problems following the existing solutions or the past experience, and don't like problems that arise while in doing their tasks. Conventional solutions are therefore expected to be found. On the other hand, the *liberal* designers tend to try any possible solutions that are not traditional and even don't exist. They like also to challenge the problems even in an ambiguous situation.

Table 1. Brief outline on the thinking styles [3]

Categories	Styles	Characteristics
Functions	Legislative	They like to do things following their own ways and especially prefer the creative or innovative planning based activities
	Executive	They like to do things following the unambiguous rules and prefer to solve pre-structured problems. They are typical implementer.
	Judicial	They like to evaluate rules and procedures and prefer such problems in which existing ideas can be analyzed and evaluated.
Forms	Monarchic	They are single-minded and don't like be interrupted while in solving a problem. They will not have great interests in what is not related to the thing that they like to do.
	Hierarchic	They tend to set priorities of goals under consideration of the need. They recognize the need to view or solve problems from a number of aspects.
	Oligarchic	They like to do more than one thing within the same time. But they tend to be motivated by several competing goals of equal perceived importance.
	Anarchic	They have difficulties in sorting out a potpourri of goals and needs. Their approach to solve problems seems random and not organized.
Levels	Global	They prefer to deal with relatively large and abstract issue, and don't like details. In other words, they prefer to see the forest rather than the trees.
	Local	They like to solve concrete problems requiring working with details, i.e. they prefer to see the trees rather than the forest.
Scopes	Internal	They are concerned with internal affairs and tend to be introverted and task oriented. They prefer to work alone and like to apply their intelligence to things or ideas in isolation from other people.
	External	They are socially sensitive and like to work with other people.
Leanings	Liberal	They like to go beyond existing rules and procedures to seek to maximize change in problem solving. They are also comfortable with ambiguous situations, and prefer some degree of unfamiliarity in their design task.
	Conservative	They like to adhere to existing rules and procedures to solve problems in a structured or relatively predictable environment. When such structure does not exist, they may attempt to create it.

### 3 METHOD

Two types of empirical studies were conducted in the research to analyze the roles of the thinking styles: (a) the questionnaire study and (b) the experimental study. Through the questionnaire study the thinking styles and the spatial ability of the subjects were indicated and used furthermore as analysis basis for the experimental study. The subjects of the empirical studies were the participants of the course "Product Design Methods and Practice" in the academic year 2005 and 2006 at the National Central University, Taiwan. There were in total 26 students consisting of 3 undergraduates and 23 graduates, also including 3 females. It was identified that all the students are novice in product design. Because this course is elective, the students can be regarded as having certain good motivation.

#### 3.1 Questionnaire study

Two kinds of questionnaires were used as tools for measuring the thinking style and the spatial ability of the subjects respectively.

**Thinking styles measurement**

To measure the thinking styles of the subjects we used a translated questionnaire from the “*Self-Assessment Inventory for Thinking Styles*” developed by Sternberg-Wagner [3]. The students wrote the questionnaire with 65 statements for about 15~25 minutes. In order to reflect the actual situation the meaning of the self-assessment for thinking style was explained to the students before they wrote the questionnaire.

**Spatial skill measurement**

The spatial ability is a basic index to indicate the design quality of a designer. The students were therefore asked to take a spatial ability test for about 45 minutes. The spatial ability test consists of the spatial relation test, the spatial orientation test [10] and the spatial organization test [11], as the sample shown in Figure 1.

**I. Spatial Relation Test: Which objects A~D can be unfolded as the right sheet?**

No		A	B	C	D	None	I don't know
1							

**II. Spatial Orientation Test: In the following questions the cube X has different symbols on the six planes. Which view (A~F) is correct if it is rotated?**  
*Note: The symbols on the cube X that are not shown in the question may appear in the view A~F after the cube is rotated.*

No		A	B	C	D	E	F	None	I don't know
1									

**III. Spatial Organization Test: There are 30 views in the following picture for description of 10 objects whereby view 1 to 10 is the front view, view 11 to 20 is the top view and view 21 to 30 is the side view, respectively. Please associate the numbers from the corresponding**

Front View		1		2
		6		7
Side View		11		12
		16		17
Side View		21		22
		26		27

Figure 1. Spatial ability test (sample)

### 3.2 Experimental study

To simplify the research, we focused the study on the roles of the thinking styles *legislative-executive-judicial*, *global-local*, *internal-external* and *liberal-conservative* in the design behaviours and were interested in the following questions:

- How will designers be influenced by external resources while in individual design work?
- What will be the performance of the designers having different thinking styles while facing to the same task?

