Research on Chemical Experimental Instrument Design Mode Based on Kansei Engineering

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Abstract. Chemical experimental instruments are essential tools which interact directly with experimenters and they are indispensable in chemical experiment. With the upgrading of the demand level from experimenters, in addition to the basic functional requirements of the instruments, they hope the instruments to have nice appearance, good using experience and reasonable interactive mode. This also puts a higher level of requirements on instrument design. First, this paper analyzes the research status of current instrument design through literature search method, and summarize the types of instruments which look beautiful and can bring users good using experience. Second, such instruments as samples are collected through network research and field research, and sensitive vocabularies are collected as many as possible, too. Then we use KJ method, principal component analysis method to screen the related samples, and establish the connection mode between instrument shape elements and sensitive vocabularies. Finally, we apply this mode to the appearance design of chemical instrument named "Micro flame combustion synthesis device" and verify the effectiveness of the connection mode through design evaluation. The study of chemical instrument appearance design pattern based on Kansei engineering established a new design mode for introducing other excellent instrument product design elements into chemical instrument design, which can improve the level of chemical instrument design and better meet people's sensuous requirements for chemical instruments. This research provides direction guidelines and design methods reference for products which focus on functionality and neglect the styling design and experience design.

Keywords: Chemical experimental instrument · Kansei engineering · Principal component analysis

1 Introduction

After decades of development, domestic chemical experimental instruments have gradually formed their own design and manufacturing mode, which has a certain production scale and development capacity, and can meet the basic experimental needs.

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However, with the progress of the times and the improvement of the level of science and technology, the users' requirements for other aspects of the instrument have gradually increased, which requires synchronous innovation inside and outside the instrument on the existing basis: internal requirements for high accuracy, strong function, good reliability, automation and intellectualization of the experimental process; external requirements for appropriate equipment volume, beautiful shape, reasonable interaction mode [1]. An excellent shape design instrument looks more professional, which can bring users better use experience, thereby improving the efficiency of the experiment, and then improving the added value of this instrument [2]. Most of the existing experimental instrument products, especially domestic products, do not attach much importance to the design of instrument appearance, or simply refer to similar one or even copy directly, lacking a complete and mature form design mode, which makes the instruments have poor user experience, low price and lack market competitiveness. In view of this situation, this paper takes Kansei Engineering as the basic research theory, establishes the mapping relationship between the appearance elements of excellent appearance design experimental instruments and the perceptual vocabulary through the principal component analysis method, extracts the design elements and applies them to the appearance design of chemical instruments, aiming at establishing a new design mode of experimental instruments and improving the design level of experimental instruments.

2 Overview of Research Theory and Methodology

This paper uses Kansei Engineering as the main theoretical basis. Kansei Engineering is a discipline that incorporates human subjective perception and objective engineering science. Its most important function is to correlate people's vague feelings with precise data through a series of related methods, find correlations in imagery and design parameters, and provide theoretical basis for design practice. In addition, Kansei Engineering is an important evaluation method, which can visualize subjective evaluation data, and make it easy for designers to accurately get consumers' perceptions and needs of products [3].

At present, Kansei Engineering is mainly used in the analysis of the shape of existing products, and redesign of them, but is seldom used in the field of innovative design. This paper applies this theory to the innovative design of chemical experimental instruments. Firstly, the vocabulary matrix of appearance perceptual image evaluation of excellent shape design experimental instrument is established by semantic difference method; secondly, the principal component analysis is used to analyze and simplify appearance perceptual image vocabulary, focusing more on the factors that can describe the appearance perceptual image of the samples; the combination of the two methods can establish the mapping relationship between appearance perceptual image vocabulary and appearance elements, and then extract the samples' appearance elements which corresponding to vocabulary, apply them to the design of chemical experimental instrument named "micro flame combustion synthesis device" and the appearance design is evaluated. The flow chart of the study is shown in Fig. 1.

