A User-Centered, Innovative NPD with Integration of Scenario-based Design and TRIZ

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Abstract. One of the key factors of today's new product development (NPD) has gradually transformed from technology-oriented to user-centric. Being able to integrate user needs and technological advantages of a company in the NPD is the key for the product success, and is also the focus of this study. Through describing scenarios in both text and images, scenario-based design (SBD) approach analyzes the interaction between people and objects with user's viewpoints. The approach helps pinpoint user's needs and what problem should be resolved, but remains the unsolved solutions to rely on the designer's own experiences and knowledge. An appropriate approach, such as, TRIZ, could help address this issue and resolve the identified problems. In this study, we integrated SBD and TRIZ tools to construct a user-centered NPD. SBD helps locate "what to solve", while TRIZ tools helps develop "how to solve". A case study was conducted to demonstrate how this newly developed approach works.

Keywords: scenario-based design, TRIZ, contradiction, user-centered design

1. INTRODUCTION

The relationships in today's consumer market are fast-changing and increasingly complex. An investigation by the China Productivity Center (2013) found that the primary issues in innovation, research, and development were (1) lack of understanding with regard to market mechanisms, (2) lack of habits and methods with innovative thinking, (3) lack of systematic and formal innovation procedures and organization systems, and (4) lack of specific long-term product strategies. In the current knowledge-based economy, innovation and the utilization of knowledge and technology are vital to market competitiveness (Thurow, 2000). Innovation in product design involves integrating professional knowledge from various areas, consumer lifestyles, and user demand. The user-oriented and cross-cutting combination of innovative designs and management will be crucial to creating new value and increasing competitiveness of transitioning industries (Liang, 2007). Developing a new product that is both innovative in design and user-centered is essential for corporations looking to enhance their competitiveness in the market. Designers and developers must develop new products using expertise in multiple fields and user-centered designs, which can in turn facilitate the continued operation of their company. Thus, during the design process of new products, designers and developers must employ a user-centered and innovative approach. Combining the user-centered scenario approach with TRIZ, the theory of inventive problem solving, can produce innovative design solutions that meet customer needs, assist designers and developers in systematic generation of design concepts, increase design efficiency, and expand the problem-solving space. With limited design resources, this approach can meet user needs effectively and increase design value.

2. LITERATURE REVIEW

2.1 Scenario Approach

2.1.1 Overview of Scenario Approach

In scenario-based design (SBD), a scenario is a story that can outline and describe how a technology of system in future life can interact with users and achieve what they want to do; such scenarios provide designers with a specific and concrete view of the future (Nardi, 1992). A scenario uses the framework of basic human thinking and expression, describing the context and story of events by “telling” and attempting to recreate events and the meaning behind feelings by “listening”. It is a story narrating people’s actions, containing at least one agent or actor and at least goal or objective. There is a plot with sequential actions and events, and it explains the causes and effects of an event using text or verbal expression, presenting who, what, where, when, why, and how (5W1H) (Carroll, 2000; Rosson and Carroll, 2007; Yu et al., 2001). The basic framework of a story includes people, places, things, and activities. Interactions among the people (such as the actions and traits of users), places (such as the background situation and environmental factor), and things (such as the attributes and functions of products) can produce usage conditions, the sequence of actions and activities, and the causal relationships among events (Yu et al., 2001). Narrative descriptions can then be used to predict usage conditions, and various methods can be employed to apply usage experiences to guide development (Rosson and Carroll, 2007). Visual sketches and storyboards are used to consider user scenarios and their needs, and even actually experiencing the product or service can aid in enriching the content of the scenario story (Rosson and Carroll, 2007; Huang, 2002).

2.1.2 Procedure of Scenario Approach

The scenario approach has no specific procedure or complete process and varies with the design factors of the product or service. With regard to the operational procedure of the scenario approach, we mainly referred to the one established by Professor David Y. C. Liang. Offering a clear process, it has been utilized in the academia and industry with success for nearly two decades. The procedure includes (1) macro forces, (2) scenario story, (3) scenario brainstorming sketch development, (4) character map, (5) scenario and situation, (6) scenario story board, (7) critical issue and key theme, (8) key theme and concept development, (9) concept drawing, (10) concept synthesis, and (11) presentation (Tang & Lin, 2011).

