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Article

The multifunctional design of English home learning spaces promotes language interaction among family members

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Abstract: This paper investigates the multifunctional design of English home learning spaces based on the Kano-QFD model. Affinity diagramming is used to organize questionnaire data, and the Kano model is applied to calculate SII and DDI values. The refined SII and DDI data are then incorporated into the QFD quality house for weight analysis of user requirements. Finally, based on the Kano-QFD model, the weight values of user requirements for modular learning spaces are obtained to provide further guidance for the modular design of learning spaces. Based on the Kano-QFD model, this paper proposes renovating home learning spaces from three aspects: electronic resource spaces, leisure and social spaces, and activity spaces. To verify that the renovated learning space can effectively enhance family members' language interaction, this paper designed a control experiment to compare the language interaction effects of family members under the traditional home learning space. The study indicates that the English home learning space designed based on the Kano-QFD model can effectively enhance family members' language interaction.

Keywords: Kano-QFD; affinity diagram method; demand elements; language interaction

1. Introduction

The development of information networks has brought about a major transformation in learning methods. The rise of online education platforms and online training institutions has made people's educational activities and learning behaviors highly flexible in terms of time and space [1]. Learning spaces are no longer confined to traditional educational venues such as schools and classrooms. Various living spaces, such as stations, subways, cafes, and homes, now have educational functions and can accommodate diverse learning activities, with the potential to "replace" traditional learning spaces [2-5]. Among these, the home is well-known for its functions as a residence or place of rest, but its role as an educational and learning space has not been sufficiently discussed or researched [6-7]. In fact, an increasing number of people are choosing to engage in educational activities such as course learning and online training at home to enhance their skills, blurring the boundaries between home spaces and learning spaces [8-9].

Due to the impact of the COVID-19 pandemic, "home-based learning" has emerged as a powerful innovative measure within China's education system to address the challenges posed by the pandemic. Within the "home," a richly nuanced "social space system," the functions of teaching and learning have been strengthened [10]. During the process of English learning, the language environment experienced by students at home differs significantly from that in a campus setting, and the language environment created within the home space plays a significant role in facilitating student learning [11-13]. If parents possess a certain level of English proficiency and can actively engage in language interaction, they can create a relaxed and enjoyable home-based English learning environment [14-15]. Additionally, in the home environment, daily English communication between parents and students can provide natural language practice opportunities, encouraging students to actively speak English and receive timely corrections for expression errors during interaction [16-18]. In this high-frequency English exposure scenario, parents and children can engage in bilingual communication, helping students grasp language rules through comparison and enabling them to effectively communicate in English [19-20]. Of course, complex spatial design strategies also contribute to the home space’s role as an alternative educational environment, such as spatial selection, object arrangement, color selection, and decorative design, which can create a conducive English learning atmosphere [21-23].

Regarding the phenomenon of learning spaces and daily living spaces being intertwined, some scholars have examined students' spatial practices and experiences in home-based learning. Literature [24] explores the impact of family language environments on English learners, noting that a positive family environment provides learners with encouragement and support, fostering language confidence and positively influencing English learning. Literature [25] focuses on parents and caregivers as research subjects to articulate the challenges faced in home-based learning, while exploring how to create inherent boundaries for education within the family environment through identity, space, and place, providing valuable insights into enhancing the effectiveness of home-based learning. Literature [26] argues that the living environment and physical learning environment in home-based learning settings directly impact students' learning outcomes. By comparing the stress levels and well-being of traditional students and continuing education students in different learning environments, it provides insights for designing immediate learning environments. Literature [27] explores the role of the learning environment as a mediating factor in influencing students' learning motivation and performance. The results indicate that a positive school or home environment significantly stimulates students' learning motivation, thereby enhancing their learning performance. Literature [28] conducted a multidimensional study on college students' acceptance of home-based online learning methods, identifying factors influencing cognitive engagement and academic performance, and offering constructive suggestions for home-based online learning. Literature [29] used multiple logistic regression analysis to investigate the relationship between family living conditions and home-based online education, concluding that a family school environment with an independent living area and good broadband network access significantly improves students' academic performance. The aforementioned studies explored the role of the home environment as an alternative educational space to traditional schools from the perspectives of parents, learners, and educational administrators. However, the specific spatial layout of the home environment and its underlying mechanisms warrant further investigation.

