A Study on Design Thinking Based Creative Product Design Process in a Design Project

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(Received 12 October 2017; final version received 20 March 2019)

Abstract

This study aimed to propose a process of creative action that is based on a version of design thinking process with six stages (i.e., understand, observe, point of view, ideate, prototype, and test) to promote T-shaped talents in design education in specific, and general education in general. The innovative process first started with literature research, field study, and brainstorming to understand and observe the target audiences resulting in inspired viewpoints, followed by nine-window method and C-sketch technique to develop creative solution concepts, and then scenario building and storytelling with both AEIOU and 5W1H techniques were introduced to help provide distinct perspectives and profound knowledge about the solution concepts with target audiences in mind. Finally, the chosen resolution was realized by prototyping and testing. A case study was demonstrated to present how this newly developed approach works.

Keywords: Design thinking, Creative thinking tools, Product design, T-shaped talent

1. Introduction

Leonard-Barton (1998) mentioned that major enterprises (e.g., Microsoft, HP, and Motorola) prefer to recruit T-shaped talents, which involve expertise and experience in a certain field as well as the capacity to collaborate across different fields (Hansen, 2010). Brown (2008) also observed that with increasing complexity in products, services, and experiences, interdisciplinary collaborators can replace genius-type talents in the past, and that such talents and capabilities are the personality traits that make a design thinker.

Design thinking places emphasis on systematic thinking processes for user-centered designs and the utilization of the 3Is (inspiration, ideation, and implementation). With constant interactions in both divergent and convergent thinking, design thinking produces innovative solutions that meet user needs (Brown, 2008; Brown & Wyatt, 2010). However, without the aid of suitable design or creative tools, difficulties in problem definition and overly limited concepts become common occurrences in conceptual development processes.

This study then employed the six steps of design thinking (understand, observe, point of view, ideate, prototype, test) proposed by d.school, Stanford University (Hasso Plattner Institute of Design at Stanford, 2007; Carroll, Goldman, Britos, Koh, Royalty, and Hornstein, 2010) as the framework and added appropriate creative tools to help develop innovative solutions which can take the consumer’s needs, technological feasibility and business sustainability into account.

The remainder of this paper is structured as follows. Firstly, relevant literature review is introduced. This is followed by description of the Design Thinking based Product Design Process in details. Thirdly, a case study on EGF application is provided. Finally, conclusions are presented.

2. Literature Review

2.1 T-shaped Talents

David Guest coined the term “T-shaped talents” in his article "The Hunt is on for the Renaissance Man of Computing" (Guest, 1991). Leonard-Barton (1998) defined T-shaped talents as a group of people with both technological and commercial abilities and the capacity to analyze commercial data and provide better service alternatives. Tim Brown explained that the vertical stroke in the T symbolizes their expertise and experience in a certain field; in contrast, the horizontal stroke represents their interdisciplinary capabilities (Hansen, 2010). Having deep knowledge in their profession, T-shaped talent, drawn more attention and welcomed in the workplace, is also able to apply knowledge across situations and work collaboratively across disciplines. With both depth and breadth in their skills, T-shaped professionals are then the driving forces to innovation.

2.2 Design Thinking

The concept of design thinking was proposed by Bryan Lawson in the book How Designers Think and later applied by Nigel Cross and Peter Rowe to general education and architecture. Professor Rolf Faste began offering a design thinking course at Stanford University, and David M. Kelley incorporated management and commercial design into the course. As of today, design thinking has become a subject of interest in various fields. Design thinking is an iterative design process that encompasses three spaces (inspiration, ideation and implementation) (Brown, 2010). It emphasizes that designers must abandon their preconceptions and intuitive thinking patterns and divulges problems via observation and empathy. At the same time, they must also consider the needs and behaviors of the users, technology feasibility as well as the market sustainability of the product or service (Brown, 2008).

However, there are no specific procedures or tools for the design process (Brown, 2008; Brown et al., 2010). Without such aids to help define problems, it is easy for designers to be easily limited by their own preconceptions and interpret the problems from a personal perspective (Thomsen, 2013). Thus, the lack of appropriate tools to assist the concept development stage means that concept generation will easily be limited.

