The Bridge between Problems and Solutions in Design: Taking a Toddler's Case as an Example

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Abstract

Problem solving in Industrial Design is focused on the realization of ideas. At the end, the ideas are applied as practical design solutions for product development. Designers generate ideas to solve problems based on their past experiences and creative thinking. However, there has been a gap between problem identification and solution generation within the design process. The bridge between problems and solutions is not clear yet. Thus, it is reasonable to study how designers find solutions.

The purposes of this research include (1) investigating design problems and solutions related to a toddler in order to show how solutions are found out; and (2) build the relationship among design problems, solutions, and their bridge. The first purpose provides designers with clues that help them to effectively solve problems as well as generate solutions based on the identified design problems. The second purpose makes it possible that designers can apply the most appropriate clues to bridge problems and solutions according to the attributes of problems. This research takes design problems related to a toddler as an example because the authors have less bias on such problem type that they are not familiar with.

Keywords: design problem, problem solving, problem identification, solution generation

1. Introduction

As technology has been progressing, lifestyles have become more rich and diverse whereas new changes have also spawned new problems, therefore many problem-solving strategies and methods have been created. In the field of design, designers usually use procedures and techniques to solve design problems, such as Brainstorming (Rawlinson, 1981), Synectics (Gordon, 1961) and KJ method (Kawakita, 1986). Additionally, the TRIZ method, which is a systematic innovative problem-solving theory, can help to solve technical contradictions in engineering (Terninko, Zusman & Zlotin, 1998). However, specific studies suggest that creative thinking methods require constant evaluation and improvement (Baxter, 1998), thus, an approach for effectively solving problems creatively and finding problem-solving strategies and methods is a crucial part in design research.

Currently, designers tend to find design problems, and use the results of the assessment and selection to set the problem-solving direction during a design development process. The designers must select specific problems to be solved in order to meet the needs of the users. Therefore, design-problem evaluation is of chief importance in the design process.

Design novices usually use their personal experience and rational design methods to solve design problems. However, when faced with a new problem area, without previous experience or with unfamiliar context, they do not know how to start. For example, if the design object is a particular group such as the elderly, infants or disabled people, their conditions must be considered by novice designers in a divergent approach including physical, mental, and cognitive ability, even though it is difficult for novices to truly understand the lifestyle and thought of the target group in order to fit their needs. Therefore, solving design problems, generating critical problem-solving ideas and understanding more-direct relationships between design problems and existing solutions have been difficulties and challenges of design education.

In view of this, the main purposes of this study is as follows: (1) to research the screening criteria for design problems related to toddlers by applying classification and scoring methods (2) to provide novices a set of cues or shortcuts for thinking and generating design solutions.

2. Literature Review

2.1 Research related to toddlers

(1) Observation of toddlers' behavior

The process of observation can be divided into (Tsai, C. M., Hong T. F., Qiu Q. H., Lu Y. M., Zhang M. J., 2008, pp.6-13):

(a) Attention
(b) Observation of target and environment
(c) Subjective intervention and record
(d) Judgment of behavior

Observation is the first step in understanding the user, but it is difficult to understand the behavior of infants and young children due to their limitations including their language skills and expression. Simultaneously, due to immature development of children's body movements, their expressed actions are all similar. Furthermore, the behavior of children is susceptible to emotional influence, so it is improper to judge their behavior simply based upon their emotional expression.

Additionally, due to individual differences, toddlers have their own unique behavioral patterns, so observers have to maintain an objective attitude during observation.

(2) Cognitive development of toddler

From a perspective of the cognitive development theory, the Swiss psychologist Piaget (1962; 1972) considered that the development of preschool children can be divided into two periods: the first stage, Sensorimotor, covers birth to 2 years. During this time, infants and toddlers learn and understand by accepting stimulus under the action and reaction through body movement and sensory perception. The main development in this stage is concrete thinking and reflex action. For example, children cannot understand the language and the use of abstract thinking and symbols. Children can explore things, through a specific object, by using their senses and movements, such as touching, grasping and sucking, etc. Reflex action responds to accepted stimuli directly rather than becoming influenced by conscious thinking. Infants and toddlers learn by doing: looking, hearing, touching, grasping, and sucking. The learning process appears to begin with coordinating movements of the body with incoming sensory data. Piaget's second stage of development is known as the Pre-Operations Stage, which was believed to have affected children aged between 2 to 7 years old.