The experiments were thus conducted in two stages, i.e. *group-effect* test and *solo-test* correspondingly. The subjects were also asked to write an after-test questionnaire after each test.

#### **Experiment I: Group effect test**

In the first stage the *gallery method* was used to explore the relation of the design behaviours to the corresponding thinking styles under the group effect. Especially the following thinking styles of designers are of interest to observe during they exchange their ideas with each other.

- Does the designer with *internal* or *external* style change his concept lightly under influence of the others?
- Is the thinking style *liberal-conservative* related to the solving behaviour of designers, i.e. a conventional or innovative solution?

The task for the test was to give an innovative design of stone thrower with human energy resource. The description of the task is shown in Figure 2. The reasons why selecting the stone thrower as the design objective are

- The students are familiar with the stone thrower (e.g. from the computer game).
- There are a variety of existing solutions for stone thrower, but an innovative solution is not easy to develop based on the conventional rules [12].

According to the procedure of the gallery method, only the first four steps were proceeded in the experiment, the last step “selection” was ignored. The procedures consists thus the following steps:

1. Introduction step: with duration 5 minutes. The design task and the corresponding requirements were explained to the students, if necessary, some questions asked by them were also answered.
2. Original idea generation step: with duration 15 minutes. The students proceeded to sketch their idea individually. They were prohibited from discussion with each other in this step.
3. Association step: with duration 15 minutes. While all their sketches were hung on the wall, the students could see and discuss these diverse ideas with each other.
4. Reversed idea generation step: with duration 15 minutes. The students developed an improved idea with the ideas and insights from the association step.

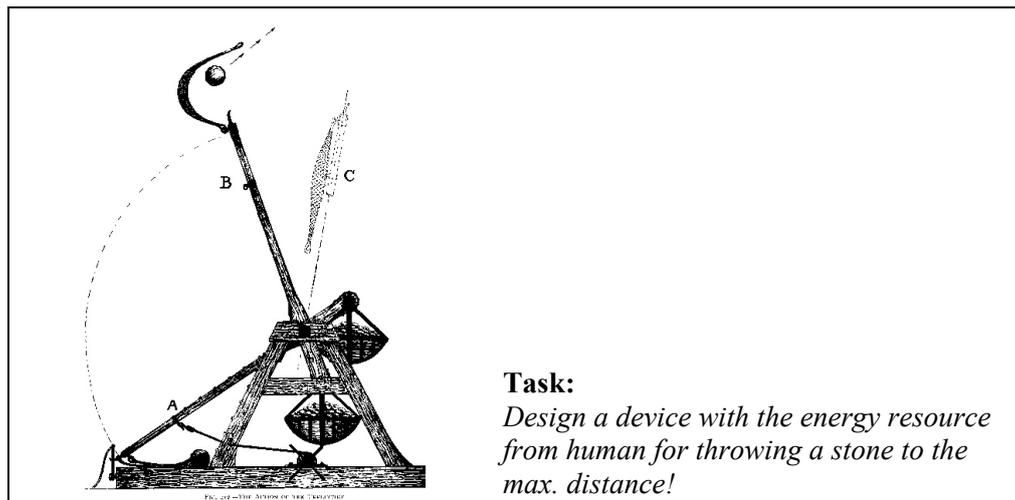


Figure 2. Task for the “group effect test”

#### **Experiment II: Solo-test**

The test in the second stage was a so-called “solo-test” whereby the students must give their improved designs for an existing one individually. The description of the task is illustrated in Figure 3. The task

was designed based on the idea that the corresponding thinking styles could be clearly found in the following behaviours under given conditions:

- Is there a significant relation between the thinking style *judicial* and the competency of the designer to evaluate an existing design?
- Does the designer solve the problem following the existing rules or the original design (i.e. the *executive* style) or based on the problem that the original design solves (i.e. the *legislative* type)?
- From viewpoint of the task definition, will the designer give more detailed and modified solutions according the original design (i.e. the *local* style) or will the designer focus on a larger picture and give a new design with additional functions (i.e. the *global* style).