To address this issue, some general guidelines are developed. For example, six steps were developed for design thinking in education based on the applications of design thinking at the Stanford University's d.school and in K-12 exploratory education environments: understand, observe, point of view, ideate, prototype, and test (Carroll et al., 2010). Understand involves the use of interviews with experts and data collection to facilitate the understanding of the design problems and challenges while exploring background knowledge. Observe involves observing the environment with empathy and then presenting questions to the users to determine their needs. Point of view integrates the first three steps by setting target users and defining their needs. Ideate involves conceptual creation based on user needs. Prototype involves making a conceptual prototype using sketches, cardboard boxes, and models. The prototype is then tested, followed by conceptual optimization based on feedback (Carroll, et al, 2010).

2.3 9-window Method

The 9-window method is also known as Mandala, a term that comes from Buddhism, and is a nonlinear thinking tool. It uses the optimum stress in stimulation reactions and its interactions with relaxation psychology to break cognitive inertia and thereby train personal creativity (Imaizumi, 1999). In addition to helping users enhance their thinking level, it has systematic rules that help users become familiar with it quickly (Chen, 2005) and also effectively improves the associative abilities of users (Lin, 2006; Li, 2009). At present, common application of this method can be seen in education, artistic design, business administration, and spiritual inspiration.

The 9-window method can basically be divided into two forms: radiant thinking, which is a divergent thinking approach that assists in ideation using lateral thinking, and spiral thinking, which facilitates induction and organization using vertical thinking (Imaizumi, 1999; Li, 2009). The subject is first diverged and associated to the first layer, producing eight elements that are then diverged again to the second layer, which produces 64 elements. The number of layers in the 9-window method can be adjusted freely. Once the divergence is completed, convergence is performed. Four principles must be followed during the process: (1) make note of any inspirations, (2) fill the blanks with concise words, (3) focus on the completed 9-window method to continue gaining inspiration, and (4) discard any unsuitable concepts (Imaizumi, 1999).

2.4 Collaborative Design

One of the important factors in a design thinker's personality is the ability to work collaboratively. The best design thinkers need to work along together with other disciplines to collaborate their own significant experience. With design thinking, they have become the enthusiastic interdisciplinary collaborators (Brown, 2008). And one of the important spaces in design thinking process is ideation – the process of generating ideas that may approach potential solution (Brown, 2008). Some memory models in cognitive psychology indicated that in order to produce more ideas group should be more effective than individuals' efforts. As a result, there has been an increasing attention on developing more effective methods for idea generation such as Brainsketching, C-Sketch, 6-3-5, and Gallery Method (Linsey, Green, Murphy, Wood and Markman, 2005; Linsey, Clauss, Kurtoglu, Murphy, Wood and Markman, 2011). Among those methods, C-Sketch is considered as a progressive idea generation method especially in design related fields (Kulkarni, Summers, Vargas-Hernandez and Shah, 2001).

C-Sketch Method, a. k. a. Collaborative Sketching, is an effective idea generation method that was proposed firstly in 1993 in the Design Automation Lab (DAL) at Arizona State University (Shah, 1993). After that, it was renamed from 5-1-4 G to C-Sketch, which was an effort for the graphical brainstorming for solutions to design problems (Kulkarni, et al, 2001). C-Sketch Method is slightly different from 6-3-5 Method, which requires individuals to describe ideas through using words only, in requiring each participant describes ideas by sketching only in a limited time then pass to another participant (Linsey, et al, 2005; Linsey, et al, 2011). C-Sketch, through some experimental results, is shown to be more effective than other idea generation methods such as Gallery Method and Method 6-3-5 to perform the quality and variety of designs (Kulkarni, et al, 2001).

3. Design Thinking Based Product Design

This study integrated design thinking initiatives and creativity tools to develop a design thinking based product design process. The six steps of design thinking proposed by Carroll et al. (2010) (understand, observe, point of view, ideate, prototype and test) served as the core framework. Different creative tools were placed in the various steps so as to help users complete the tasks in each step. In understand, users can understand the problems and challenges via data collection and expert interviews and thereby quickly grasp relevant background knowledge. In observe, they conduct actual market research and interviews and divulge customer needs as well as usable technologies and products. In point of view, users integrate and analyze data to clarify user needs and design problems. In ideate, they use the 9-window method to diverge idea combinations and create sketches and employ AEIOU and 5W1H to define the usage environment, functions, and target customers of the design concepts. Then, they use scenario-based design to depict character features and scenario stories to generate user-centered design concepts. Finally, the prototype is tested to help users in producing design solutions that accept technical limitations and fulfill user (market) needs. The details of the procedure are as shown below, and Fig. 1 displays a flowchart of the design thinking process.