2.2 Research related to classification methods

(1) Grounded Theory

Grounded theory is a method through systematic data collection and analysis in order to generate a theory. Strauss and Corbin (1990; 1998) considered there are three distinct processes of analyzing data involved in grounded theory. There are: open

coding, axial coding and selective coding. In the three-phase method, the purpose of open coding is to categorize data while axial coding is to identify core categories through the development of relationships between the categories. In selective coding, analysts are charged with the task of verifying the core category and other categories (Figure 1). In terms of applying the method in design problems, the framework of the problems generated in the initial step helps the researcher to identify the core category of the problems.

Because the core category has more connection than the other categories, it is more influential. As a result, if the problems in the core category are solved, it is possible that the problems of other subcategories can be solved simultaneously by distinct aspects of phenomenon such as causal relationship. In other words, understanding the relationships between different problem categories can help the researcher to select important problems. In terms of problem selection in design field, if we can solve the fundamental and essential problems first, then we can prevent other problems generated. In addition, it provides researchers to discuss the level of the core problems involved in relationship to the width or depth of other problems.

(2) Card Sorting

Card sorting is to find out valuable improvements of collecting and classifying of data. Ross and Murphy (1999) believe that subjects tend to classify objects by their own thoughts rather than classify by scientific taxonomy. Therefore, the card sorting method can be used to understand the cognitive differences between designers and users. However, if items can be classified into more than two categories, it is difficult for users to categorize.

(3) Kawakita Jiro Method, KJ Method

Kawakita (1986) developed KJ method in his anthropological writings. The purpose of KJ method is to generate new ideas to establish an ordered system or structure from chaotic data. In the process, subjects write their ideas on cards and then sort the related cards into the same groups and name each of them (Figure 2.a). Finally, analysts can develop clusters of similar properties. Classified patterns made by KJ method can be analyzed by a correlation between groups to see the overall structure. Vacancies in the configuration spaces of the layout provide the analysts an understanding of previously insufficient direction to generate new ideas (Fig 2.b) (Ohiwa , Kawai, & Koyama, 1990; 1997).

