A New Design Thinking Model Based on Bloom’s Taxonomy

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A superior design thinking model can improve the quality of design education. In recent years, universities and design institutions already proposed many design thinking models around the world. Existing well-known design thinking models focus on cultivating students’ creative thinking but ignore the product’s inherent characteristics and users’ demands. This paper proposes a step-by-step design thinking model based on Bloom’s taxonomy, which is divided into lower-level and higher-level considerations. The lower-level consideration includes remembering, understanding, and applying, and the higher-level consideration includes analyzing, evaluating, and creating. The former integrates the function analysis method, form restriction method, and Evaluation Grid Method (EGM) to help students understand the target product and its users. The latter first evaluates any existing alternatives by using the AHP and then further redesigns the color and material of the highchair to provide an optimum solution. A highchair was used as the example product for classroom teaching. Classroom teaching results showed that the new design thinking model can help students understand target products and user demands, thereby improving the concept design’s feasibility.

Keywords: Bloom’s taxonomy; Design education; Design thinking model; AHP; EGM;

1 Introduction

In the 21st century, with technological advancements and changing user demands, the life cycle of products has gradually shortened. Many enterprise managers realized that a superior design could extend the product life cycle, thereby bringing greater benefits to the enterprise. An excellent design talent must include basic skills, good design thinking, creative thinking, critical thinking, and metacognition (Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., Rumble, M., & Rumble, M., 2012). The International Council of Societies of Industrial Design has also emphasized that cultivating students’ thinking skills are more important than cultivating their technical skills (Cartier, 2011).

Design thinking is an activity that is implicit in the process of design. However, design thinking emerged only in the latter part of the twentieth century (Koh, J. H. L., Chai, C.S., Wong, B. and Hong, H. Y., 2015). According to Kimbell (2011), one of the earliest book-length treatments of the concept was in Peter Rowe’s Design Thinking, published in 1987. Brown (2008) and Denning (2013) regard design thinking as an iterative process that can quickly develop and test multiple possible alternatives and finally obtain an optimal solution. Design thinking is a people-oriented approach to solving problems. However, the design thinking model has become an effective toolkit for the innovative design process, integrating various design tools and methods into the design process. Design thinking is a process that provides designers with abstract divergence and convergence of ideas. The design thinking model is a concrete toolkit. Modula design thinking has different stages and provides a structured framework (Sandars & Goh, 2020). After years of development, numerous design organizations and design colleges have proposed several classical design thinking models; these can clarify the design innovation process to provide a reference for designers or students. Tschimmel (2012) and Sandars and Goh (2020) analyzed several well-known design thinking models, including the 3 I model (Brown, 2008), the HCD model (http://www.ideo.com/work/human-centered-design-toolkit), the Double Diamond model (http://www.designcouncil.org.uk), the Design Thinking model of the Hasso-Plattner Institute (http://www.hpi.uni-potsdam.de/d_school/designthinking), and the Service Design model (Stickdorn &
In particular, the 3 I model involves three stages: inspiration, ideation, and implementation.

HCD model also involves three stages: hearing, creating, and delivering. The Double Diamond model involves four stages: discover, define, develop, and deliver. The Design Thinking model of the Hasso-Plattner Institute involves five stages: empathize, define, ideate, prototype, and test. Finally, the Service Design model involves four stages: exploration, creation, reflection, and implementation. The above-mentioned design thinking model mainly focuses on improving innovation in design activities, but it does not propose the logical relationship of each stage of the design methods according to the design thinking model to help students understand the characteristics of products and users’ underlying demands.

Bloom (1956) proposed a taxonomy of educational objectives based on the perspective of cognition, which summarized educational goals into six stages: remembering, understanding, applying, analyzing, evaluating, and creating. Specifically, these six stages are a process from simple to complex, from abstract to concrete. Ben-Zvi and Carton (2008) applied Bloom’s taxonomy to business courses. Lajis & Aziz (2018) proposed a model for evaluating computer students’ learning efficiency based on Bloom’s taxonomy. Sharunova et al. (2020) applied Bloom’s taxonomy to engineering design courses and experimentally verified the effectiveness of Bloom’s taxonomy. The abovementioned literature confirms that Bloom’s taxonomy could improve teaching quality regarding various subjects. However, few scholars have combined Bloom’s taxonomy with design education. Therefore, if a series of effective design methods could be integrated into it based on the six levels of Bloom’s taxonomy, a useful step-by-step design thinking model could be proposed. This research is based on Bloom’s Taxonomy’s design thinking model. In the new design thinking model that understanding consumers’ demand it’s a very important part. In the product innovation design stage, students understand consumers’ demand through Evaluation Grid Method (EGM) interviews and sort out the three-layer hierarchical diagram to obtain design reference standards and program evaluation standards.