2.1.3 Advantages and Disadvantages of Scenario Approach

The scenario approach can effectively present macro factors such as user experiences, society, environments, and user objectives, which are extracted and their elements restructured into scenario story. In this manner, design problems and proposals can be clearly defined and discussed, thereby enabling the evaluation of design concepts early on in the design phase (Fulton and Marsh, 2000; Nardi, 1992). However, the scenario approach cannot solve every problem; scenarios are merely a perspective approach (Nardi, 1992), and many problems are often encountered during the phases of producing and implementing design ideas. The resulting design proposals may not be optimal, and producing design ideas relies heavily on the designer’s own instincts and experience. Consequently, the design problems may not be clearly defined, or the design proposals may be unfocused or too abstract. Thus, other product analysis methods are needed to aid the detail aspect of product design (Chou, 2009; Tang and Lin, 2011). The subsequent application of TRIZ would enable the effective convergence and focusing of uncovering design problems or objectives and thus produce clear and specific product problems. The knowledge base provided by TRIZ can also guide designers in generating design concepts and solutions with specific and suitable direction.

2.2 TRIZ

2.2.1 Overview of TRIZ

TRIZ is the abbreviation of the Russisan term *teoriya reshniya izobretatelskikh zadatch*, which translates to "the theory of inventive problem solving". It is a problem solving theory developed by Genrch Altshuller and his colleagues following the analysis of a large quantity of patent examinations and research literature. TRIZ is also a philosophical and systematic thinking approach that encompasses a number of methods and tools (Kaplan, 1996; Terninko et al., 1998). In 1946, Atshuller's experience in examining numerous patents at the Soviet navy's patent office led him to contemplate whether discernable procedures existed behind invention and innovation. He thus began to examine inventive problem solving, which brought about the birth of TRIZ (Terninko et al., 1998). TRIZ includes a number of tools and methods, but they can basically be divided into analytic tools, which format problems, and knowledge-based tools, which provide concepts. The conceptual core and problem-solving methods of TRIZ mainly focus on contradictions, evolution, ideality, functionality, and resources (Mann and Hey, 2003; Savransky, 2000; Terninko et al., 1998).

2.2.2 Contradiction

Altshuller (1984) stated that for a problem to become an inventor problem requires the overcoming of contradictions during problem solving. The majority of the problems encountered during new product development are contradictions. Basically, an innovative solution can eliminate the contradictions and increase the chance of adding innovative inventions (Mann, 2007; Savransky, 2000; Terninko et al., 1998). In TRIZ, contradictions are divided into technical contradictions and physical contradictions. Solving problems with technical contradictions generally requires the Contradiction Matrix and the 40 Inventive Principles to search for appropriate solutions (Savransky, 2000; Terninko et al., 1998). Separation Principles can be used to solve problems with physical contradictions: separation in space, separation in time, separation within a whole object and its parts, and separation upon condition (Mann, 2007; Terninko et al., 1998).

2.2.3 TRIZ Problem Solving Process

The basic problem-solving process of TRIZ is to first perform the abstraction of specific problems and then convert and define them into a TRIZ generic problem. Then, TRIZ methods and tools or knowledge bases are used to generate the TRIZ generic solution, which is then applied to the specific problem. Compared to the divergent thinking of trial-and-error, TRIZ can solve problems more effectively (Kaplan, 1996; Mann, 2007). On this basis, Shulyak (1998) proposed three steps for solving inventive problems involving technical contradictions: (1) analyze the technical system, (2) state a technical contradiction, and (3) resolve the technical contradiction. The procedure analyzes the product, identifies the problems and contradictions, and then finds the suggested inventive principle solution via the Contradiction Matrix. We referred to and modified the procedure presented by Shulyak for our design process. The framework is simple and enables TRIZ beginners and personnel in other fields to use TRIZ more easily.