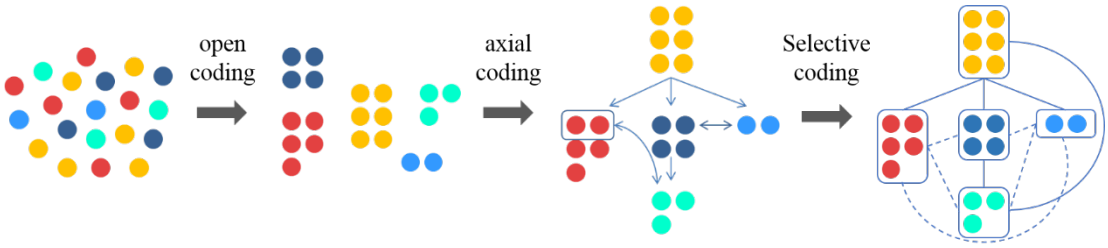

Figure 1. Process of analysis in grounded theory

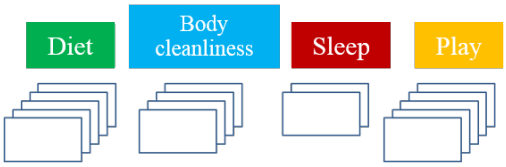

Figure 2.a. Process of KJ method

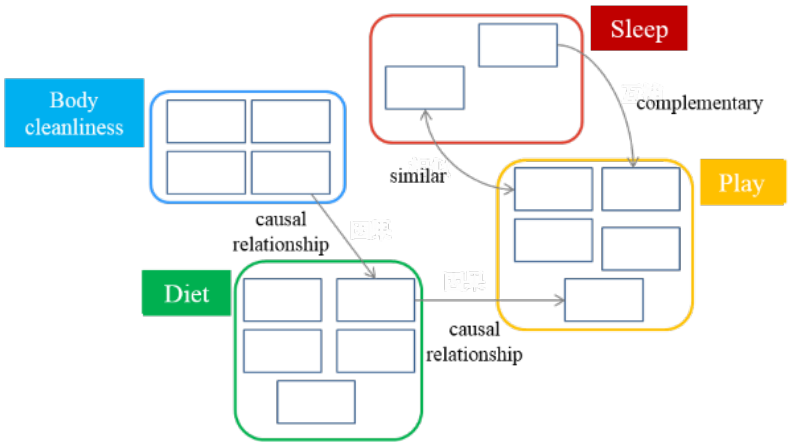

Figure 2.b. Process of KJ method

2.3 Score screening method

(1) Metrics for measuring ideation effectiveness

Shah and Vargas-Hernandez (2003) proposed two new methods measurement for concept scoring. There are: novelty and variety. Novelty is a measure to evaluate unusual or unexpected ideas compared to other ideas. If characteristics are less predictable, the level of novelty is higher (Table 1). Variety is a measure of the different types of functional forms in the process of idea generation. If the types of forms are more, the level of variety is higher (Figure 3).

Although severe problems seldom happen and they are usually ignored, they could lead to irreversible consequences if we do not deal with them. Therefore, during the assessment, analysis should be based on “severity” of the problem as an important classification, just as "novelty" is the measurement of evaluating concept.

According to the measure of "variety" which helps to understand what type of forms of ideas and how many types of ideas, "universality" can be used as one of assessment criteria when analysts screen problems. In everyday life, users usually have similar problems which occurs in diverse place and situations. It means that the problem has higher level of universality, so it is an essential part in design field to identify common problems which always happened in our life.

Table 1. Measurement procedure of novelty

		Novelty sub-score S_I		
J	*Attribute*	$S_I=3$	$S_I=7$	$S_I=10$
1	Propulsion	Jet	Turbine	Other
2	Medium	Ground	Air	Other
3	Motion	Wheels	Fly	Other
4	Parts	1	2	2+

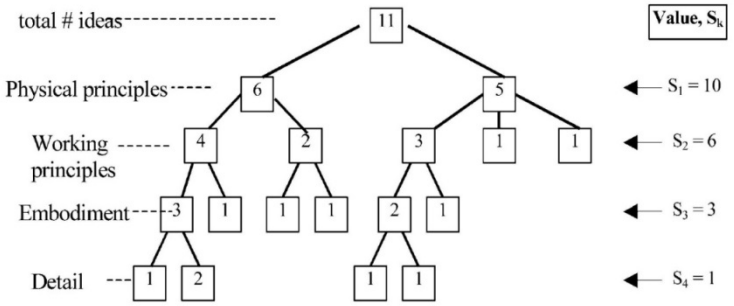

Figure 3. Measurement procedure of variety

(2) Concept Selection in Flexible Design Strategies

Concept selection is a process to select the best combination of the highest performance and lowest cost from various concepts (King & Sivaloganathan, 1999, p. 329). The purpose of the method is to assess the compatibility of concept combination objectively by using the compatibility matrix, so analysts not only can eliminate the problem-solving concept which is not suitable in the design project but also can see the relative utility of each concept from the values (Figure 4). If a concept with compatibility of high scores, then it is the basic needs of common core which can help concept selection. Function is used to evaluate concept in the method, as during problem assessment, criterion is used to estimate the problems and the possibilities of combination between different problems. It also helps to develop new solutions when concepts generate.