This study combines the Kano model and QFD to propose a Kano-QFD-based home learning space service quality optimization model. The model's application is primarily based on the needs of households for home-based English learning. Using the Kano model, the various usage needs of home learning spaces are categorized into attributes. Then, the QFD quality house method is applied to conduct weight data research on the categorized needs, forming a weighted ranking of household needs under the Kano-QFD framework. Based on this, a modular home learning space design scheme is developed. To test the promotional effect of the English home learning space designed based on Kano-QFD on family members' language interaction, the article designed a control experiment, describing and analyzing the effects from four dimensions: interaction frequency, content depth, content breadth, and feedback quality.

2. Research on improving the quality of home learning space services based on Kano-QFD

2.1. Kano Model

The Kano model can be used to express the nonlinear relationship between functional requirements and user satisfaction. The Kano model classifies user requirements into five types: basic requirements, expected requirements, delight requirements, indifferent requirements, and reverse requirements [30]. The model structure is shown in Figure 1.

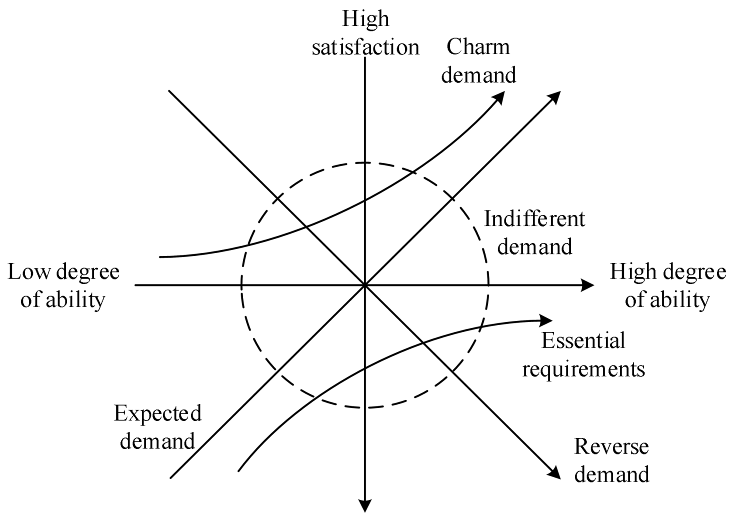

Figure 1. Kano model structure

The meanings of the five types of user needs are as follows:

(1) Essential needs (M): Providing this need does not increase user satisfaction. However, not providing this need significantly reduces user satisfaction.

(2) Expected needs (O): Also known as one-dimensional needs. Providing this need results in a linear increase in user satisfaction, while not providing it results in a decrease in user satisfaction.

(3) Delightful Needs (A): Needs that bring users a sense of surprise. If this need is not provided, user satisfaction will not decrease, but if it is provided, it can significantly improve user satisfaction.

(4) Indifferent Needs (I): Whether this need is provided or not, user satisfaction will not change, meaning it is a need that is optional for users.

(5) Reverse Requirements (R): Users have no such requirements, and when such requirements are provided, user satisfaction actually decreases.

After designing the Kano questionnaire, user requirements can be classified by comparing the frequency with which each quality attribute is selected. The Kano questionnaire poses questions from both positive and negative perspectives for each feature, and users select the option that aligns with their own views. The classification of Kano evaluation results is shown in Table 1. Convert users' responses to each feature into quality attributes, and count the number of times each quality attribute (A, O, M, I, R, Q) appears in each feature. The quality attribute with the highest frequency is determined as the quality attribute for that feature.