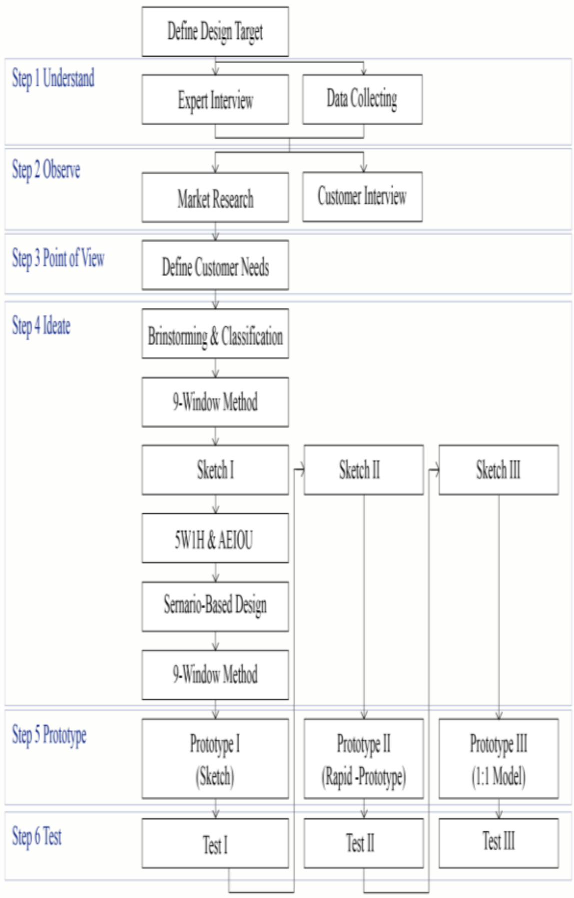

Fig. 1 Framework of this study

Step 1 Understand: After the design goal has been set, this step is divided into two phases to help users understand the problems and challenges in the field: (1) search for relevant references and data based on three questions: what is it, what can it do for us, any application in our daily life and understand the background, technology, and limitations of the industry; (2) invite field experts to engage in exchange and problem clarification. This step helps users quickly grasp relevant technology features to aid in the subsequent market research, interviews, and idea generation.

Step 2 Observe: Compile the data obtained in Step 1, and conduct actual market research to look for other usable products and technologies and understand whether products associated with said technologies already exist on the market. Then, use methods such as interviews to understand and divulge customer (market) needs, which help the users in defining the design problems and customer needs from the perspective of user-centered design.

Step 3 Point of view: Integrate and analyze the data from the two previous steps, and define customer needs and the design problems. Step 4 Ideate

4-1 Brainstorming and classification: Brainstorm on the market products, technologies, background knowledge, and usable products derived in the first three steps and give brief explanations on post-it notes. Categorize and number them as the elements of the first layer in the 9-window method. This step helps users focus and fulfill the usable technologies or products that meet the needs of the technologies in the field during the concept divergence process.

4-2 9-window method: This step helps users break cognitive inertia to develop creative concept combinations and find creative design concepts from within these combinations. During this step, the users place the design subject in the center of the 9-window chart and put the categories derived in Step 4-1 in the boxes of the first layer of elements. The elements of the first layer are then placed in the boxes of the second layer for divergence. During the process, brief descriptions should be made intuitively until the form is completed, regardless of whether they are correct. The users can define any number of divergence layers. If there are fewer than eight categories, then other elements are used to fill out the boxes before divergence. Finally, the convergence of the 9-window chart starts from the outmost layer toward the center. Aside from the central subject of each layer, two other elements must be selected for idea combination generation. The written format of idea combinations is "Subject = Element 1 + Element 2 + Element 3 + … + Element x." This step helps users generate more creative solutions during ideation. The 9-window chart is showed in Figure 2.