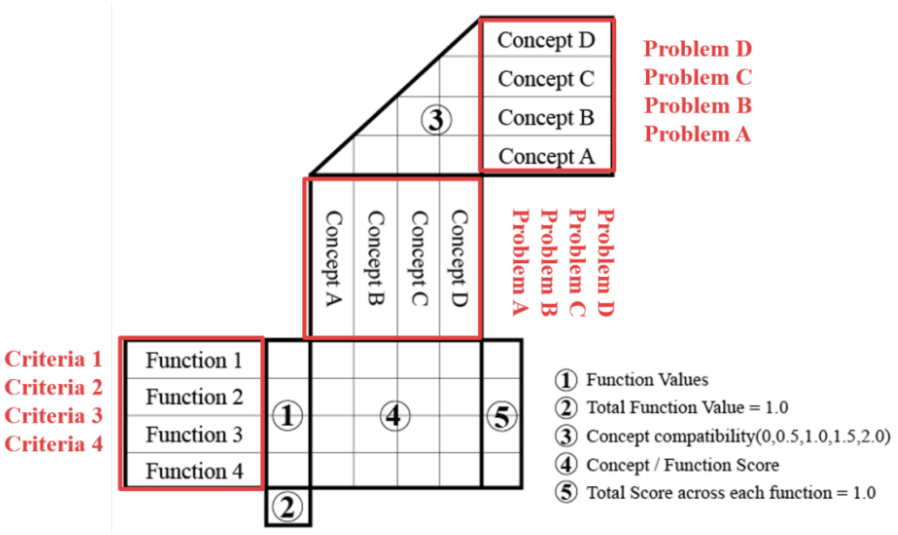

Figure 4. Application of concept selection in problem assessment

(3) Problem-solving approach of design problems

From the point of view of cognitive science, people want to achieve a specific purpose, while suitable approaches can not be used in a condition, and then the activity they engage in, are called problem-solving (Li, Li, Wang, & Zhao, 2007). According to the Ideal problem-solving method developed by Bransford and Stein (1984), the process of problem-solving can be divided into the following five stages: (1) to confirm the problem; (2) to define and describe the problem; (3) to explore the possibility of solving strategies; (4) the implementation of the policy; (5) to review and evaluate (Figure 5).

Problem-oriented innovative design, which aims to improve the performance of existing products or systems, will affect the product or system for the problem of the main function to solve. Therefore, TRIZ is the most suitable method which can improve the performance of existing products or systems by applying contradiction matrix and innovative principles of TRIZ.

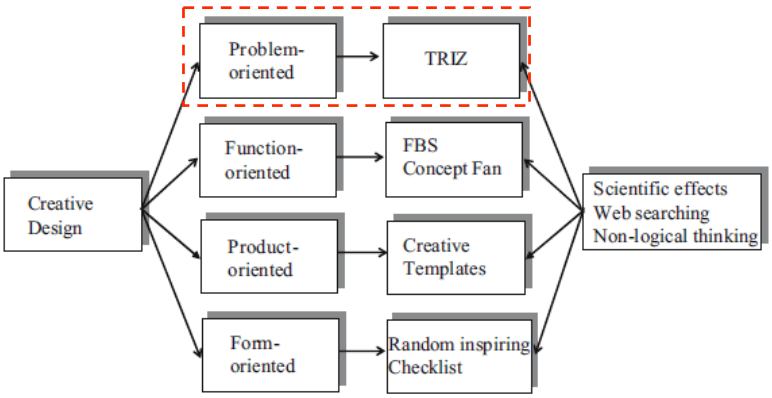

Figure 5. Category and strategy of innovative design

(4) Theory of Inventive Problem Solving (TRIZ)

In basic principles of TRIZ, the researchers begins to transform the problem as the corresponding general problem in TRIZ, and then apply the general solution of TRIZ to their specific problems in order to find the solutions. Generally, in the first stage of TRIZ problem solving process, the secondary problems are removed in order to clearly define the core problems, and then the analyst begins to conceptualize the characteristics of the ideal answer. During the conceptualization, problems require to be disassembled as basic components in order to understand the most basic form of each component. In addition, TRIZ developed out of 76 standard solutions can be used as a reference to help concept generated.

3. Procedure

This study would be based on event sampling (Martin, 1999), to observe a two-year-old toddler in a variety of different types of places by activities he participating. In addition, the researcher interviews with parents to discuss different situations in order to understand the daily life of child care, while the research recorded the process though photos, record and notes, to found problems in the toddler's life.