This study’s proposed design thinking model is divided into two levels: lower-level and higher-level considerations. The remainder of this paper is organized as follows. Section 2 describes the methods and theories involved in the new design thinking model, and Section 3 describes the implementation procedures for applying this design thinking model. Section 4 uses the product example of design the highchair involving in-class teaching as a case for describing how students carry out design activities based on these six stages. Finally, the last section provides this study’s conclusions.

2 Theoretical background

This section describes the theoretical background related to the research of design education. It includes Bloom’s Taxonomy, EGM, QTT I, function analysis method, form restriction method, and analytical hierarchy process. The aim is to clarify the new design thinking model and establish the basis for the case study by the theoretical background.

2.1 Bloom’s Taxonomy

Bloom’s taxonomy was first proposed by Bloom (1956), and Bloom’s taxonomy includes three regions: cognition, emotion, and spirit (Anderson & Krathwohl, 2005). Among these, the cognition field is the most influential (Lahtinen & Ahoniemi, 2005). Subsequently, Bloom’s students and other researchers revised Bloom’s taxonomy. The revised taxonomy has been expanded to a two-dimensional matrix that combines successive knowledge with cognitive processes. The knowledge dimension represents from the concrete to the abstract, and the cognition dimension represents the assumption of complexity. This paper mainly uses the six stages of Bloom’s taxonomy in the cognitive field along with design methods for generating a new design thinking model. The six stages are remembering, understanding, applying, analyzing, evaluating, and creating (Haring, P., Warmelink, H., Valente, M., & Roth, C., 2018). This research is based on Bloom’s Taxonomy’s use of EGM as the understanding part of the design thinking model. Therefore, the students obtain design reference criteria and evaluation criteria through the three-layer hierarchical diagram in the product innovation design stage. The design method used in this study follows Bloom’s Taxonomy of design thinking models. The bold fonts as shown in Table 1 are the design methods applied in this research. The previous three stages were designated as the lower-level design thinking processes, which use the emanative design methods; The last three stages were designated as higher-level design thinking processes, which use the convergent methods (Narayanan & Adithan, 2015).
Table 4. The design thinking model follows Bloom’s Taxonomy (this research collated).

<table>
<thead>
<tr>
<th>Level</th>
<th>Design Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remembering</td>
<td>Literature Review, Data Collection, User diary;</td>
</tr>
<tr>
<td>Understanding</td>
<td>Evaluation Grid Method, Form Restriction Method, Function Analysis Method, Focus Group, Persona, Affinity Diagram, Scenario story, Brainstorming, Quantification Theory Type I, Competitive product analysis;</td>
</tr>
<tr>
<td>Applying</td>
<td>Prototype Design, Freehand Sketch, 3D modeling, Experience prototype, Service blueprint;</td>
</tr>
<tr>
<td>Analyzing</td>
<td>Comparison matrix, Factor Analysis, Regression Analysis;</td>
</tr>
<tr>
<td>Evaluating</td>
<td>Analytical Hierarchy Process, Grey Relational Analysis, Pugh, Fuzzy Comprehensive evaluation method;</td>
</tr>
<tr>
<td>Creating</td>
<td>Advance Design, Test Iteration;</td>
</tr>
</tbody>
</table>

The six stages are based on knowledge understanding, and they include continuous learning ranging from simple domains to complex domains. Each stage is followed by a knowledge ladder based on lower-level learning. After that, the middle-level is more complex than the previous stages, which is a prerequisite of different stages. Furthermore, the accumulated stage means that each higher-level stage contains the cognitive behavior of the next stage (Fig.1). Bloom’s taxonomy is used for teaching in different faculties, and it can improve students’ understanding and cultivation of learning skills; it can also enhance their critical thinking (Nentl & Zietlow, 2008). This study uses Bloom’s taxonomy to integrate innovative course-teaching cases with progressive thinking processes and design thinking.