4-3 Idea sketching: This part involves sketching the idea combinations obtained in Step 4-2 using C-sketch and writing down the idea combination and code on the top of the paper. This reveals the context that can be followed during the ideation process and also facilitates the later induction and organization. The number of C-sketch exchanges is based on the number of team members (for example, if there are three team members, then three exchanges are made). In this step, a three-round C-sketch is performed: (1) after the first round, a group discussion is conducted to select and propose the optimal concept, which is then discussed with experts to clarify the technical limitations and the feasibility of the concept; (2) based on the feedback derived in the first round, the optimal concept is subjected to the second round of design concept optimization followed by expert discussion; (3) further design concept optimization is then performed based on the expert feedback from the second round. This step helps users generate technologically feasible design concepts that meet customer needs. Visualizing the design concepts can facilitate group discussion and the later definition of concept functions.

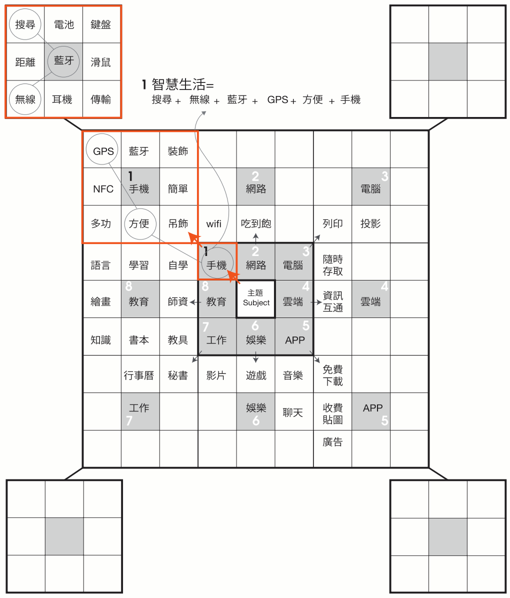

Fig. 2 9-window chart

4-4 AEIOU and 5W1H: Based on the optimal concept selected in the first round of c-sketch in Step 4-3, the usage environment, components, functions, mechanisms, and target customers of the design concept are then defined using AEIOU (activity, environment, interface, object, user), which helps the users define target customers and products (services). The usage environment, functions, and usage methods of the product are then examined using 5W1H (who, where, what, when, why, how), which helps clarify the requirements of the design concept so that the design is more detailed and complete and so that the user can construct the later personas and scenarios. The 9-window chart with AEIOU & 5W1H is showed in Figure 3.

4-5 Scenario building and storytelling: This part involves writing the persona of the target customers obtained in Step 4-4 and giving brief but specific descriptions of their basic characteristics (name, gender, occupation, education, hobby and personality). With who, where, what and when as the focus, the procedure framework of the scenario is written down, and a brief description of the problems that customers may encounter in specific situations when they use the product (service). The scenario framework is then refined using text or images, which assists users in discussing and exploring scenario problems for design concept optimization and prototype construction. Chart for scenario building and storytelling are showed in Figure 4.