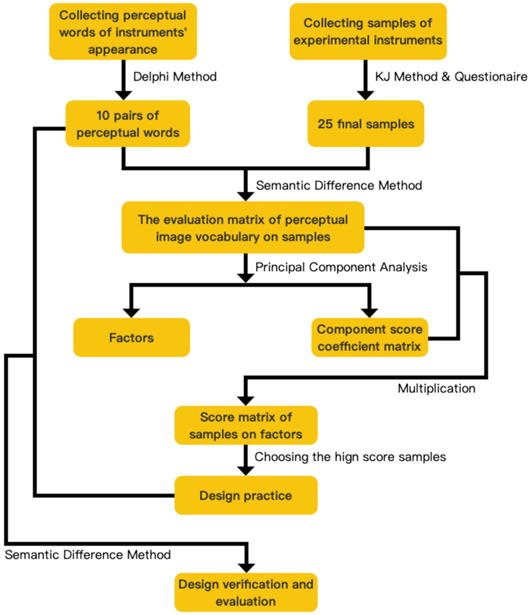

Fig. 1. The flow chart of the study.

3 Research Procedure

3.1 Sample Selection of Chemical Experimental Instruments

Chemical experimental instruments cover a wide range of fields and types, the number of enterprises producing related equipment on the market is huge, and the number of products is countless, so it is difficult to study all the instruments roundly. In order to simplify the research object and ensure the reliability of the research results, 10 famous instrument companies are selected as the sample sources according to the factors such as enterprise popularity and turnover data, including 6 foreign companies and 4 domestic companies, they are Thermo Fisher Scientific (Massachusetts, America), Danaher Corporation (America), Agilent Technologies Incorporated (California, America), Waters Corporation (Milford, America), PerkinElmer (Waltham, America), Shimadzu (Japan), Persee (Beijing, China), Inesa (Shanghai, China), Fuli Instruments (Zhejiang, China), and Kezhe (Shanghai, China) [4]. For the main object of this study is the appearance design of the instruments rather than the function, to ensure the validity of the research results, we only consider on the appearance factor and ignore the different instrument functions, weaken the phenomenon that some sample characteristics are unique due to the functional requirements of the instrument in the process of sample collection. The steps of the research are as follows.

Firstly, we collected the experimental instruments produced by these 10 companies from books, literatures, and websites of the companies as much as possible. We gathered 178 pictures as standby samples. Secondly, we used KJ method to classify the samples and did screening on the basis of this for two times. In the first screening, we removed the samples which have large appearance similarity or particularity and got 80 samples left. Then we used these samples to make appraisal questionnaire for aesthetics of appearance to screen the samples with excellent appearance design as the final experimental samples. To make sure the validity of the research consequence, the objects of our questionnaire are expert users, including experimenters, designers and professors of design. We invited the subjects to grade appearance design of every instrument, the score is one to ten, and 50 questionnaires were collected. Analyzed the questionnaires and selected 25 samples which got the highest scores as the final experimental instrument samples with excellent appearance of the research [5]. The pictures of the samples are shown in Fig. 2.

Fig. 2. 25 experimental instrument samples with excellent appearance.

3.2 Selection of the Perceptual Words

The perceptual words describing the appearance of the experimental instrument or related to it are widely collected from the networks and literatures, pair words with opposite meanings. After preliminary screening, 50 pairs of adjectives are obtained. After discussion by the research group, we analyzed the sensible image meanings of the words, the adjectives with similar meaning or repetition, remote usage and ambiguous adjectives are deleted, and the remaining 30 pairs are made. Then we used Delphi Method to screen the perceptual words [6], the relevant experts and the designers engaged in the design of experimental are invited to select the most suitable words to describe the perceptual image of experimental instruments' appearance. And we got 10 pairs of perceptual words shown in Table 1.