2.2 Miryoku Engineering and Evaluation Grid Method (EGM)

Miryoku engineering was proposed by a Japanese scholar Masato Ujigawa and his group, in 1991; it aims to focus on consumer preferences, and the main design concept involves creating attractive products (Ujigawa, 2000). Students can use in-depth interviews to identify attractive factors that attract users when they choose products and the products’ charming elements, which can be comprehended in order to create popular products (Asano, 2001). Thus, Miryoku engineering is a method that applies consumers’ image feelings toward product design and transforms them into design elements. Miryoku is a vague concept that cannot be measured with specific tools. Moreover, the evaluation grid method (EGM) is used for analyzing products’ charming factors, which attract users; this allows designers to produce a three-layer hierarchical diagram. Students can use the acquired magnetic elements in the design to greatly enhance users’ satisfaction. The EGM is one significant research method from the Miryoku philosophy of engineering; it is based on the psychologist’s Repertory Grid Method of Kelly in 1986 (Kelly, 1955), and it was proposed by Japanese scholars Junichiro Sanui and Masao Inui. EGM can transform interviewees' abstract emotions into concrete emotions and capture users' emotions regarding products through in-depth interviews. First, participants were invited to compare and evaluate the merits of selected product sample photos during interviews, which aimed to obtain original evaluation items based on interviewees’ perspectives and senses. Second, through repeated actions, EGM can classify the three-layer repertory of abstract reasons (upper layer) and original evaluation items (middle layer), which connect consumers’ emotional attitudes and product concrete conditions (lower-layer) (see Fig.2) (Imai & Kawamura, 2009). Finally, Students organized interview data and structured a three-layer hierarchical diagram, which carefully analyzed attractive product elements that attract consumers (Chen et al., 2012). This research is based on Bloom’s Taxonomy’s use of EGM as the understanding part of the design thinking model. Therefore, students will use the emanative thinking higher weight lower layer (CEI) items of
the three-layer hierarchical diagram as design criteria and use them as design references in the product innovation design process. The middle layer (OEI) is used as the evaluation standard to evaluate the design cases so that students can accurately grasp the consumers’ demand and design evaluation standards.

Figure 3. A three-layer hierarchical diagram.

2.3 Quantification Theory Type I (QTT I)
Quantification theory type I (QTT I) is a qualitative multiple regression analysis that involves categorical multiple regression analysis methods, which can be used for establishing the mapping relationship between the independent variable X and the dependent variable Y, and furthermore, for predicting the dependent variable Y (Hayashi, 1950). In previous studies, QTT I was used for analyzing the data generated by EGM, based on the credibility of set charming factors and the classification results and correlation index (Ho & Hou, 2015). The purpose of QTT I is to establish a relationship between adjective semantics and design considerations in order to find an approximate function of the variable of a purpose and other qualitative independent variables. Multiple regression analysis methods were used for detecting the intensity of each qualitative item’s influence on the variable (Wang, 2009). Each qualitative variable contains several question items that can be used for establishing regression formulas. In this study, students need to converge the collected design elements and find out the design criteria the lower layer (CEI) with high weight through QTT I to help them clarify which special charming factors can be used during the creative design stage to catch consumer demand.

2.4 Function Analysis Method
Previous product design practices have proved that product innovation mainly involves the function analysis method and that it forms restrictions in the scheme design stage. Therefore, designers should focus on the functional analysis of product development. The definition of the function can broaden product innovation and seek out optimum ways for solving the problem. The function analysis method can confirm the basic functions and problem levels of a given product. This analysis method regards the system of the target product as a “black box.” The left end of the “black box” is the “input” of function, and the right end of the “black box” is the “output” of the target that needs to be achieved (Cross, 1994). As shown in Fig.3, the function analysis process should not be limited to the original function system, which should reflect the overall function of the product as much as possible and expand the boundaries of the function system in order to improve the innovation of the target product. The detailed operation steps for function analysis are as follows: 1) According to “input” and “output,” define the overall function of the black box and, as far as possible, enlarge the system border; 2) Decompose the overall function into a series of necessary sub-functions; 3) Draw a frame diagram of sub-functions to display the relationship between them; 4) Plan out reasonable system boundaries; and 5) Find suitable elements for realizing the relationship between the sub-functions (Lu & Hsiao, 2019). This study can discover the functional limitations of the target product through the functional analysis method, which can be combined with consumers’ demand to enlarge the system border innovation product function, which encouraged students to consider whether the functional system met the design aims during the entire design innovation process.

Figure 4. Function “Black Box.”

2.5 Form Restriction Method
Recent literature has shown that the modularization product framework can be applied in multiple ways (Stone, Wood, & Crawford, 2000). Hansen and Lenau (2013) provided the example of behavioral pattern analysis and manufacturing analysis performed by a student team after detaching bicycle gear when participating in a workshop. Students team created a geometric flow chart describing how the bicycle bell would be used. For the team, the most important part when creating a flowchart was identifying individual components and inferring an assembly sequence that confirmed the material and craftsmanship of each component. Furthermore, the most significant element was the practical experience of using these
components. For example, using the weights and temperatures of the hand.