Based on the literature review, two researchers classified the problems according to distinct properties by using card sorting and KJ method. Design problems were selected and scored while the criteria were established in order to select important representative design problems. According to the selected design problems, the researchers sequentially generated the solution-oriented concepts which depend on what kinds of products in market and how parents improve the problems for each problem. In the next phase, the researcher immersed herself in exploring the relationship between the problems and the related solutions in order to find problem-solving cues.

4. Analysis

4.1 Problem classification

By observation and interview, the researcher collected 156 problems and then defined them. The design problem is observed in accordance with the different locations and different types of activities. Problems in the category “indoor” are divided into the subcategory of “Home” and “Superstore”. Furthermore, the problems are classified according to three distinct properties of “behavior”, “product” and “environment”, while the problems were sorted into subcategories, shown in Figure 6.

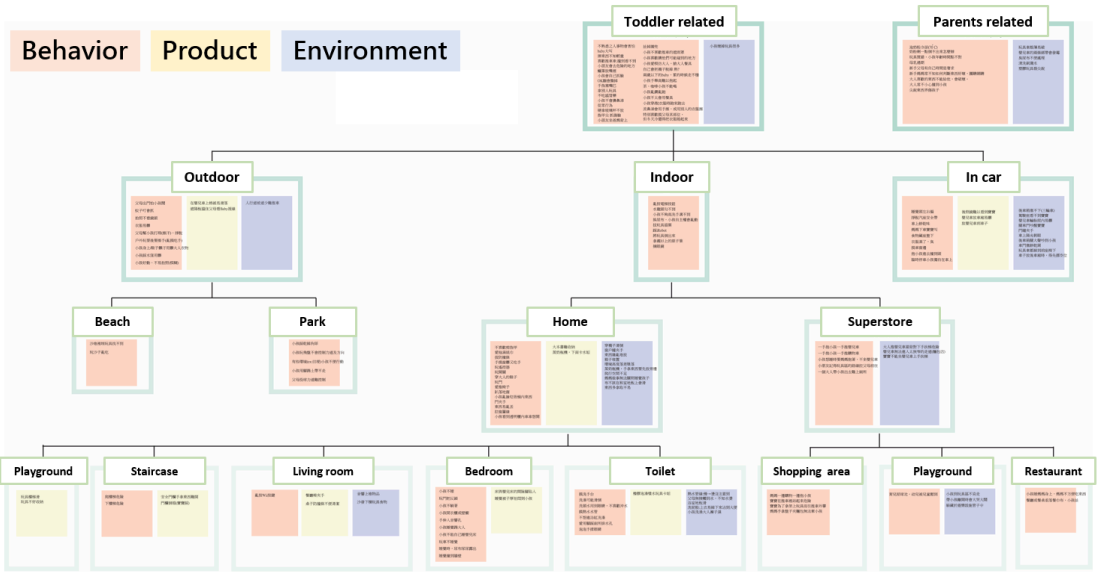

Figure 6. Process of problem classification

4.2 Criteria of problem evaluation

In order to select the most important problems in terms of users for designers to solve, the problems collected through observation and interviews were conducted to understand the needs, and then the criteria were set for the assessment of the important problems. This study provides the six criteria to assess problems respectively:

(1) Occurrence of high frequency
(2) To occur widely in different locations
(3) Damage of personal safety
(4) Difficulty of subsequent treatment
(5) To have an influence on others
(6) To remain traces of damage

The first and second criteria are to assess the frequency of a problem happened in the same place and whether it occurs in different locations respectively. In other words, the two criteria can measure a problem in terms of the breadth of problems. Furthermore, the third and fourth criteria are to assess the level of severity of an occurring problem, that is to say, whether the problem will cause personal injury and if the subsequent process is difficult or the processing time is longer. Finally, the fifth and sixth criteria are to measure whether a problem derived from user behavior will cause other sub-problems. The former is to explore whether a user's problem would affect others or even generate more follow-up problems. The latter is when a problem has influence on objects and environment, whether the problem would cause damage or indelible traces. For instance, the problem" a toddler as a user disassembles objects or breaks a glass cup" fits the sixth criterion because people need to fix the objects and clean the broken glass after the problem occurred.