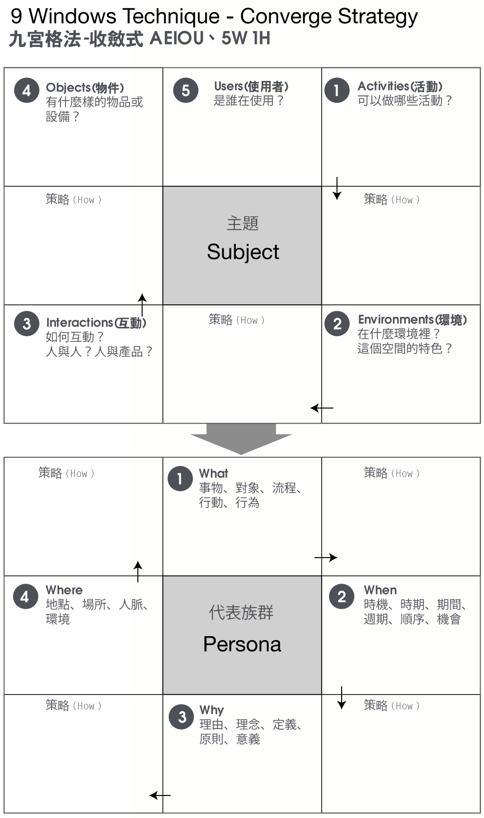

Fig. 3 9-window chart with AEIOU & 5W1H

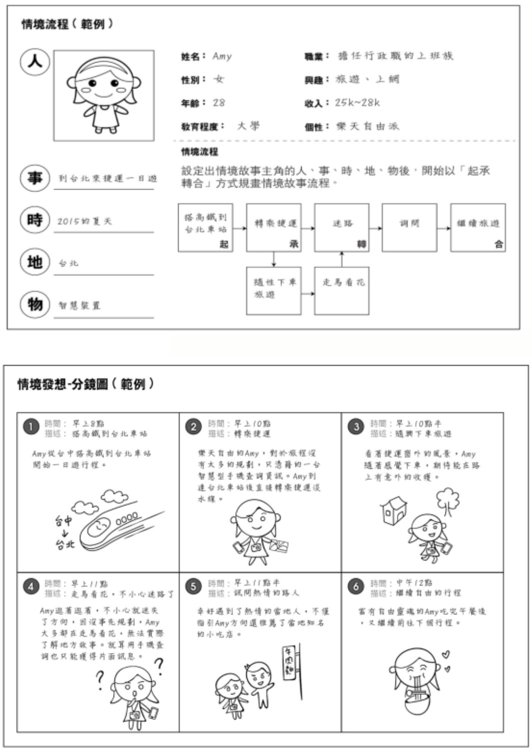

Fig. 4 Charts for scenario building and storytelling

Step 5 Prototype: This step integrates the results of the previous steps for design concept optimization and model construction, which assists design teams in determining whether the design meets the needs of target customers during the construction process and whether any revisions and improvements are needed during the usage process. This step is executed three times: (1) using sketches to visualize the concepts, (2) using sketches and 1:1 rapid-prototypes to help the users determine whether concept needs any improvements in aspects such as size, function, or mechanism, and finally, (3) using sketches, 1:1 models, rendering of the product, package designs, and relevant introductions (such as usage processes) to fully present the design concepts.

Step 6 Test: This step uses concept tests for both experts and target customers to help make the design concepts more focused and confirm whether the concepts meet market and user needs and whether they can be used effectively. This step requires three rounds of tests: (1) the first proposal and expert discussion are conducted with the optimal concepts obtained in the first round of Step 4-3, which helps the users in understanding the pros and cons, feasibility, and marketability of the design concepts; (2) based on the expert feedback derived in the first round, a second round of design concept optimization is performed using c-sketch, followed by discussion where one optimal design concept is chosen for the 1:1 rapid-prototype, and the second proposal and expert discussion are conducted; (3) finally, based on the expert feedback derived in the second round, 1:1 models, rendering of the products, package designs, and relevant introductions are made for proposal. This helps the users in creating design concepts that are technologically feasible and meet target customer (market) needs from a user-centered perspective.

4. A Case Study on EGF Application

The study was performed during the Industrial Design course of the first semester of the 2016-2017 academic year and lasted a total of ten weeks. The design topic was epidermal growth factors (EGF), which was provided by the client (a biochemistry expert). The goal was to apply the client's EGF production to generate innovative EGF products in commercial markets. There were 12 graduate students (divided into four groups), 1 design expert, and 1 biochemistry expert, participating in this study. The Design Thinking based Product Design process was proposed and chosen for this study. The results were as follows.

Step 1 Understand: After the design topic is defined, this step helped the participants quickly understand the industry and correctly define the design problems and develop the design concepts. This step was divided into two phases. The participants first gained an understanding of the EGF background, technology, and current market by collecting information on their own. Interviews with the expert (in this phase, the interviewee was the biochemistry expert, who was also the client) helped them understand new and conventional manufacturing processes, the types of wounds EGF can be applied to, costs, required sales, methods of preservation, shelf life, and its advantages.

Step 2 Observe: In this step, the participants performed actual market research and interviews based on the information they obtained in the previous step to divulge customer needs and usable technology and products, which helped them define the design problems from the perspective of the target customers. After compiling the information, they discovered that currently EGF technology is mainly used in beauty care and wound care; EGF can accelerate healing and improve skin condition. Based on these results, the participants then conducted actual market research and interviews in corporate channels associated with cosmetics.

Step 3 Point of View: After compiling and analyzing the results of the information searches, expert interviews, and actual market research, the participants defined the design problems and customer needs. In this case study, the design problems were defined as follows: (1) how do customers accelerate healing and reduce discomfort after micro-cosmetic surgery? (2) How can bacteria growth be reduced in beauty care products? (3) No beauty care product combining beauty bars and skin care products exists on the market yet.