The product model structure follows the modular approach proposed by Seligren (1999), which treats technology as a medium between components and junctions. The component expounded the contact between the function surface and the product form structure. A modular structure can facilitate the modification of the product model structure (Seligren & Andersson, 2005). The diagrammatic rules of the product during the redesign process are shown in Table 2. The internal product for indicating one big part has more than one function. Alternatively, one large part can be divided into several parts. It includes two different geometric figures and lines. The external product focused on the circumstance of the contacted part. It also includes two different geometric figures and lines. The overall flowchart of the process forms a restriction method. Students can use diagrammatic rules for disassembling the analysis and for understanding the structure and model of the product. Students can also find the demerits of the selected product from the flowchart while redesigning the product. This study used restrictions in order to analyze the existing product model and structure, find the problems of product structure, and optimize the solution scheme.

**Table 5. Diagrammatic rules**

<table>
<thead>
<tr>
<th>Internal Legend</th>
<th>External Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moving part</td>
<td>People/body in contact with a part, Ex: hand, foot, eye, etc.</td>
</tr>
<tr>
<td>Non-moving part</td>
<td>Object in contact with a part, Ex: orange, material, water, etc.</td>
</tr>
<tr>
<td>In contact with an internal part</td>
<td>Surroundings in contact with a part, Ex: floor, table, hanger, etc. In contact with an external part.</td>
</tr>
</tbody>
</table>

### 2.6 Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) was first proposed by Saaty in 1980; its main purpose is helping decision-makers select the best solution in an environment characterized by multi-criteria decision making. AHP is a multi-objective analysis method that combines quantitative and qualitative analysis; it can obtain the comparative weight of various options through pairwise comparison and then achieve the evaluation effect (Kubler, S., Robert, J., Derigent, W., Voisin, A., & Le Traon, Y., 2016). The operating pattern of the AHP involves decomposing a complex problem and constructing multiple levels. Participants indicate their overall preference for each decision option, calculate the relative weight of any alternatives and obtain a ranking (Aguilar-Lasserre, A. A., Bautista, M. A. B., Ponsich, A., & Huerta, M. A. G., 2009). Participants actively communicated and reached an agreement by discussing their providing subjective experience, thus ensuring the rigor of the evaluation results. The main operation steps of AHP are described as follows.

- Define the decision problem: First, confirm the purpose of the decision-making problem and then list all evaluation criteria and alternatives.
- Building hierarchical analysis: Resolve complex problems by deconstructing them into multiple hierarchical structures. The first layer is the main goal, the second layer is the evaluation criteria, and the last layer is the alternative. The evaluation criteria are used for evaluating all alternatives, and the evaluation criteria are weighted at the final stage.
- Construct a paired comparison matrix for evaluating the criteria: According to the advice of experts, compare the criteria in pairs and use the nine-point scale in Table 3 to create a decision matrix.
- Obtain the relative weight of the evaluation criteria. There are many ways to calculate weights. For instance, the eigenvector method (EVM), weighted least squares method (WLSM), theoretical analysis, and the geometric mean method. The geometric average method used in this study has high accuracy.
- Consistency testing: The execution result is verified by calculating the Consciousness Relation (CR) when the weight of the evaluation criteria is obtained, as shown in Equation (1).

\[
C.R. = \frac{(C.I.)}{(R.I.)}
\]

\[
C.I. = \frac{(\lambda_{max} - n)}{(n - 1)}
\]
Table 6. AHP scale of 9 points used in the paired comparatives (Satty, 1980)

<table>
<thead>
<tr>
<th>Comparison intensity</th>
<th>Comparison intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equally important</td>
</tr>
<tr>
<td>3</td>
<td>Moderately more important</td>
</tr>
<tr>
<td>5</td>
<td>Strongly more important</td>
</tr>
<tr>
<td>7</td>
<td>Very strongly more important</td>
</tr>
<tr>
<td>9</td>
<td>Extremely more important</td>
</tr>
<tr>
<td>2,4,6,8</td>
<td>Intermediate judgment values</td>
</tr>
</tbody>
</table>

In practice, the accuracy of the weights is determined by decision-makers. Where CI is the consistency index, RI is the random index (see Table 4), n is the order of the matrix, and $\lambda_{\text{max}}$ is the largest eigenvalue of the matrix. The CI of the research problem is compared with the average RI obtained from the n-order random matrix to measure the error caused by the inconsistency. The concordance ratio ($\text{CR} = \text{CI} / \text{RI}$) when CR<0.1, or less, indicates that the judgment matrix is acceptable; otherwise, the paired comparison matrix should be modified (Satty, 1980). This study based on consumer demand, product function analysis, and structure analysis, students applied design criteria to design product cases and establish the alternatives comparison matrix of evaluation criteria through AHP to help students evaluate alternatives and choose the best solution.