Table 1. Kano evaluation meter

Quality attribute		**Functional deficiency (Reverse problem)**				
		Like it very much	**It should be so**	**No matter**	**Reluctantly accept**	**Dislike**
Functional capability (positive question)	Like it very much	Q	A	A	A	O
	It should be so	R	I	I	I	M
	No matter	R	I	I	I	M
	Reluctantly accept	R	I	I	I	M
	Dislike	R	R	R	R	Q

However, this method of determining quality attributes based on frequency of occurrence has a certain degree of subjectivity. Especially when two quality attributes are selected the same or similar number of times, it is difficult to make an accurate judgment. To address this shortcoming of the Kano model, the Better-Worse quartile chart can be introduced as a reference. The Better-Worse quartile chart not only provides a more intuitive representation of a feature's quality attributes but also indicates the degree of user preference based on its coordinate position within the four quadrants. The Better-Worse coefficients enable more precise judgments of quality attributes, measuring the extent to which each feature can increase user satisfaction or reduce dissatisfaction.

The Better coefficient represents the extent to which user satisfaction increases when a feature is added. When the Better coefficient is positive and the difference between its value and 1 is smaller, it indicates higher user satisfaction. The Worse coefficient represents the extent to which user dissatisfaction increases when a feature is removed. When the absolute value of the Worse coefficient is closer to 1, it indicates higher user dissatisfaction. Therefore, features with higher absolute values of the Better-Worse coefficients should be prioritized for implementation.

2.2. Quality Function Deployment

Quality Function Deployment (QFD) is a methodology that focuses on the conversion of customer requirements into product design characteristics. The Quality House is a visual framework that enables this conversion through a matrix structure, embodying the essence of the QFD approach.

The Quality House is divided into the left wall, ceiling, room, roof, right wall, and basement, representing user requirements and their importance, technical characteristic expansion, correlation matrix, self-correlation matrix of design characteristics, market competitiveness assessment, and technical competitiveness assessment [31], respectively. The components of the Quality House are shown in Figure 2.

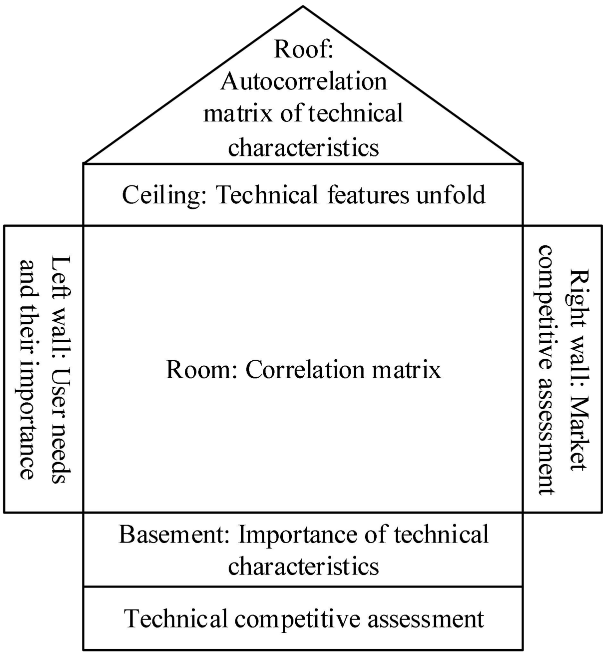

Figure 2. Quality house component

The left wall represents user requirements, which can be derived through methods such as desktop research and surveys. The importance of user requirements is determined by quantifying and scoring each requirement. The ceiling represents technical characteristics, which are derived from user requirements and are measurable technical requirements. The room represents the relationship between user requirements and the technical characteristics required to fulfill those requirements. The roof represents the relationships between various technical characteristics. The right wall represents market competitiveness assessment, which evaluates the competitiveness of selected products in the market from the user's perspective. The basement represents technical competitiveness assessment, which evaluates the technical level of selected products from the technical personnel's perspective and determines the technical features that should be prioritized for implementation.

Quality Function Deployment (QFD) can be primarily divided into five stages: user requirement expansion, quality planning, technical feature expansion, correlation matrix, and technical planning.

(1) User requirement expansion

User requirement expansion includes three parts: user requirement acquisition, user requirement analysis, and initial user requirement importance calculation. First, user requirements are identified through market research, user studies, and other methods. Then, user requirements are paraphrased using concise and professional language. Next, the KJ method is used to sort the hierarchical structure of user requirements. Finally, a judgment matrix is used to compare user requirements in pairs to determine the initial importance ranking of user requirements.