Step 4 Ideate

4-1 Brainstorming and classification: The participants then brainstormed regarding the current products, possibly usable products, and technologies derived in the three previous steps, briefly described them on post-its, and then categorized them as the first layer of elements in the 9-window method. In this case study, the participants produced a total of 31 elements and divided them into four categories: skin care products, skin care tools, beauty care, and getting rid of the old to make way for the new (details in Fig. 5).

4-2 9-window method: Using the 9-window method, the participants diverged and converged the information obtained in the three previous steps to generate idea combinations in hopes of producing creative design concepts. With EGF as the central focus, the number of categories obtained in the first layer in Step 4-1 was less than eight, so four other elements associated with EGF technology were added (cosmetics, healthcare, trauma, and regeneration) to fill in the first layer of boxes in the 9-window method. The first layer of elements was then placed in the second layer for divergence, which was then followed by convergence. This case study produced a total of 9 idea combinations (details in Table 1).

Skin Care Products		Skin Care Tools	Beauty Care	Getting rid of the old to make way for the new
Hand Mask	晚安瓶	Shower Ball	Nail Polish	Face Washing Machine
Lip Mask	Toner	Wet wipe	Bath Lotion	Shaver
Mask	Finger Stall	Tissue	Dark Spot Corrector Pen	Deep Cleaning Pore Strips
Foot Mask	Lotion	Beauty Bar	Make-up Pad	Blackhead Remover Gel
Eye Mask	Capsule	Make-up cotton	Lipstick	Razor
Eye Cover		Ball		Hard Skin Remover
Lip Balm				File a Foot
				Pimple Clips

Fig. 5 The detail of brainstorming and classification

4-3 Idea sketching: The participants sketched and coded the idea combinations obtained in Step 4-2 to facilitate discussion and organization. Six of the idea combinations were chosen for brainstorming using C-sketch and divided into two major groups, ABC and EFG, before brainstorming and sketch coding (Table 2). During C-sketch, the six idea combinations A, B, C, E, F, and G were exchanged three times. In the end, a total of 18 design concepts were produced.

The design concept C-A-B developed from idea combination C was chosen for sketch optimization. For the sake of portability, the original can design was changed to a pen design and combined with a facial massage tool. The optimized sketch was then numbered as C-A-B-1. Another C-sketch was performed, and the final number chosen was C-A-B-1-c-b-a (Table 3) for the first proposal and expert discussion. Discussion revealed that the problems with the design included cleaning after use, discharge of EGF ball waste, fixing the balls in place, the means of ensuring that the EGF balls will burst, and finally, whether bursting and spraying will be better than bursting alone. The design was optimized based on the first expert feedback to determine whether any functions or components needed to be added or removed. After discussion, the original design was changed to a detachable design; after use, washing the massage head would clean off the EGF ball waste. Wall tubes stabilized the tubes, slide rails controlled the dispensation of the balls, and bursting them used the EGF balls. The resulting optimized sketch code was C-A-B-1-c-b-a, which was used in the second proposal and expert discussion (details in Table 3). Discussion of the mechanisms and ease of use prompted the slide rail design to be changed to a turntable. Refills were made using a soft silicon tube. The final design sketches are as shown in Fig. 8.

Table 1 Idea Combinations and Coding

No.	Idea Combinations	Code
1	Brow growing + Makeup + Brow pencil + Pigmented adhesive crayon + Body painting + 3D Printing	/
2	Beauty tools + Hair dye + Facial massage + Ion (skin) cleansing + Hole + Psychologist	/
3	Regeneration + AI + Human cloning + Earthworm + Soil + Tail Regeneration	E
4	Getting rid of the old to make way for the new + Teeth whitening + Blue light + Alpha-hydroxy acid + Albinus' muscle + Face-blotting papers	C
5	Joint surgery + Shavers + Cover + Wound + Spring + Airbag	A
6	Regeneration + Beauty + Hydrogen Peroxide Solution + Sticker + Tattoo + Deform	G
7	Medical + Makeup + Band-aid + Needle + Tourniquet + Drip + Rocket launcher	B
8	Skin care + Sleeping pack + Laser + Mole removal + Spot corrector + Pen	F
9	Makeup + Lipstick + Concealer + Orthodontics + Mydriatic + Eye contact	/