3. INVENTIVE DESIGN PROCESS FOR NEW PRODUCT WITH USER-CENTERED DESIGN

This study integrated the scenario approach and TRIZ to develop an inventive design process for new products with user-centered designs. We referred and modified the scenario approach developed by Professor David Y. C. Liang and the three-step inventive problem-solving process proposed by Shulyak (1998) for the core framework of our design process. The scenario approach first helps users to uncover and define problems and thereby identify "what to do". Via the people, places, and objects in the scenario, the interactive relationships between users and products can be clarified, and the possible user issues and needs can be explored. Specific design problems and objectives can then be divulged through the user behavior models as the scenario progresses. The problem of "how to do it" is then solved with TRIZ as the analytical tool and knowledge-based tool. By deconstructing the system, exploring key elements, and clarifying the impact factors, the user problem can be converged and focused to identify the contradiction. Then, the Contradiction Matrix, Inventive Principles, and the Separation principle can be used to find suitable solutions to assist designers in developing concept designs and identifying appropriate solutions. The TRIZ-based innovative design process for products with user-centered designs can connect users, the scenario approach, and TRIZ, and it is hoped that it can produce creative new products that meet user needs. The details of the procedure are as follows, and a flow chart is presented in Figure 1.

- Step 1-1: Define design theme: Based on the design and development needs, confirm the design theme or set possible directions for development based on the resource conditions of the enterprise.

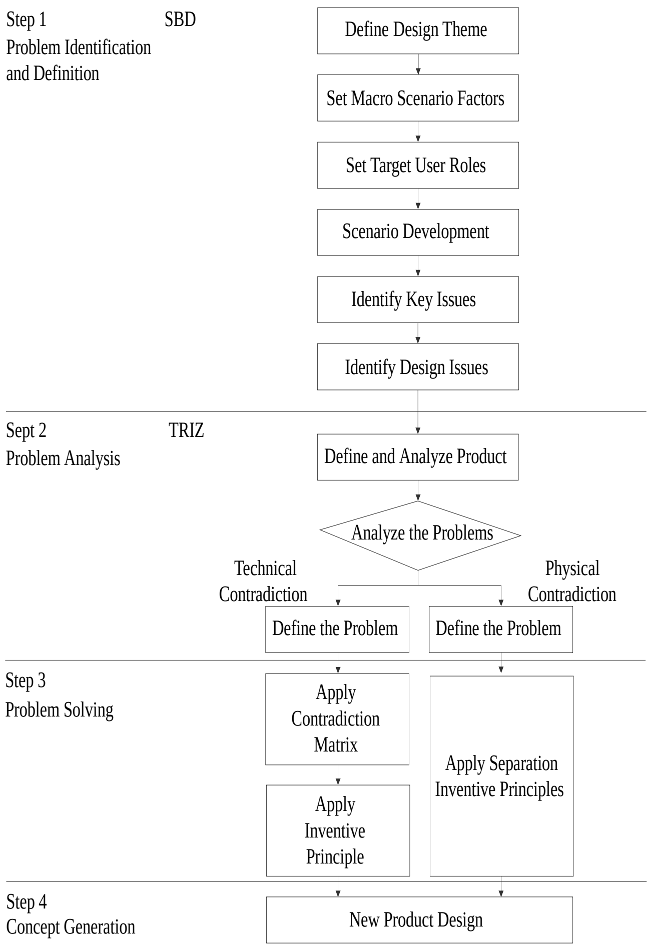

Figure 1: Inventive design process for new products with user-centered designs.