Table 7. Table of random indexes

<table>
<thead>
<tr>
<th>Number of criteria (n)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random index (RI.)</td>
<td>0</td>
<td>0.58</td>
<td>0.90</td>
<td>1.21</td>
<td>1.24</td>
<td>1.35</td>
<td>1.40</td>
<td>1.45</td>
</tr>
</tbody>
</table>

3 Implementation procedures of the new design thinking model

The design thinking model based on Bloom’s taxonomy was divided into six stages. The detailed implementation steps are as follows. The specific process framework is shown in Fig. 4.

Stage 1 (Remembering): Students create a design group of 3-5 people in order to construct an information table about the target product through an online survey; next, they use the established information table as a stimulus sample for the subsequent in-depth interview.

Stage 2 (Understanding): First, the design team uses the function analysis method to clarify the functional system of the target product (understand the functional attributes of the product). The form restriction method is then used for analyzing the structure and form of the target product (understand the appearance properties of the product). Furthermore, the evaluation grid method is used for conducting in-depth interviews with professional users in order to acquire a three-layer repertory map (understand the users’ demand).

Stage 3 (Applying): First, students set up a questionnaire with a three-layer repertory map. After that, quantification theory type I is used for analyzing the results of the low-layer (CEI), thus obtaining a set of high weight design criteria as attractive factors with reference values. Finally, a group of alternative schemes is designed based on the analysis results of quantification theory type I, function analysis method, and form restriction method.

Stage 4 (Analyzing): The middle layer (original evaluation item) in the three-layer repertory map is used as the evaluation criteria, and the AHP is used for determining the importance of each evaluation index (evaluation criterion).

Stage 5 (Evaluating): Students uses evaluation criteria to evaluate alternatives and accordingly obtains a priority order for the alternatives.

Stage 6 (Creating): Diversified market demands are satisfied from the perspective of color matching and material innovation redesign.
4 Case study on classroom teaching

In course teaching, teachers usually suggest that students complete the product design in a cooperative manner with three to five other people. Team members work together to ensure the progress and quality of the design process. This study took a set of children’s highchairs as the teaching case in order to illustrate how the student team conducted design practice based on the six-step Bloom’s Taxonomy design thinking model. The detailed implementation steps are as follows.

4.1 Stage 1: Remembering

The design team accumulated the relevant product information from different online retailers (e.g., Jingdong, Taobao, and so on); this included images, seat widths, weights, textures, and table sizes for the product. To ensure that the product sample would be representative, the students were required to select the goods having the highest sales volume as their research samples. Thirty samples were collected. After the group discussion, similar and unrepresentative samples were deleted. Finally, six highchairs from different brands were included within the interview sample (as shown in Table5). Team members sort out and remember product related information of different brands.
Table 8. Information about the target product

<table>
<thead>
<tr>
<th>Brand model</th>
<th>China</th>
<th>America</th>
<th>Japan</th>
<th>Netherlands</th>
<th>Denmark</th>
<th>Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Henryrabbit</td>
<td>Babycare</td>
<td>Farska</td>
<td>Zaaz</td>
<td>Kadi</td>
<td>Chicco</td>
</tr>
</tbody>
</table>

Product images

<table>
<thead>
<tr>
<th></th>
<th>Seat width/ mm</th>
<th>Weight / kg</th>
<th>Texture</th>
<th>Table size / mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>340</td>
<td>13</td>
<td>Wood</td>
<td>480</td>
</tr>
<tr>
<td>America</td>
<td>500</td>
<td>8.5</td>
<td>PLA/Fabric</td>
<td>520</td>
</tr>
<tr>
<td>Japan</td>
<td>460</td>
<td>8</td>
<td>Wood/Fabric</td>
<td>470</td>
</tr>
<tr>
<td>Netherlands</td>
<td>290</td>
<td>10</td>
<td>AL/PLA</td>
<td>400</td>
</tr>
<tr>
<td>Denmark</td>
<td>310</td>
<td>4</td>
<td>PLA</td>
<td>350</td>
</tr>
<tr>
<td>Italy</td>
<td>470</td>
<td>10.5</td>
<td>SUS/PLA</td>
<td>450</td>
</tr>
</tbody>
</table>

4.2 Stage 2: Understanding

4.2.1 Analyze product features through function analysis method

Use function analysis method was made to black-box the functional system of highchairs and broadened the functional system’s boundary, as shown in Fig.5. The input end of the functional system was “A baby ready seat,” and the output end was “Baby after dinner,” which comprised several sub-functions. The functional system of the highchairs obtained by the functional analysis method was divided into two types: foldable and non-foldable. Therefore, team members understood the functionality of the target product.

Figure 6. The function analysis of highchair.