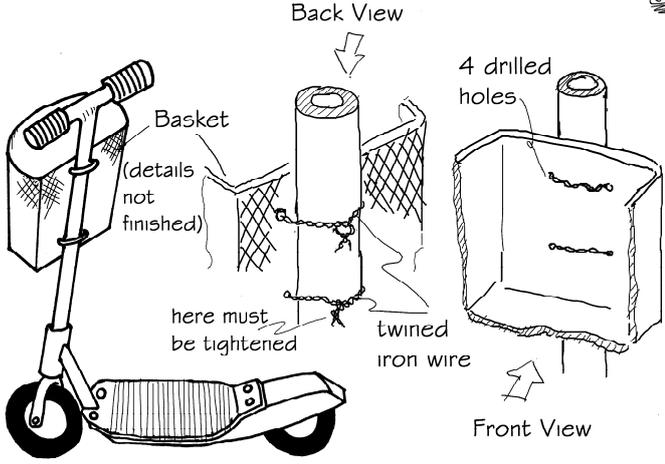
The duration of the test was about 60 minutes. The students were not allowable to discuss during the test.

**Task:**

For a design project John had an innovative idea for convenient shopping that a shopping basket is integrated in a *kick scooter*. In order to solve the fixing problem of the basket on the scooter, he sketched his principle solution as in the figure shown. John deemed it not only a simple design but also an economic one.

As his partner you receive now his sketch and also know that John doesn't have any other idea about the design of the new kick scooter besides fixing of the basket.

Please read his sketch carefully, and then finish the following issues for further discussion with John:



1. List the not appropriate design in the new scooter and also the corresponding resulted problems!
2. Give your improved design.

**Note:** You can give a new design for improvement including the new added functions.

Figure 3. Task for the solo-test

## 4. RESULTS AND DISCUSSIONS

Because the number of the subjects is not enough for statistical analysis, we studied only some unique or special cases, such that a rough correlation between the thinking styles and the design behaviours can be found as fundamental for further research. From the 26 subjects we selected 8 students for analysis. Their background and the measurement results (of the spatial ability and the thinking style) are shown in Table 2. The scale of the measurement for thinking style in the radar chart consists of six levels: very high, high, high middle, low middle, low and very low, representing the value from high to low correspondingly. The spatial ability, on the other hand, is illustrated in a column chart represented as percentage scale.

### 4.1 Group-effect test

The results of the group-effect test are summarized in Table 3. The most subjects claimed in the after-test questionnaire that they were indeed influenced by the others while improving their original ideas. However, the cross analysis with their sketches revealed that most of them didn't change their original ideas. From the viewpoint of thinking style, they tend to be more *internal* than *external*. For example, HSW has high *internal* style. In original idea generation step he has generated in total 8 variants, and after discussion with the others, the variant #8 was selected for further development of the detailed solution, Figure 4. Another example shows a different but interesting aspect. The subject CJT, who is also more *internal* than *external*, has changed his idea after surveying the sketches of other students, see Figure 5. Similar ideas of his modified design can be found in the designs of the others.

Table 2. Measurement results of the subjects

Thinking Styles	Spatial Abilities	Thinking Styles	Spatial Abilities
<b>CCH (male/graduate)</b>		<b>CJH (male/graduate)</b>	
<p><b>CCH</b></p>	<p><b>CCH</b></p>	<p><b>CJH</b></p>	<p><b>CJH</b></p>
<b>CJT (male/graduate)</b>		<b>CST (female/graduate)</b>	
<p><b>CJT</b></p>	<p><b>CJT</b></p>	<p><b>CST</b></p>	<p><b>CST</b></p>
<b>HCS (male/graduate)</b>		<b>HSW (male/graduate)</b>	
<p><b>HCS</b></p>	<p><b>HCS</b></p>	<p><b>HSW</b></p>	<p><b>HSW</b></p>
<b>HWM (male/graduate)</b>		<b>LYC (male/graduate)</b>	
<p><b>HWM</b></p>	<p><b>HWM</b></p>	<p><b>LYC</b></p>	<p><b>LYC</b></p>

On the other hand, the subject CST and LYC gave very different but very good solutions, and HSW gave many multi-variant solutions. It is apparent to find that they tend to go beyond existing design and to seek for possible change during solving the task with ambiguous conditions. All of them have a high middle or high *liberal* style.