- Step 1-2: Set macro scenario factors: Macro scenario factors have three aspects: social, economic, and technological (SET). According to the design theme or preset direction, collect, observe, or clarify available resources and the interactive relationships among users, existing objects, and the environment. Then, analyze, discuss, and select a suitable design direction and objective. For future settings, a future time point can be set on the timeline. Subsequently, predict possible future conditions based on current influential conditions (Yu et al., 2001) and then collect and converge the SET factors accordingly. In our procedure, this step has a forward operating model and a reverse operating model, depending on whether the design theme is clear. The conventional forward search method for SET factors employs the fuzzy concept to assist in extensive searches for possible development resources. However, if the design concept is clear, then it will instead easily cause the message to diverge away from the theme. For this reason, if the theme is clear, then the reverse operating model is adopted, and usable resources associated with the theme are searched for and explored starting from the design theme.
- Step 1-3: Set target user roles: Setting micro scenario factors is based on SET factors focusing to set and search for the lifestyles of target user groups and set the roles of personas. Shaping the overall archetype generally requires three to five people and a short description of who, what, where, and when. Most of the information is presented in visual form to humanize the design focus, enable scenario testing, and facilitate the conveyance of the design. Actual communication with users (such as interviews or user observations) and relevant user information research (such as cultural anthropology and ergonomics) will offer a more precise grasp of the subsequent scenario development and prevent deviation from the design theme.
- Step 1-4: Scenario development: Set user role conditions for scenario development according to the defined design theme (or direction) and objective. A scenario can be aimed at four to five design directions, so three to five stories are preferable (Yu et al., 2001). Developing the story using pictures and text and clearly specifying the problems that users may encounter when using the product and in their lifestyle scenarios, with 5W1H to aid the narrative. As the scenario develops, the content of the story is further organized and analyzed to identify the main scenario problems and present the problems that users want to solve (e.g., “If only…”, or “What should be done for…?”). Finally, the design objective (design issue) of the problem to be solved is produced based on the scenario problems (key issues).
- Step 2-1: Define and analyze product: Integrate the results obtained using the scenario approach and then define the primary functions, goals, components, and operating methods of the product to be developed.
- Step 2-2: Analyze and define the problems of the product: By integrating the results obtained using the scenario approach and defining and analyzing the product, the partial or component problems of the product that need to be solved are confirmed.
- Step 2-3: Identify contradictions of product problems: Perform contradiction analysis on the confirmed problems of the product. Comparisons can first be made against the short list of opposite characteristics compiled by Savransky (2000) to determine whether the product has problems with its physical features. If so, then it has physical contradictions; if not, then it

has no physical contradictions, and the analysis will begin with technical contradictions. The problems are converted using the 39 Engineering Parameters to identify the ones that need to be improved. If there are no contradictions, then the table proposed by Chen and Liu (2001) will suggest the principle corresponding to single engineering characteristics, which can then be used for concept generation and problem solving.

- Step 3: Problem solving: Based on the contradiction analysis results above, the concept generation and problem solving of physical contradictions can be achieved via the four Separation principles. The four Separation principles proposed by Mann (2007) correspond to the 40 Inventive Principles to provide a greater selection of design concepts. The suggested Inventive Principles corresponding to technical contradictions can be derived using the Contradiction Matrix.
- Step 4, Design concept generation: Design concept generation for the new product is performed according to the design objectives derived using the scenario approach and the solution suggested by TRIZ. In addition, external knowledge bases (such as internet searches and patent databases) can also aid in design concept generation. Systematic charts can facilitate design resource sorting (such as fishbone diagrams, association graphs, and tree diagrams), which in turn produce and stimulate design ideas. This process will facilitate the generation of new and innovative design concepts and solutions for new products that meet user needs.

4. CASE STUDY

We adopted the design process of a pen as our case study, with design concept generation as our primary objective. We then discussed the concept results derived using the proposed methodology. The results of the experiment procedure were as follows:

- Step 1: Starting with the design of a pen, we set the macro scenario factors of the scenario approach and adopted the reverse model to collect SET factors, the results of which are displayed in Table 1. Based on the SET factor analysis results, we then set the roles and lifestyles of our user personas for scenario development, the details of which are shown in Table 2. Next, we organized and analyzed the scenario development results and generalized two scenario problems: (1) how to write Chinese characters beautifully when first learning Chinese and (2) how to improve one's writing habits in the digital lifestyle of today. After looking up information and literature associated with writing and integrating the scenario problems, we formulated two design literary objectives: (1) engaging in good textual communication requires correct and neat writing and (2) abnormal writing behavior, incorrect writing, and problematic behavior are reflected in strokes, writing style, structure, writing speed, and writing posture.

Table 1: SET factors of pen-related products from reverse collection.