4.2.2 Analyze the product model through form restriction analysis method

First, the design team deconstructed the form and structure of the highchair and inputted this information into a visual flow chart; furthermore, the team used different geometric figures to represent each component’s connection mode. The design team then analyzed the visual flow chart of six products (see Fig.6), in which the numbers 1-6 represented the problems that required improvement. Subsequently, the design team discussed in detail how to solve each problem found, which can be better understand the form and structure of the product.

Figure 7. Form restriction analysis of highchair.

4.2.3 Identify the interviewees and conduct in-depth interviews

The team members invited and interviewed experts and staff members from baby stores. With each member inviting two interviewees, 10 interviewees participated in the study (four men and six women). Before the interview, students were required to introduce the product card and information table to the interviewees (see Table5). After the interviewees understood the samples and then compared them based on experience;
Students and interviewees conducted in-depth interviews where they explained whether interviewees liked it and why interviewees liked it. First, students learned the merit features of the product based on the interview content; this could be used as the original evaluation item (middle layer). The interviewees were then guided to answer the abstract reason (upper layer) and concrete condition (lower layer). Furthermore, the entire interview process was recorded to avoid any “missing information” situations. During the interview, one or two members were responsible for asking the questions, and the other members were responsible for recording the questions and ask the questions. After the interview, the students sorted out a three-layer hierarchical diagram that had a higher frequency of mentions. There were three upper layers, eight middle layers, and twenty-one lower layers in the three-layer hierarchical diagram (see Fig.7). Students regard the middle layer as an evaluation criterion. In addition, the attractive factors with high weight in the lower layer are regarded as important design references. In order to further clarify the degree of importance of the charm factors, it is necessary to invite more users to conduct QTT I questionnaire survey.

![Diagram](https://example.com/diagram.png)

*Figure 8. Interview: A three-layer demand chart form.*

4.2.4 Questionnaire survey and quantitative analysis

An online questionnaire was created based on the three-layer hierarchical diagram. For the three abstract reasons (AEI), the original evaluation item (OEI) was used as the topic, and the concrete condition (CEI) was used as the option. The team members distributed the questionnaires online. A total of 83 questionnaires were collected, of which 70 were valid. Then, the students analyzed the questionnaire data using QTT 1 to clarify the degree of influence of the lower layer on the middle layer. We set the lower-layer (CEI) as the independent variable X and the middle-layer (OEI) as the dependent variable Y. The relationship between the two was established through multiple regression analysis, and the analysis results of this process are shown in Tables 6–8. The coefficient of determination ($R^2$) represents the reliability of the analysis results, the partial correlation coefficient represents the contribution of the middle layer to the upper layer, and the category score represents the contribution of the upper layer to the lower layer. The largest category score was formed by the eight items in Tables 6–8, regarded as a reference for design indicators. During the design stage, the students tried their best to use the eight high weight indexes in the lower-layer for product design. In addition, the OEI (middle layer) was more concrete than the AEI (upper layer) and CEI (lower layer) in the three-layer hierarchical diagram. Moreover, the eight middle layers were more suitable as evaluation criteria.
Table 9. The result of QTT1 regarding convenient

<table>
<thead>
<tr>
<th>Feeling</th>
<th>Item</th>
<th>Category</th>
<th>Category Score</th>
<th>Partial Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convenient</td>
<td>X1 Easy to clean up</td>
<td>Easy to remove plate</td>
<td>0.397</td>
<td>0.364</td>
</tr>
<tr>
<td></td>
<td>X2 Save space</td>
<td>Folding design</td>
<td>0.424</td>
<td>0.556</td>
</tr>
<tr>
<td></td>
<td>X3 Easy to move</td>
<td>Lightweight material</td>
<td>0.513</td>
<td>0.426</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R=0.649, coefficient of determination(R²)=0.421</td>
</tr>
</tbody>
</table>

Table 10. The result of QTT1 regarding warm and fragrant

<table>
<thead>
<tr>
<th>Feeling</th>
<th>Item</th>
<th>Category</th>
<th>Category Score</th>
<th>Partial Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm and fragrant</td>
<td>X1 Good color matching</td>
<td>Pastel tone</td>
<td>0.921</td>
<td>0.599</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leather cushion</td>
<td>0.872</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X3 Good morphological</td>
<td>Curvilinear form</td>
<td>0.561</td>
<td>0.491</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R=0.709, Coefficient of determination(R²)=0.503</td>
</tr>
</tbody>
</table>