Table 3. Summary of the results of the group effect test

Subject	Amount of ideas in Phase I	Changing Solution in Phase II	Self-assessment if the external influence exits	Comments
CCH	3	None	Yes	Continue to finish the original idea
CJH	7	None	Yes	Continue to develop two variants from the original ideas systematically
CJT	1	1	Yes	Change the original idea and give a new design with the idea initiated through the ideas of the other students
CST	3	None	Yes	Continue to finish the original ideas and 3 variants
HCS	3	None	Yes	Continue to finish the original idea and give detailed design
HSW	8	None	Yes	Continue to finish the original idea and give more detailed design
HWM	3	None	Yes	Continue to finish the original idea through integration of various design
LYC	3	None	Yes	Continue to finish the original idea through integration of various design

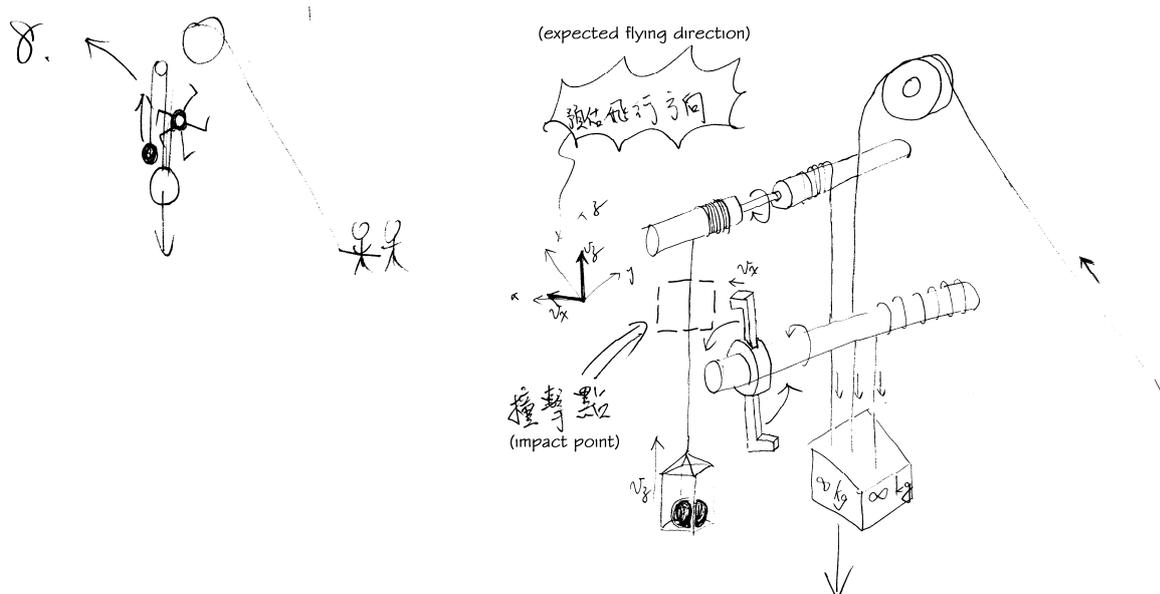


Figure 4. Change of the idea of HSW

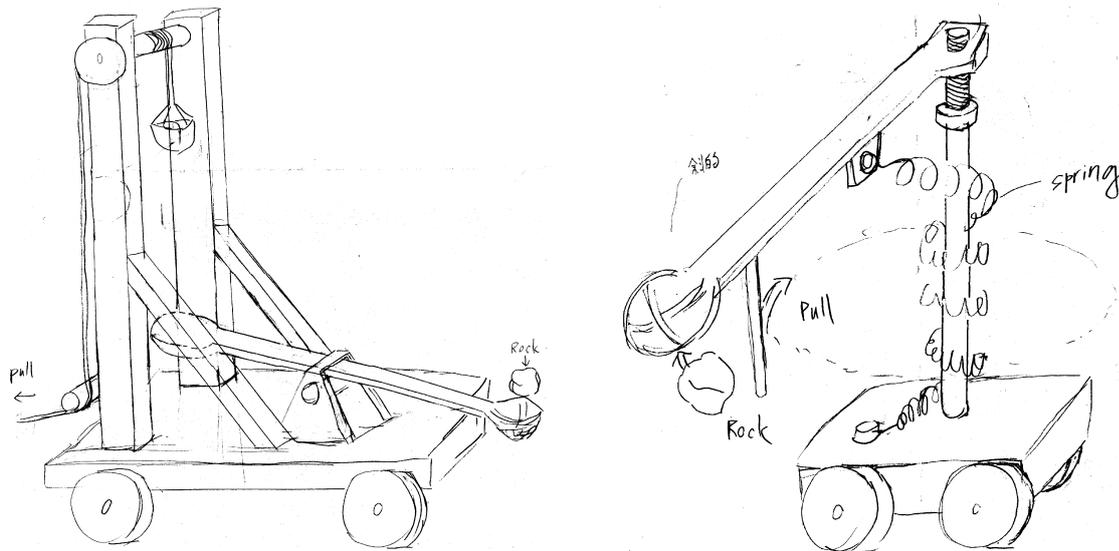


Figure 5. Change of the idea of CJT

#### 4.2 Solo-Test

From the results of the solo-test in Table 4, some interesting findings are listed in the following:

- CJH, LYC, HSW and HWM gave the most number for critiques for the original solution, while CJT and CST the least number. From the measurement result in Table 2, CJH, LYC and HSW tend to high or very high *judicial* style, and CJT, CST and HWM low or low middle *judicial* style. Besides HWM, the design behaviour “*evaluation of solutions*” of most of the subjects agrees with the thinking style *judicial*.
- HWM gave the most variants for improvement of the task. With respect to the details, however, his design doesn’t follow conventional rules. To a certain extent, HWM tends to have *legislative* style. In contrast to that, the influence of the existing rules can be found from the detail solutions of HSW (see Figure 6) and HSC. This behaviour corresponds to their *executive* style.