	Social	Economic	Technological
Compiled results	Compulsory education Message conveyance Customary tool Symbol of status Historical Documentary Literary New residents Aesthetic concept	Declining birth rates Cloud services Personalized economy Environmental protection Green economy	Paper Electronic paper Ink Human factors engineering Capacitive touch screen Ultrasonic position sensing Dematerialization/ digitization Graphical interface Technology always comes from human nature

- Step 2: The scenario problems and design objectives were compiled from the scenario results and problems. We used TRIZ to perform the preliminary definition and analysis of the product objectives, components, functions, and method of use. The contradictions and problems of the product were analyzed based on the design objective and relevant information. Our analysis indicated the presence of technical contradictions and confirmed the parts that requirement improvement, as shown in Table 3.
- Step 3: We defined the specific technical contradictions in the parts and components that needed improvement in the product based on the two scenario problems and two design objectives. After identifying the contradictions among the parts and components of the product via the descriptions of the problems, we then convert them into the engineering parameters that needed to be improved or deteriorated. Subsequently, we looked up these parameters in the Contradiction Matrix to obtain the suggested inventive principles. The details are as shown in Table 4.

Table 2: Role settings of target users.

Role settings of target users		
	User A	User B
Picture of user		
Name	Judy	Chih-ming Chen
Age	8	28
Nationality	USA	ROC
Occupation	Elementary student	Illustrator
Native language	English	Chinese Mandarin
Traits	Half Chinese, half American; recently transferred from school in the USA to Shanghai, China; has just begun to learn Chinese for the first time	Good at drawing and designing but has poor handwriting; uses the computer frequently
Scenario development	Judy was born in the USA. When her father transferred to China for work, she moved with him to Shanghai. Just starting elementary school, Judy is learning Chinese, but Chinese characters are much harder to write than English letters. There are many characters, and many look very similar, so it is very hard to learn. Her father says that although it is the digital era, having good handwriting will make a good impression. Judy looks so pretty; wouldn't it be nice if her handwriting were pretty, too? Judy is very worried about this. How can she write neatly with beautiful handwriting?	After finishing military service, Chih-ming began work as an illustrator. Being good at drawing, his business is booming as he gains experience. Every customer that sees his work exclaims that he is very talented. However, when he writes documents or signs contracts in front of his clients, his flamboyant handwriting always leaves a deep impression. Moreover, being used to working on the computer, he often writes the wrong characters. "It is said that illustrators all have bad handwriting." How can Chih-ming make his handwriting more beautiful?

Table 3: Product definition and analysis.

Product name	
Pen for handwriting practice	
Primary function and objective of product	
Enabling neat and beautiful handwriting and the correct strokes and characters	
Primary components and functions of product	
Component	**Function**
Nib	Writing
Shaft	Gripping
Gripper	Facilitating the correct grip
Copybook/font	Conveys/writes characters/phrases
Characters/phrases	Writing results
Paper	Writing space
Hand	Holds shaft, controls nib
Eyes	Observe
Description of how to operate product (Method of use)	
Hold the gripper/shaft with hand; observe the characters and writing space on the copybook; control shaft and nib; write in the designated space on the paper; imitate the writing of the correct character.	
Determine the part or component that needs improvement or should be removed	
Paper, gripper, shaft, copybook/font, characters/phrases	

- Step 4: Developing the concept design of a new product can be based on suggested inventive principles and available resources, and external knowledge bases (such as internet searches and patent databases) can also aid in the generation of design concept that meet user needs. We converted the inventive principles into design ideas as follows. (1) 10 Preliminary action: On the paper, we first obtained information regarding the copybook and line spacing to simplify the process of having to look at a copy book and then back to the writing space, thereby enhancing the effectiveness of writing practice. (2) 15 Dynamics: The temporary and variable content and location of the dynamic copybook can be moved to any writing space. (3) 24 Intermediary: The temporary link between the copybook and the paper of the writing space can removed at will. (4) 26 Copying: The copybook can be virtually copied to the desired writing space. (5) 28 Mechanics substitution: Observation using the human eye is replaced with optical projections. (6) 32 Color changes: The color of the desired writing space is changed, or the projected light trace becomes the desired stroke or shape, thereby facilitating the acquisition of information during writing. Finally, by integrating the design concepts converted from the inventive principles, we developed the Easy Writing Smart Calligraphy Pen