Table 11. The result of QTT1 regarding cost-effective

<table>
<thead>
<tr>
<th>Feeling</th>
<th>Item</th>
<th>Category</th>
<th>Category Score</th>
<th>Partial Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost-effective</td>
<td>X1 Functional diversity</td>
<td>Height adjustable</td>
<td>0.508</td>
<td>0.693</td>
</tr>
<tr>
<td></td>
<td>X2 Strong practicality</td>
<td>Folding design</td>
<td>0.658</td>
<td>0.692</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R=0.824, Coefficient of determination(R²)=0.680</td>
</tr>
</tbody>
</table>

4.3 Stage 3: Applying

4.3.1 The space layout of the highchair

The innovative design highchair had a 2D space layout. First, the function of the highchair was deconstructed into a series of sub-function units, including the support unit, load unit, linkage unit, protection unit, and operating unit, and it was represented with different geometric figures. Subsequently, innovative design of 2D space layout based on the design indicators of the high weights lower layer in the EGM, the geometric figures that created different space layout schemes obtained four space layout schemes (see Fig.8). Each space layout scheme had its own innovation, which was embodied in Layout 1. The front of the operation unit and the back of the protection unit were connected through. In Layout 2, the protection unit and the support unit were connected horizontally, and in Layout 3, the linkage unit was situated above the load unit. In Layout 4, the linkage unit and the support unit were connected up and down to the stretchable. Students analyzed the space layout of the highchair; this activity not only improved students' cognition of the product's form and structure but also helped those with feeble sketch skills improve their skills. Thus, it opened their thinking about innovative models.
4.3.2 Use rhino software to build rough product models

In accordance with the 2D space layout schemes, the team members used the Rhino 3D software to draw the preliminary model design and obtained four 3D schemes, as shown in Fig. 9. Concepts 1-4 were optimized based on the four space layouts in Fig. 8, which improved the pain points found using the form restriction method. Concept 1 combined Layout 1 and Layout 4, where chair legs could be stretched. Concept 2 was a combination of Layouts 2 and 3, where the linkage and load parts were up and down. Concept 3 was a combination of Layouts 1 and 3, and the connections between the dining table and the protection parts were detachable. Finally, Concept 4 was a combination of Layouts 2 and 4—protection and linkage parts in a horizontal state.

4.3.3 Alternatives concepts

Based on the four conceptual designs, the design team created some detailed designs and produced three alternatives, as shown in Fig. 10. To be specific, the attractive factors used in Alternative 1 included “Easy to remove the plate,” “Folding design,” “Pastel tone,” “Leather cushion,” “Curvilinear form,” and “Height adjustable.” The shape design referred to Concept 1. The attractive factors used in Alternative 2 included “Folding Design,” “Lightweight Material,” “Pastel Tone,” “Leather Cushion,” and “Curvilinear Form.” The shape design referred to Concept 2. The attractive factors used in Alternative 3 included “Easy to remove the plate,” “Wood material,” “Folding design,” “Leather cushion,” and “Height adjustable.” The shape design referred to Concept 3.

4.4 Stage 4: Analyzing

The eight middle layers (OEI) in the three-layer hierarchical diagram were used as the evaluation criterion of the design scheme (see Fig. 11). The design team established a paired comparison matrix of eight evaluation...
criteria and invited experienced designers and users to score the matrix. Then, the geometric average method was used to analyze the relative weight of each evaluation criterion (see Table 9), and the results showed that the weights of the D, E, and H evaluation criteria were obviously greater than the others. Finally, the team members used the Excel software to test the consistency results. The operation steps were simple and easy to understand. The students obtained the following results through Excel analysis: 
\[ CI = \frac{(9.091-8)}{7} = 0.156, \]
\[ CR = \frac{CI}{RI} = \frac{0.082}{1.41} = 0.058 < 0.1. \]
Accordingly, the pairwise comparison matrix was acceptable.

4.5 Stage 5: Evaluating

4.5.1 Analytical hierarchy process evaluate alternatives

The goal of the design was selecting an optimum scheme from among the alternatives. The design team should therefore apply an evaluation criterion for evaluating the three alternatives. The design team built a pairwise comparison matrix of eight evaluation criteria and invited experienced designers and users to make pairwise comparisons and scores. The weight of the pairwise comparison matrix and the consistency result (see Table 10) were calculated using Excel, and eight pairwise comparison matrices were judged to be acceptable according to the CR.