- From the point of view of detail design, LYC (see Figure 6) gave not only a new concept to shift the basket to the footboard, but also a very good and detailed design for his concept. On the other hand CJT (Figure 6) focused on the improving the fixing problem of the basket. His design shows not only a well detailed representation for fixing of the basket, but also the ergonomic consideration of the improved design. Both designers are attentive equally to be *global* and *local*, corresponding to both thinking styles in high or very high level.

Table 4. Summary of the results of the solo-test

Subj.	number of critiques	number of improvements	evaluation of concept representation	comments on the solutions
<b>CCH</b>	3	2	represented both in graphics and words; poor graphical representation	focus on the fixing design of the basket; conventional solutions
<b>CJH</b>	5	4	represented mainly in graphics; good graphical representation	solutions developed systematically
<b>CJT</b>	2	1	represented both in graphics and words; very good graphical representation	focus on the fixing problem of the basket
<b>HWM</b>	5	6	represented mainly in words; poor graphical representation	improvement items given from overall view; poor quality in detail design

Subj.	number of critiques	number of improvements	evaluation of concept representation	comments on the solutions
CST	2	4	represented both in graphics and words; adequate graphical representation	giving not only the solutions for the fixing problem of the basket, but also another idea to change the position of the basket on the scooter.
HCS	3	3	represented mainly in graphics; very good and clear graphical representation	focus on the fixing problem of the basket; using the existing principles mainly
HSW	5	1	represented both in graphics and words; very good and detailed graphical representation	considering the problem from global view by changing the position of the basket, not the original problem of fixing;
LYC	5	2	represented mainly in graphics; very good graphic representation	considering the problem with global view; many efforts on the details of the improved design.