(Figure 2). Upon preparing to practice handwriting (step 1), the desired font is scanned and stored via the tip of the Easy Writing Pen and converted into projected information (step 2). While writing, the Easy Writing Pen projects the virtual copybook onto the paper (step 3). Users can then write the character according to the stroke order given (steps 4 & 5). This produces neat and beautiful handwriting (step 6). The instructions of the Easy Writing Smart Calligraphy Pen are shown in Figure 3.

The design process for new products in this study used the scenario approach to identify the problems that users may encounter when using the product, which are then converted into TRIZ contradiction problems. Suggested directions for solutions are then given via corresponding TRIZ tools. This case study revealed that (1) both the scenario approach and TRIZ use deconstruction and reconstruction to facilitate problem solving; (2) the scenario approach gives specific descriptions of user problems and guides designers in understanding the sources of the problems from perspective of the user; (3) when using TRIZ, scenarios can provide a clear and specific view of the contents of the problems and aid designers in problem definition and analysis.

Table 4: Definition of product contradictions and lookup of inventive principles.

Description of component problems in currently existing products	
Component needing improvement	Problem
Paper	How can strokes be precisely positions without interrupting the flow of writing?
Shaft	How can shaft design complexity be reduced while maintaining its grip function and aesthetics?
Copybook/font	How can writing be fast without affecting the conveyance of information?

Component needing improvement	Approach to solving problem and possible undesirable outcomes	Improved engineering parameter	Deteriorated engineering parameter	Corresponding inventive principle
Paper	Increase and limit prevision of writing space / flow of writing may be limited	#28 Accuracy of measurement	#39 Productivity	10 34 28 32
Shaft, gripper	Reduce complexity of pent / shaft design	#35 Adaptability	#12 Shape	29 13 28 15
Copybook/font	Reduce writing time / conveyance of information	#25 Waste of time	#24 Loss of information	24 26 28 32

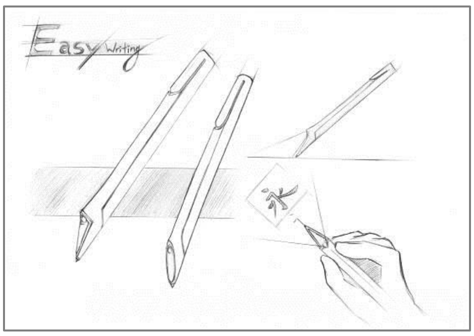

Figure 2: Design concepts of Easy Writing Pen.

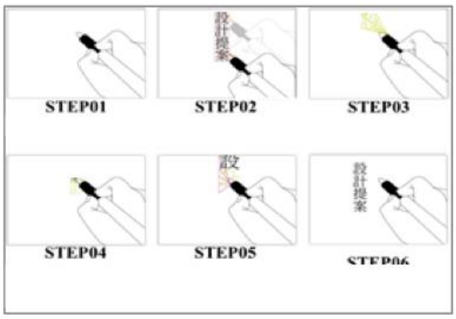

Figure 3: Instructions of Easy Writing Pen.

5. CONCLUSION

This study integrated the scenario approach and TRIZ to develop a design procedure for new products with user-centered designs and presented a preliminary case study to demonstrate its feasibility. The scenario approach can only divulge what problems should be handled for users, whereas TRIZ merely deals with how the problems are handled. Using the systematic problem-solving tools of TRIZ, the problems and contradictions of the product are defined, following which suggested directions for solution can be found. The two methods complement each other in the inventive design process, and after a preliminary execution of the process, we confirmed that the proposed approach is useful reference for designers and can assist designers and developers in generating design concepts in a systematic manner and producing innovative products that meet user needs. The concept design presented in this study is only the preliminary phase of the design process. Limited by time and space, we did not include the information of actual users or consider cost and manufacturing factors or the degree of practicality. Future studies can continue in this direction.

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