Through the pairwise comparison matrix of the evaluation criterion, the students obtained a judgment matrix \( \alpha \) for all the alternatives (see Table 10) and a weight matrix \( \beta \) for the evaluation criterion. Therefore, the significant ranking of the three alternatives was indicated by \( S \), and the calculation results were as follows.

\[ S = \alpha \cdot \beta = \begin{bmatrix} 0.637 & 0.258 & 0.258 & 0.731 & 0.731 & 0.731 & 0.637 & 0.279 \\ 0.105 & 0.637 & 0.637 & 0.081 & 0.188 & 0.081 & 0.105 & 0.072 \\ 0.258 & 0.105 & 0.105 & 0.188 & 0.081 & 0.188 & 0.258 & 0.649 \end{bmatrix} \]

\[ \cdot \begin{bmatrix} 0.029 & 0.058 & 0.039 & 0.227 & 0.332 & 0.074 & 0.074 & 0.167 \end{bmatrix}^T = \begin{bmatrix} 0.600 \\ 0.171 \\ 0.229 \end{bmatrix} \]

In summary, the significant ranking of the three alternatives was as follows: Alternative 1>Alternative 3>Alternative 2. The results showed that Alternative 1 was the best design scheme (Fig. 12). This design scheme adapted the lower-layer design factors in the three-layer demand map, including “Easy to
remove the plate,” “Folding design,” “Pastel tone,” “Leather cushion,” “Curvilinear form,” and “Height adjustable.” Based on the scientific judgments of the users and designers, it was the optimum scheme because it satisfied users’ demands, was perfect in terms of function, and satisfied the requirements for beauty of form.

![Image of a high chair]

**Figure 13. Obtain optimum case.**

### 4.6 Stage 6: Creating

#### 4.6.1 Product design

To meet the diversified market demands of users, the team members selected the best scheme as an example for implementing their detailed design. According to the CEI of the three-layer hierarchical diagram that suggested that higher frequencies are material and color factors, the best scheme for redesigning. In terms of color matching, students found eight popular colors in 2021 through online research. The main color was yellow (Fig. 13). The design team used popular colors to redesign the best schemes (see Fig. 16).

![Color palette with eight popular colors]

**Figure 14. Eight popular colors found in 2021.**

In terms of material, team members found four popular materials by analyzing existing products and CEI of the three-layer hierarchical diagram: plastic, wood, metal, and leather (Fig.14). Students used different materials and vogue colors to create innovative designs (Fig.15). Six different schemes were produced.

![Materials: metal, plastic, leather, wood]

**Figure 15. Four widely used materials.**

![Innovative design for product color and material]

**Figure 16. Innovative design for product color and material.**

### 5 Conclusion

Considering that the current design thinking models (DTMs) focus on how to improve the innovation of design activities but ignore how to help students understand the characteristics of the target product and the real
demands of users. Therefore, this article proposes a new DTM with two levels based on the six steps of Bloom’s taxonomy, namely low-level consideration and high-level consideration. Low-level consideration includes three stages, namely remembering, understanding and applying. Remembering stage: Students sort out an information form about the target product through online research. Understanding stage: First, students adequately understand the product’s inherent characteristics by using the function analysis method and the form restriction method. Then, students fully understand the demands of users by using the evaluation grid method. Applying stage: Based on the information obtained in the remembering and understanding stages, a set of alternatives is designed. High-level consideration includes three stages, namely analyzing, evaluating and, creating. Analyzing stage: Based on the remembering and understanding stages, students draw up a set of evaluation criteria for evaluating alternatives. Evaluating stage: According to the evaluation criteria, an optimal solution is selected by the AHP. Creating stage: Redesigning from the perspective of color matching and material, thereby enhancing the creativity of the solution. The characteristics of the proposed DTM are as follows: 1) this DTM is a gradual and progressive process, that is, the latter stage depends on the previous stage; 2) This DTM provides students with effective methods at each stage, and these methods can be regarded as an innovative toolkit; 3) The methods provided in the understanding stage can not only help students understand the functional system and configuration of the target product, but also help students understand the potential demands of users; 4) During the interview process, students have to communicate face-to-face with professional users or sales staff of the product, so this process cultivates students’ communication and expression skills; 5) The Excel provided to students during the evaluating stage can help students quickly obtain the priority order of alternatives.

In conclusion, the DTM based on Bloom’s taxonomy can help students to carry out design activities step by step so as to obtain the accurate functional system, reasonable structural configuration, and beautiful form and color matching. Finally, design the best solution that meets the real demands of users. In other words, the proposed DTM enhances the possibility of transforming the conceptual design into commodities. In addition, this DTM can help design educators follow Bloom’s Taxonomy’s six steps to teach students eminently and designated thinking. Students can accurately understand consumers’ demand and product pain points, innovate product design according to design reference criteria, and use evaluation criteria to evaluate the plans. The new model is not only suitable for design educators to promote in the curriculum but also suitable for design students to constantly try in the design process.

6 References


Stickdorn, M., & Schneider, J. (2010). This is service design thinking: basics, tools, cases. Amsterdam: BIS Publisher Press.


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