Table 1. 10 pairs of perceptual words

Word pair 1	Word pair 2	Word pair 3	Word pair 4	Word pair 5
Fragmented/Integrated	Sharp/Obtuse	Complicated/Simple	Steady/Lightweight	Cold/Warm
Word pair 6	Word pair 7	Word pair 8	Word pair 9	Word pair 10
Conservative/Innovative	Stifling/Fresh	Obstructed/Fluent	Traditional/Technological	Metallic/Non-metallic

3.3 Establishment of Semantic Difference Questionnaire

The content of the questionnaire of the Semantic Difference Method should include three factors: sample pictures, perceptual word pairs and subjects [7]. The questionnaire adopts five-point scale method. There are five intervals between each pair of perceptual words on the scale. By choosing numerical values, the subjects express their understanding and perception intensity of the sample's appearance image, so as to achieve the goal of digitalizing the cognition of the appearance image. Taking "fragmented-integrated" as an example, this group of perceptual words pair is used to express the perceptual image of experimental instrument products, with interval values of 5, i.e. −2, −1, 0, 1, 2; Choosing −2 means that the perceptual words are biased towards the "fragmented" image; Choosing 0 means that the perceptual words cannot resonate with the subjects; Choosing −2 means that the perceptual words are biased towards the "integrated" image. The questionnaire was designed with 10 pairs of perceptual vocabulary and 25 sample pictures. A total of 261 valid questionnaires were collected through the Internet.

3.4 Questionnaire Statistics and Data Analysis

The collected questionnaires were sorted out and the average value of the sample data was calculated. The evaluation matrix of perceptual image vocabulary was obtained as follows (see Table 2).

Table 2. The evaluation matrix of perceptual image vocabulary on samples

Samples	Words				
	Fragmented/Integrated	Sharp/Obtuse	Complicated/Simple	Steady/Lightweight	Cold/Warm
1	0.48	0.75	−0.34	−1.22	−0.63
2	0.69	−0.99	0.83	1.18	−0.01
3	0.79	1.23	1.16	0.57	0.77
4	0.87	1.55	−0.12	−1.07	0.64
5	0.68	1.45	0.75	−0.31	1.2
6	0.76	1.16	0.23	−0.03	0.72
7	0.42	0.34	−0.77	−0.64	−0.23
8	0.72	0.39	0.28	−0.48	0.21
9	0.7	−0.01	1.57	0.19	−0.03
10	0.82	1.23	−0.24	−1.56	0.59
11	0.77	0.32	0.27	−1.08	0.21

(*continued*)

Table 2. (*continued*)

Samples	Words				
	Fragmented/Integrated	Sharp/Obtuse	Complicated/Simple	Steady/Lightweight	Cold/Warm
12	0.73	−0.31	0.35	0.44	−0.21
13	0.37	−0.6	−0.93	−0.77	0.19
14	0.21	−0.33	−0.77	−0.28	0.21
15	0.67	0.81	−0.03	0.18	0.79
16	0.12	0.45	−0.87	−0.43	−0.39
17	0.66	0.64	−0.39	−0.41	0.24
18	0.98	0.19	0.23	−0.26	−0.46
19	0.72	1.25	0.04	−0.48	0.59
20	0.34	−0.03	−0.38	−0.44	0.37
21	−0.21	0.56	−0.99	−1.01	−0.18
22	0.97	0.78	0.41	−0.08	−0.44
23	1.01	1.68	1.45	0.67	0.56
24	0.65	0.38	0.59	1.03	0.33
25	0.93	−0.76	0.72	−1.14	−0.23