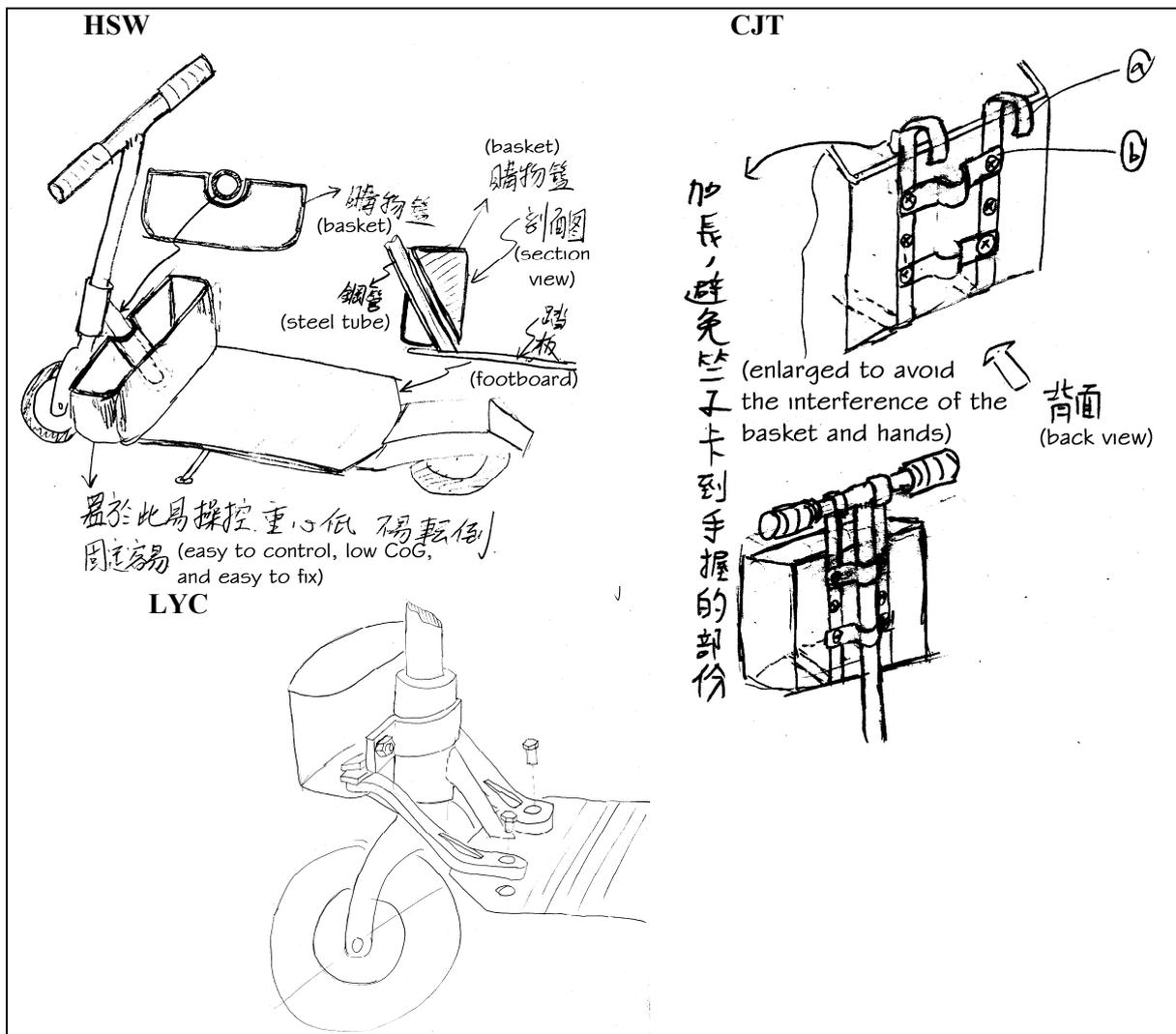


Figure 6. Sketches from the solo-test

## 5. CONCLUSIONS

This study investigated the roles of the thinking styles of novices on their design behaviour. Some observed behaviour of the novice designers in the study can be indeed explained and predicted based on the framework of Sternberg on thinking styles. From the analysis of the test results for the design behaviours of novices we might have the following conclusions:

- The designers with *internal* style tend to carry out their own ideas without influence of others.
- The designer with *liberal* style tends to give innovative solutions in comparison with those with *conservative* style.
- Most of the subjects with the thinking style *judicial* tend to behave very well to *evaluate the solutions*.
- The *legislative* designer gives more variants beyond the existing rules while the *executive* designer solves the problem following the existing rules.
- The *local* designer gives more detailed and modified solutions according the original design. In contrast, the *global* designer gives a new design with additional functions.
- An ideal designer who meets the characteristics of a methodologically trained designer should think both in the styles *legislative* and *judicial*, and/or both in the style *local* and *global*.

These results are very useful for us to develop the teaching strategies of the design courses. The thinking weakness of the students on the problem-solving can be therefore improved. However some questions still arises during the study. They are listed in the following and should be considered for further research on this topic:

- How designers are influenced by external resources cannot be absolutely identified. Some cases revealed that not only one thinking style (e.g. *internal-external*) but various styles play an important role for the design behaviour. The cross actions between the thinking styles are needed further to investigate.
- A significant bias was found in some self-assessment questionnaires of the students. They valued the statements in the questionnaire developed by Sternberg not according to their actual situations, but to their expectation. This phenomenon is often found by the Taiwanese students. A suitable questionnaire for thinking styles should be further designed.
- The relation between the thinking styles and design behaviours was analyzed based on the sketches of the students. The behaviours in the course of the test were not recorded and further analyzed. This leads to the lack of sufficient information for detailed analysis. The method video-recording for the design process should be applied in the future.
- This study was focused only on the design behaviours of novices, not on those of experts. The results of this study offer however a possibility for further research on the thinking styles of design experts. This topic should be conducted in the next stage based on the results and experience of this study.

## REFERENCES

- [1] Chen F.C., Yeh T.L. et al. Exploring the Portfolio Assessment of Novice Engineering Students Creativity, Design and Implementation Processes - Setback Episode Based Analysis, in Aung W., et al. (eds.), *Innovations 2005, World Innovations in Engineering Education and Research*, 2005, Chap 30, pp 363-380 (iNEER, Arlington, VA).
- [2] Bransford J., et. al. *How people learn*, 2000 (National Academy Press, Washington, DC).
- [3] Sternberg R.J. *Thinking Styles*, 1997 (Cambridge University Press, Cambridge).
- [4] Hilton K.H., A relationship between thinking styles and design degree student motivation, in *CLTAD Conference Enhancing Curricula*, RIBA, London, April 2002.
- [5] Pahl G. and Beitz W., *Konstruktionslehre. 4th Ed.*, 1997, pp. 58-67 (Springer Verlag, Berlin).
- [6] Ehrlenspiel K, *Integrierte Productentwicklung*, 1995 (Hanser, Munich)
- [7] Cross N, Christiaans H and Dorst K (Eds), *Analysing Design Activity*, 1996 (John Wiley & Sons, Chichester).
- [8] Frankenberger E., et al. (Eds), *Designers - the Key to Successful product development*, 1998 (Springer-Verlag, New York).
- [9] Lindemann, U. (Ed.), *Human behaviour in Design – individuals, teams, tools*. Springer-Verlag, Berlin, 2003.

- [10] Gittler, B., *3-D-Würfeltest. Verfahren zur Erfassung des räumlichen Vorstellungsvermögens*, 1990. (Beltz, Weinheim).
- [11] Hoischen, H., *Technical Drawing* (in German). 26th Ed., 1996 (Cornelsen Verlag, Berlin).
- [12] Tsai S.-J., Wu J.C. and Wang W.Y. Developing a Web-Based Tool for Engineering Design and Its Application. *Proceedings of the International Conference on Engineering Education 2002*, Manchester, August 2002.

Contact: S.-J. Tsai  
National Central University  
Department of Mechanical Engineering  
No. 300, Jhong-Da Road  
Jhong-Li City  
Taiwan  
Tel: +886-3-4267301  
Fax: +886-3-4254501  
E-mail: sjtsai@cc.ncu.edu.tw