(2) Quality Planning

Quality planning consists of three parts: market competitiveness assessment, setting product feature points, and calculating the final relative importance of user requirements. First, in the market competitiveness assessment, the degree to which existing products and competing products on the market meet user requirements is compared, and a target satisfaction level is set to calculate the improvement rate of user requirement levels. Subsequently, requirements are assessed, primarily focusing on whether they can become marketing priorities, and product feature points are set in quantitative form. Finally, combining the initial importance of user needs, the improvement rate of user needs, and product feature points, the importance of user needs is calculated, then normalized to obtain the relative importance.

(3) Technical Feature Expansion

Convert user needs expressed in language into technical features expressed in technical terms to make the needs concrete. Extract measurable quality elements from customer needs, primarily including physical elements, time elements, functional elements, human (effectiveness) elements, economic elements, production elements, and market elements, as technical characteristics.

(4) Correlation Matrix

The correlation matrix consists of the user demand expansion table and the technical characteristic expansion table, providing an intuitive and quantitative description of the complex relationship between user needs and technical characteristics.

(5) Technical Planning

By inviting experts and reviewing relevant literature and patents, assess the technical characteristic levels of existing products and competitors. Unlike market competitiveness assessments, technical competitiveness assessments are conducted by professional technical personnel rather than users. By comprehensively considering the importance of technical characteristics, the difficulty and cost of technical implementation, the relationship matrix between user requirements and technical characteristics, and the strengths and weaknesses of current products, the product can achieve market competitiveness while meeting the minimum standards.

2.3. Analysis of Resident Needs

Residents' needs must be identified in order to provide them with quality services and ensure that their needs are met in the learning space. Through literature review and on-site interviews, residents' needs were identified, and two sets of questionnaires were designed based on these needs. The first questionnaire, the Resident Service Needs Survey, was used to determine the basic importance of each need. The second questionnaire is the Learning Space Service Needs Kano Evaluation and Importance-Satisfaction Survey Form, which consists of two parts: Kano evaluation and scoring of the importance and satisfaction of the needs. This questionnaire is used to obtain the Kano classification, importance, and satisfaction data for each need, and after a series of calculations, the final importance is determined.

1) Determination of Requirement Items

To obtain the relevant requirements of residents needed for this study, data must be collected to ensure its authenticity. By reviewing literature to identify the major dimensions of demand, and then conducting field interviews to obtain firsthand demand information from residents, the collected data is organized to provide researchers with a reference, making the data more precise. During the field data collection process, a tailored approach is adopted to collect demand information from different genders and categories of people, aiming to make the services of English home learning spaces as comprehensive as possible to meet the needs of every group.

2) Basic Importance of Needs

Since residents' needs vary greatly, appropriate algorithms must be applied to collect their needs. During the collection process, many ambiguous issues require further refinement through algorithms to clarify them. The steps are as follows:

(1) Establishment of a Fuzzy Consistency Matrix

This analysis method compares two different factors i and j and quantifies fuzzy factors to derive a judgment matrix $A=(a_{ij})_{n\times n}$. Assuming that this matrix complies with the following algorithm:

$$0 \le a_{ij} \le 1, a_{ii} = 0.5, a_{jj} = 0.5, i = 1, 2, \cdots, n \tag{1}$$

$$a_{ij} + a_{ji} = 1, i, j = 1, 2, \cdots, n \tag{2}$$

Define it as a fuzzy complementary judgment matrix. When any element ij of the fuzzy complementary matrix satisfies $a_{ij} = a_{ik} - a_{jk} + 0.5$, it is a fuzzy consistent matrix.

(2) Establishment of the priority relationship judgment matrix

By comparing the two factors in the above matrix, it is found that there is a certain degree of relativity between them. The 0.1-0.9 scale method is typically used to quantitatively describe the relative importance of two factors to a criterion.