Samples	Words				
	Conservative/Innovative	Stifling/Fresh	Obstructed/Fluent	Traditional/ Technological	Metallic/ Non-metallic
1	0.56	−0.62	−0.02	0.34	−1.56
2	0.79	0.81	0.52	0.81	0.48
3	0.69	1.11	1.34	0.98	1.35
4	−0.48	−0.65	0.54	−0.85	1.33
5	1.39	0.96	1.17	0.57	1.78
6	0.75	0.4	0.09	−0.67	1.24
7	0.71	0.39	0.58	0.99	1.25
8	0.23	0.22	−0.23	−0.46	1.18
9	0.24	−0.11	−0.74	−0.42	1.3
10	−0.57	−0.75	−0.54	−0.75	1.34
11	0.56	0.78	0.24	1.03	1.43
12	1.14	0.87	0.87	−0.66	1.04
13	0.57	0.55	−0.79	0.37	−0.82
14	0.41	0.66	0.2	0.35	−0.31
15	0.16	−0.24	−0.25	0.1	1.07
16	−0.01	−0.67	−0.65	0.48	−0.23
17	−0.23	0.25	−0.44	−0.42	0.9
18	1.06	0.38	0.57	0.82	0.44
19	−0.7	−0.63	−0.37	−0.94	1.37
20	0.01	0.44	−0.24	−0.23	1.19
21	−0.16	−0.18	−0.44	−0.45	1.23
22	0.83	0.22	0.71	1.09	0.27
23	0.38	0.82	1.02	−0.83	1.4
24	0.03	0.23	0.22	−0.01	1.22
25	0.24	−0.68	−0.12	1.04	−0.17

Principal Component Analysis (PCA) was used to further analyze the vocabulary evaluation matrix of perceptual images of experimental instruments by SPSS [8]. It was imported into the software, and the maximum variance rotation method was used to rotate orthogonally. The factor whose eigenvalue is greater than 1 is used to calculate the principal component analysis. A total of three principal component factors are selected. The cumulative explained variance is 73.024%. The results of principal component analysis are arranged into Table 3. Factor 1 contains four groups of perceptual vocabulary: steady-lightweight, conservative-innovative, stifling-fresh, obstructed-fluent. Factor 2 contains four groups of perceptual vocabulary: sharp-obtuse, cold-warm, traditional-technological, metallic-non-metallic, and Factor 3 contains "fragmented-integrated, complicated-simple" two groups of perceptual vocabulary. Because most of the vocabulary in factor 1 is related to the style of the experimental instrument, it is named "style factor". Most of the vocabulary in factor 2 describes the texture of the experimental instrument, so it can be named "texture factor". Most of the vocabulary in factor 3 is related to the shape of the experimental instrument, so it is named "shape factor".

Table 3. The results of principal component analysis

Factor	Word	Element loading	Eigenvalue	Explained variation (%)	Cumulative variation (%)
Style factor	Steady/Lightweight	0.679	2.861	28.611	28.611
	Conservative/Innovative	0.776			
	Stifling/Fresh	0.946			
	Obstructed/Fluent	0.706			
Texture factor	Sharp/Obtuse	0.701	2.549	25.491	54.102
	Cold/Warm	0.829			
	Traditional/Technological	−0.698			
	Metallic/Non-metallic	0.804			
Shape factor	Fragmented/Integrated	0.933	1.892	18.922	73.024
	Complicated/Simple	0.791			

In the factor analysis table, we can see that the key words are "fresh, innovative, warm, non-metallic, integrated and simple", and the secondary words are "fluent, lightweight, obtuse, traditional". This shows that users have a higher perception of these words in the perceptual image vocabulary of experimental instruments with excellent appearance design.