Table 2 C-sketch code sequences and categories

Group	Member	Sketch sequences and code numbers					
ABC	Member A	A	A-B	A-B-C	A-B-C-1-a	A-B-C-1-a-b-c	A-B-C-1-a-b-c
	Member B	B	B-C	B-C-A	B-C-A-1-b	B-C-A-1-b-c	B-C-A-1-b-c-a
	Member C	C	C-A	C-A-B	C-A-B-1-c	C-A-B-1-c-b	C-A-B-1-c-b-a
EGF	Member E	E	E-G	E-G-F	E-G-F-1-e	E-G-F-1-e-g	E-G-F-1-e-g-f
	Member G	G	G-F	G-F-E	G-F-E-1-g	G-F-E-1-g-f	G-F-E-1-g-f-e
	Member F	F	F-E	F-EG	F-E-G-1-f	F-E-G-1-f-e	F-E-G-1-f-e-g

4-4 AEIOU and 5W1H: The participants used AEIOU to define the usage environment, function, components, and target customers of the design concept and then re-examined the product functions, usage method, and necessity of the concept using 5W1H. In this case study, people who pay attention to their appearance were set as the target customers. The movable mechanism design enables facial care at home, outdoors, or during travel at any time. The small size of the product makes it easy to customers to carry it with them, and the EGF balls are dispensed at fixed quantities to reduce wastefulness and bacteria growth. Finally, using steel balls can increase the absorption rate of the beauty care product (details in Fig. 6).

Table 3 Sketches of concept development in Group C

Sketch			
Codes	C-A-B-1-c	C-A-B-1-c-b-a	C-A-B-1-c-b-a concept optimization

How Can carry everywhere	What Beauty care	How EGF Beauty care balls
Where Everywhere	The person who care their face	When Go out, travel, at home
How Increase the speed of absorb by massage	Why Increase the effect of facial care	How When we doing the facial care

Object Two step turntable, valve ,ball	Users The person who care their face	Activities Facial care
How Manual control	EGF Getting rid of the old to make way for the new + Teeth whitening + Blue light + Alpha-hydroxy acid + Ibinus' muscle + Face-blotting papers	How Massagers
Interactions Movable mechanism	How Go out, travel, at home	Environment Everywhere

Fig. 6 AEIOU and 5W1H

4-5 Scenario building and story telling: After us-ing AEIOU and 5W1H to define the products and the target customers, scenario-based designs and personas assisted the participants in creating us-er-centered op-timized design concepts and explor-ing scenario prob-lems. In this case study, people who pay attention to their appearance were set as the target customers. To refine character features, the scenario process frame-work was based on the following: On Sunday after work (when), Joanna (who) goes home (where) to use her EGF face mas-sager (what) to perform her daily facial care (why). The process framework was then further refined to divulge the scenario problems. In this stage, the par-ticipants did not find any scenario prob-lems (Fig. 7).