(3) To convert the priority relationship judgment matrix into a fuzzy consistent matrix, first add the data in each row of the judgment matrix:

$$a_i = \sum_{i=1}^{n} r_{ik}, (k = 1, 2, ..., n) \tag{3}$$

Then, using the consistency formula:

$$a_{ij} = \frac{a_i - a_j}{2(n-1)} + 0.5(n \text{ is the order of the matrix}) \tag{4}$$

This can be converted into a fuzzy consistency matrix.

(4) Calculate the relative importance w_i between factors. The first step is to calculate the row sum of the fuzzy consistency matrix:

$$\overline{w_i} = \sum_{j=1}^{n} a_{ij} - 0.5 \tag{5}$$

Research on improving the quality of learning space services based on Kano-QFD[32]:

$$\sum_i \overline{w} = \frac{n(n-1)}{2} \tag{6}$$

$$w_i = \frac{w_i}{\sum_i \overline{w}} \tag{7}$$

According to formulas (5) to (7), the relative importance of each element can be calculated sequentially.

(5) Calculation of comprehensive importance

The value of $W*$ obtained by multiplying the relative importance of each element by the relative importance of the factor dimension constitutes the basis for subsequent research.

3) Final importance of requirements

(1) Statistical analysis of survey data

To better survey residents' needs, it is necessary to consider various factors comprehensively to improve the quality of learning space services and meet residents' needs. Therefore, different methods must be used to collect these data, and further statistical analysis and summarization must be conducted based on the collected data. A second survey questionnaire was designed, divided into two parts: the Kano model and importance and satisfaction scoring. Based on this questionnaire, the Kano classification, importance, and satisfaction levels of each need can be obtained.

(2) Calculation Process for Each Parameter

a) Kano Classification and k Values

Using the second questionnaire, the Kano classification of needs can be statistically determined based on the majority principle. The k values are determined according to the corresponding Kano classifications. In this study, the values are assigned as follows: A = 4, O = 2, M = 1, I = 0.

b) Adjustment factors

By analyzing various resident needs and adjusting them based on different relevant factors, both resident satisfaction and dissatisfaction are represented by specific numerical values (SII) and satisfaction coefficients (DDI). The specific calculation methods are as follows:

$$SII = (A + O) / (A + O + M + I + R + Q) \tag{8}$$

$$DDI = (O + M) / (A + O + M + I) \tag{9}$$

The table shows different letters and numbers representing different types of needs. Therefore, comprehensive evaluation can enable further adjustment of the corresponding factors:

$$f = Max(| cs || Ds |) \tag{10}$$

c) Improvement ratio

Further calculations and analyses are conducted based on the needs and satisfaction levels of residents to further improve the ratio. Improvement ratio:

$$R_0 = I / U \tag{11}$$

Among them, I represents the average importance value of demand, and U represents the average satisfaction level value of current demand.

(3) Adjusted improvement ratio

The method of incorporating the k value into QFD analysis yields the formula for calculating the adjusted improvement ratio in this paper. The adjusted improvement ratio is:

$$R_1 = (1+f)^k \times R_0 \tag{12}$$

(4) Final importance of requirements

The importance and satisfaction level of each requirement have a certain impact on the improvement ratio, and this result can directly reflect the authenticity of the residents.

4) Expansion of quality characteristics

Quality can generally be defined as consumers' intuitive perception of whether it is good or bad, which determines the level of quality and better meets customer needs. During the expansion process based on quality characteristics, it is necessary to further refine residents' quality needs, comprehensively consider their influencing factors, and conduct further evaluations. The definition of quality characteristics must meet the following conditions:

(1) Quality characteristics must focus on users' specific needs for further determination.

(2) The expansion of quality characteristics must be measured against certain standards to facilitate research.

(3) The expansion of quality characteristics must be further measured and studied based on their overall characteristics, taking into account their overall nature for further evaluation. Resident needs are diverse, and the final quality characteristics are derived by summarizing and extracting them based on existing industry standards.

5) Establishment of the Quality House

Fill the left and right walls of the Quality House with the resident needs and their importance derived from the above analysis and calculations, and fill the roof with the expanded quality characteristics. Analyze the relationship between resident needs and quality characteristics based on the left and right walls and the roof, fill the correlation matrix based on the degree of correlation, and use the symbols "●", "○", and " ▲" to indicate the degree of correlation, and then calculate the priority of quality characteristics. By ranking the priority of quality characteristics, the service quality characteristics of the English home learning space can be obtained.