Next, the relationship between each component factor and sample appearance is further analyzed in order to extract the perceptual image feature elements of experimental instruments. By multiplying the perceptual vocabulary of appearance evaluation matrix with the Component Score Coefficient Matrix (see Table 4) calculated in SPSS, the Score Matrix of the experimental instrument Samples on Factors is obtained (see Table 5). The formula is as follows (a represents the Score Matrix of Samples on Factors, b represents the perceptual vocabulary of appearance evaluation matrix, c is the Component Score Coefficient Matrix).

$$a_{ij} = \sum\nolimits_{k=1}^{10} b_{ik} c_{kj} \, (i = 1, 2, 3, \ldots .25, j = 1, 2, 3) \tag{1}$$

Table 4. Component score coefficient matrix

Perceptual words	Style factor	Texture factor	Shape factor
Fragmented/Integrated	−0.185	−0.094	0.615
Sharp/Obtuse	−0.089	0.246	0.122
Complicated/Simple	−0.02	−0.027	0.436
Steady/Lightweight	0.251	0.063	−0.036
Cold/Warm	0.122	0.356	−0.128
Conservative/Innovative	0.266	−0.155	0.003
Stifling/Fresh	0.421	0.087	−0.26
Obstructed/Fluent	0.203	0.011	0.129
Traditional/Technological	0.096	−0.289	0.082
Metallic/Non-metallic	0.118	0.334	−0.071

Table 5. Score matrix of samples on factors

Sample	Factor		
	Style factor	Texture factor	Shape factor
1	−0.80	−0.91	0.66
2	1.03	−0.38	0.52
3	1.13	0.68	0.89
4	−0.70	1.18	0.70
5	1.07	0.99	0.61
6	0.30	0.99	0.39
7	0.43	0.00	−0.02
8	−0.07	0.57	0.40
9	−0.14	0.39	0.92
10	−1.07	1.03	0.50
11	0.37	0.17	0.46
12	0.88	0.25	0.34
13	0.00	−0.57	−0.40
14	0.39	−0.23	−0.36
15	−0.03	0.71	0.35
16	−0.60	−0.32	−0.04
17	−0.22	0.64	0.08
18	0.36	−0.45	0.81
19	−0.75	1.20	0.49
20	0.14	0.57	−0.24
21	−0.37	0.60	−0.57
22	0.26	−0.40	1.04
23	0.61	1.25	1.11
24	0.43	0.63	0.51
25	−0.60	−0.90	1.12

It can be seen from Table 5 that the scores of the samples on three factors are mostly positive, and the samples with negative scores are fewer and the absolute values are generally smaller except for very few samples. This shows that the users have a lower perception of the negative images of the three factors of the samples. It can be concluded that the users prefer the samples with positive images on all factors. Therefore, this paper used the samples with positive images and high absolute values (Taking absolute value greater than one as standard) as samples of final design elements extraction sources. The samples selected on “style factor” are 2, 3 and 5; the samples selected on “texture factor” are 4, 10, 19 and 23; and the samples selected on “shape factor” are 22, 23 and 25. Summarize the characteristic elements of these samples and add them into chemical instrument product design. The results are summarized in the following Table 6.

Table 6. Characteristic elements of high score samples

Factor	High score samples	Characteristic elements
Style factor		Bright, lightweight, fluent, lively and fresh in style. Colour collision is one of the main design methods
Texture factor		Round in appearance, strong sense of tradition, mainly warm color, giving users a soft and warm feeling, more inclined to use non-metallic texture materials and matte materials
Shape factor		Modeling integrity is good, concise, not too much decoration

4 Design Practice

4.1 Development of Micro Flame Combustion Synthesis Device

This paper will take the chemical experimental instrument “micro flame combustion synthesis device” as an example to do product design practice. “Micro Flame Combustion Synthesis Device” is developed by Professor of Materials College of East China University of Technology (ECUST). It is suitable for the production of micro-nano-sized materials in universities, research institutes and laboratories of enterprises in the fields of chemical industry and materials. It is also used in the fields of photocatalysis, photoelectric conversion and lithium-ion batteries. The flame combustion technology used in this instrument is a method of preparing nanoparticles through the chemical reaction and physical agglomeration of precursors by providing energy in the combustion process. It has been widely used in the industrialized preparation of nanoparticles such as SiO2, AlO3 and TiO2. The prototype machine has been produced, as shown in the follow (see Fig. 3). This case is based on the existing prototype machine for appearance design, and try to follow and use the previous research results, from the outstanding samples of three factors to extract design elements into the design practice. We designed two different schemes (see Figs. 4 and 5).