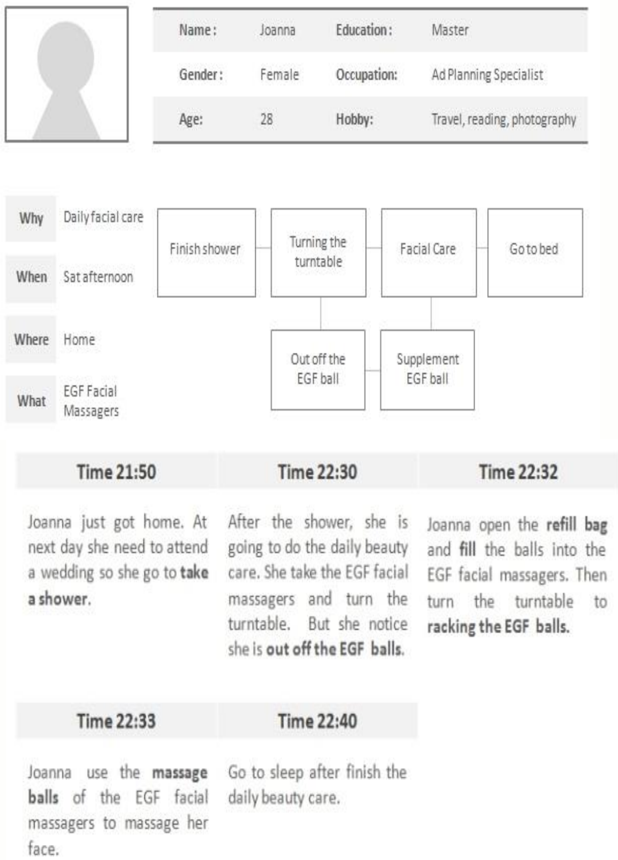

Fig. 7 Persona and scenarios

Step 5 Prototype: Following the compilation of the information from the various stages and design concept optimization was model construction, which helped the design team in re-examining whether the design met their needs and whether any revisions or improvements were necessary. The final concept de-signs produced by this case study are as shown in Figs. 8 and 9.

Step 6 Test: This step helped to confirm whether the design concepts meet technological limitations, market needs, and the needs of the target users. This step includes two concept proposals, two expert dis-cussions, and one achievement proposal. Two experts served as advisors during the process, an industrial design expert and a biochemistry expert.

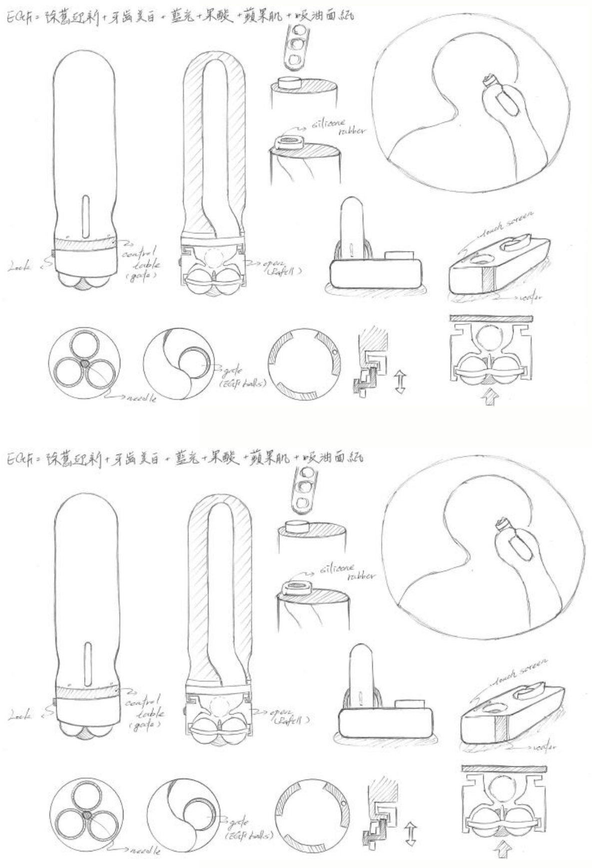

Fig. 8 The final design sketch

Fig. 9 EGF massager

5. Conclusion

This study employed the six steps of design thinking proposed by Carroll et al. (2010) as the research framework and added appropriate innovation tools to develop a structured design thinking process. Understand and observe help users quickly grasp background knowledge and divulge user (market) needs to clarify customer needs and design problems (point of view). Subsequently, the 9-window method is used to break cognitive inertia for the development of design concepts, and sketches are made. The concepts are designed using AEIOU and 5W1H, following which character features and scenario problems are described using scenario-based designs to divulge scenario problems (ideate). Finally, testing is performed using the prototypes, which helps the users create design solutions that accept technological limitations and fulfill user (market) needs. With the integration of design thinking and innovative thinking tools, users have steps to follow and tools to use. In addition, the preliminary procedures of the structured design thinking process can serve as reference for designers and assist designers and developers in brainstorming design concepts systematically. The design concepts proposed in this study serve as the initial stages of the design concept stage for product development. Limited by time and space, we did not include the actual user data and did not consider the costs, manufacturing factors, or feasibility of the design concepts. We will continue in this direction in later research.

6. Acknowledgements

We thank the Ministry of Science and Technology, Taiwan for funding this project, project no. MOST 105-2221-E-131-024- and MOST106-2221-E-131-017-. We also thank the anonymous reviewers for their valuable suggestions, which improved this study. Finally, we thank Professor Liang-jung Chien, Shih-chen Lai, and Zi-han Li for their participation and efforts, which made this study progress more smoothly.

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