Furthermore, the values of 0 and 1 are used to evaluate if a problem meets a criterion in accordance with the six criteria, while the total score of one problem is six. According to the assessment method, the result of a part of the problems is shown in Table 2. The higher is the total score of a problem, the more important is the problem. Therefore, the important problems can be selected by the result. For example, the problem "a toddler rips off Band-Aids from his body" fits many evaluation criteria and the problem has 5 points, so it can be selected as the important design problems.

Table 2. Result of scoring problems

Criteria / Problem	1	2	3	4	5	6	Total Score
child fall from bed	1	0	1	1	0	0	3
child go up and down stairs dangerous	1	1	1	1	0	0	4
Toddler tore Band-Aid from his body	1	1	1	1	0	1	5
Adult closed the door awakened child	1	0	0	0	0	0	1

After evaluating each problem through the criteria and calculating the total scores, the result shows that there is no 6-pointe-problem; the number of 5-point problems are 3; the number of 4-point problems are 33; the number of 3-point problems are 65 points; the number of two-points problems are 24, and the number of one-point problems are 11. The problems which have more than 3 points are selected as the important design problems while there are 94 problems in total. However, 50 design problems have to be selected in this stage, so this study screened 3-point problems again from different categories based on the previous result of the classification because the diversity of the problems have influence on the difference of solutions. The 50 important problems are selected for the follow-up study.

4.3 Collection of existing products and solutions for parents

On the base of the selected 50 important problems, the solutions of each problem are sequentially generated from existing products. In order to ensure the diverse thinking in the further research, two or more solutions must be generated for each problem, which includes existing product solutions or parents' solutions. In spite of that existing brands have a variety of design of the product appearance, toddler-related products in the market are taken as an example according to the purpose in this study and judgmental sampling. For example, the solution such as Band-Aids with cartoon

images is collected from existing products based on the problem “a toddler rips off Band-Aids from his body” while the solution fit toddlers’ own preferences, so they do not want to rip off them.

Through interviews with parents in the process, the solutions from parents are collected by understanding the way which parents resolve the solution, and the solutions, which is the use of the existing environment and lower cost, are not limited to product-related solutions. For example, the parents’ solutions such as “drawing toddler’s favorite cartoon images on the Band-Aid” and “sticking the stickers above the Band-Aid on their body” for the problem “a toddler rips off the Band-Aid on his body”. However, after the collection of solutions, there is only one solution or no solution for some specific problems, the insufficient number of its solution can affect the relation between design problems and solutions due to the diversity of solution, so the problems which lack of related solutions were deleted, and the last 35 problems are selected in this stage.

4.4 Establish the relationship between solutions

In this study, grounded theory is used to analyze the design solutions of 35 problems while the open coding and axial coding are used to encode the classified solutions. Through the exploration of the relationship between the categories, the correlation between problems and solutions is organized and analyzed. In this phase, the solutions are inducted and the solution are classified in the categories of "happened before" and "happens after" according to the occurring time of problem.

4.5 Build problem-solving approach

Through the analysis on the design problems and solution, the solutions of similar properties were classified in the same group. For example, the solutions such as Band-Aid with cartoon images, a toy car seat combined a shopping cart and toddler syrup, are all for the improvement of child care by fitting their own preferences, therefore, they are classified in the same category. In addition, based on 40 TRIZ inventive principles and the complementary TRIZ inventive principles from *Matrix 2003: Updating the TRIZ contradiction matrix* (Mann, D., Dewulf, S., Zlotin, B., & Zusman, A., 2003), this study takes the advantage of the 77 TRIZ inventive principles to make research and development of 11 problem-solving approaches.

According to TRIZ inventive principles and the analysis of the relationship between problems and solutions, this study presents 11 approaches to solve the problem, as shown in Table 3. The first approach "to make it modular" is to separate an object or a plan into each part to make it modular, easy to assemble and disassemble, or to split into sections. With reference to the problem “toddler throws objects on the ground”, if the approach “to make it modular” are used to generate ideas, the solution like assembled cars of Lego building blocks can be generated because it can be re-assembled even if it is thrown on the ground. Additionally, the approach "to change the local" is to change the local of an object or a plan on order to make each part perform different or complementary functions. For example, the solution of toddler non-slip socks with rubber soles can prevent toddlers falling on the floor. The third approach "to merge" is used to merge the same or related items or plan to make it act together simultaneously.