Fig. 3. The prototype machine of micro flame combustion synthesis device

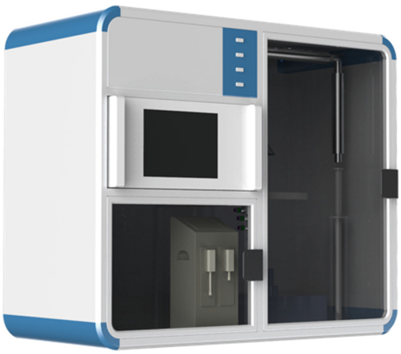

Fig. 4. Design case 1

Both of the case 1 and case 2 take into account the convenience of interpersonal operation, the need of experiment process, the rationality of space, the beauty of appearance and so on. Color collision design is formed by the combination of metal and organic glass, which makes the instrument give people a fresh feeling; the shape is

Fig. 5. Design case 2

made on the basis of square angle and rounded corner, which increases the richness; and the instrument is more integrated, simple, and not much decoration. We added blue as embellishment on the basis of white in scheme 1, and symmetrical design is adopted in the experimental area and operation area, which made the appearance more regular; we used double doors in the right experimental area in scheme 2, and deliberately used asymmetrical design in appearance to make the shape vividly.

4.2 Development of Micro Flame Combustion Synthesis Device

The author makes the semantic difference questionnaire of design schemes again in the form of pictures, and still chooses 10 groups of perceptual vocabulary screened previous to score with Likert scale. A total of 34 questionnaires are collected. According to the statistical results, the evaluation matrix of the perceptual vocabulary of the appearance image of the design case is obtained as Table 7. Then the score matrix of design cases on factors is obtained by multiplying it with the component coefficient matrix shown as Table 8.

Table 7. The evaluation matrix of perceptual image vocabulary on cases

Case	Word				
	Fragmented/Integrated	Sharp/Obtuse	Complicated/Simple	Steady/Lightweight	Cold/Warm
1	0.73	0.7	0.98	0.65	−0.15
2	0.69	0.25	0.64	0.86	−0.23
Case	Word				
	Conservative/Innovative	Stifling/Fresh	Obstructed/Fluent	Traditional/Technological	Metallic/Non-metallic
1	0.28	0.69	0.89	−0.35	−0.21
2	0.76	0.89	0.14	−0.29	0.12

Table 8. Score matrix of cases on factors

Case	Factor		
	Style factor	Texture factor	Shape factor
Case 1	0.42	0.12	0.88
Case 2	0.62	0.04	0.49

From the above table, we can see that the two cases have positive performance on three factors, but the value of factor two is smaller, which indicates that the user's perception of the texture factor is not strong enough. The author believes that due to the functional requirements of the instrument, the client requires the use of metal as the shell material, and the design is not round enough, the color is mainly cold, resulting in poor performance of the instrument in the texture factor. In the later stage, the design can be improved gradually by changing the color matching and increasing the arc shape of the surface.

5 Conclusion

In this paper, the mapping relationship between perceptual image words of appearance and experimental instrument appearance elements is established through the theory of Kansei Engineering. On this basis, design elements are extracted from samples which are outstanding in various perceptual image factors, and the appearance design of "micro flame combustion synthesis device" is carried out. The accuracy and the reliability of the research results is preliminarily verified by questionnaire survey. This research will help designers to extract design elements from excellent experimental instruments and add them into the design of chemical instrument products reasonably and scientifically, and provide a new design idea, so as to improve the level of instrument design, grasp the user's perceptual image more accurately and better meet the user's perceptual needs. At the same time, the research results also provide theoretical guidance and reference for similar design ideas of applying elements of one excellent design work to another product, which is of great significance.

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