"To pre-buffer” is prior to buffer in order to remove or mitigate a problem. For instance, the solutions of putting lazybones on the ground and desk corner cushion are used to reduce the risk of falling from a bed and hitting in the head respectively. “To advance prevention” means beforehand to compensate or use an alternative way to remedy the relatively low reliability of an object or a plan. For example, in order to let toddlers quit the habit of sucking fingers, a nail biting treatment, which is the bitter liquid, is used on toddlers’ fingers, so toddlers would not want to suck due to the bitter taste of their fingers. “To make it adjustable or changeable” means an object can be adjusted or changed in order to achieve the best results, that is to say, an object can be split to make it movable, folding or removable, in order to increase their freedom. Removable toddler car seat cover, for example, can improve the problem that it is hard to clean food scraps dropped in a car seat gap. “To meet user’s preferences and ability” means the improvement according to abilities and preferences of target groups, for instance, toddlers usually want to rip off Band-Aids on their body, but after using existing products of Band-Aids with cartoon images, toddlers do not want to rip off the band aids because of the cartoon images. In addition, a toy car seat combined a cart toddlers want to sit in the car seat to prevent them climbing out of the shopping cart.

The approach “to import isolated objects or mediator” means isolated objects or mediator which can gather negative part are imported, or making an object or a plan itself can isolate from the negative part, such as the smell of diapers can be isolated by diaper pails. The approach "to remove or modify the part causing the problem" is to remove the object or the source of the problem, or modify the part causing the

problem in order to preventing it occurring. For example, pants diapers as existing products, can improve the problems that the bed is soiled with pee from a leaking diaper when toddlers sleep due to adhesive tape of disposable diapers losing stickiness. The approach "to reduce the sensitive or enhance the anti-harm" means the reduction of the extent of the damage or the increase of resistance, for example, disposable nappy bags with fragrance can reduce users' sensitivity to smell the diapers. The approach "to limit problem occurred" means certain conditions are set to limit an object or a plan, so that the problem cannot occur, such as baby safety gate blocking dangerous actions performed.

Table 3. Problem-solving approaches based on TRIZ inventive principles

TRIZ inventive principles	Problem-solving approaches
01 Segmentation	01 To make it modular
03 Local Quality	02 To change the local
05 Merging	03 To merge
09 Preliminary Anti-Action	04 To pre-buffer
11 Cushion in Advance	05 To advance prevention
15 Dynamics	06 To make it adjustable or changeable
61 Adapt a tool to a person	07 To meet user's preferences and ability
64 Isolation/ insulation	08 To import isolated objects or mediator
67 Remove or modify the source of harm	09 To remove or modify the part causing the problem
69 Increase resistance to harmful effect	10 To reduce sensitive or enhance the anti-harm
77 Block dangerous action	11 To limit problem occurred

5. Conclusion

This study presents the six evaluation criteria of the design problems related to toddlers as follows: (1) occurrence of high frequency, (2) to occur widely in different locations, (3) damage of personal safety, (4) difficulty of subsequent treatment, (5) to have an influence on others, and (6) to remain traces of damage.

In addition, this study proposed 11 problem-solving approaches based on the relationship between design problems and solutions, as follows: (1) to make it modular, (2) to change the local, (3) to merger, (4) to pre-buffer, (5) to advance prevention, (6) to make it adjustable or changeable, (7) to meet user's preferences and ability, (8) to import isolated objects or mediator, (9) to remove or modify the part causing the problem, (10) to reduce sensitive or enhance the anti- harm, (11) to limit problem occurred. Therefore, design novices can come up with concepts to solve problems by applying different approaches. In the follow-up research, researchers can discuss the utility of the problem-solving approaches and explore the correspondence between design problems, problem-solving approaches and solutions.

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