3. Multifunctional design transformation of home learning spaces

This chapter uses the Kano-QFD model to design English home learning spaces and improve resident satisfaction.

3.1. Design Requirements Acquisition

With resident needs as the core of the design, it is essential to consider both explicit and implicit needs when gathering demand data. First, using "English home learning space functionality" as the starting point, a team of experts comprising designers and project managers active on the front lines of the market was assembled to conduct research. Functional requirements for the product were collected from multiple dimensions, with duplicate content removed, resulting in a total of 15 identified requirements. The key elements of these requirements are shown in Table 2. Based on the interconnections among functional requirements, the hierarchical relationships of the requirements were organized, with primary requirements (hardware facility requirements C1, environmental requirements C2, learning resource and tool requirements C3, learning content support requirements C4) and secondary requirements (comfortable seating C11, appropriate desk and chair height C12, Electronic Devices C13, Power Outlets C14, Quiet Environment C21, Adequate Lighting C22, Good Ventilation C23, Soundproofing Measures C24, Learning Materials C31, Network Connectivity C32, Interactive Tools C33, Personalized Decorations C41, Learning Schedule C42, Sufficient Storage Space C43, Flexible Space Layout C44).

Table 2. Requirement element

Primary demand	Secondary demand
Hardware requirements C1	Comfortable seat C11 The suitable table and chair is highly C12 Electronic equipment C13 Power outlet C14
Environmental requirements C2	Quiet environment C21 Sufficient light C22 Good ventilation C23 Sound insulation measures C24
Learning resources and tool requirements C3	Learning material C31 Network link C32 Interactive tool C33
Learning content supports class requirements C4	Personalized decoration C41 Learning schedule C42 Enough storage space C43 Flexible space layout C44

Secondly, an online survey questionnaire on the functional requirements for an English-language home learning space was created and distributed to gather further data. Based on the previously identified secondary requirement categories, each functional requirement was addressed with both positive and negative questions to minimize subjective bias among the expert team. The online questionnaire was distributed to university students, households without purchased essential housing, households of different housing types, and relevant professionals, with a total of 150 questionnaires distributed and 10 questionable questionnaires excluded. A total of 140 valid questionnaires were actually recovered, with a questionnaire qualification rate of 93.33%. The data was imported into SPSS software for reliability analysis, yielding $\alpha > 0.76$, indicating good reliability and meeting the requirements for data analysis.

3.2. Data and Demand Attribute Calculation Analysis

Determine the design attribute types and calculate the SII and DDI values. After collecting and validating 140 completed questionnaires, analyze the residents' demand attributes using the survey data and the design attribute classification evaluation table to identify and categorize the types of resident demands. The questionnaire statistics are shown in Table 3.

Table 3. Kano user questionnaire statistics

N	Factor selection	Like it very much	It should be so	No matter	Reluctantly accept	Dislike
C11	Possess	53	31	22	6	28
	Unpossess	0	66	46	24	4
C12	Possess	35	11	31	7	56
	Unpossess	36	10	21	16	57
C13	Possess	17	37	29	49	8
	Unpossess	57	32	25	12	14
C14	Possess	66	12	12	11	39
	Unpossess	63	15	39	14	9
C21	Possess	61	44	12	5	18
	Unpossess	15	0	28	25	72
C22	Possess	51	9	33	9	38
	Unpossess	63	36	13	25	3
C23	Possess	3	55	22	54	6
	Unpossess	8	32	41	10	49
C24	Possess	44	24	13	14	45
	Unpossess	6	1	38	44	51
C31	Possess	27	16	30	34	33
	Unpossess	14	57	31	34	4
C32	Possess	47	42	39	8	4
	Unpossess	48	29	10	42	11
C33	Possess	43	5	57	24	11
	Unpossess	3	59	7	47	24
C41	Possess	30	23	47	1	39
	Unpossess	12	13	43	31	41
C42	Possess	5	55	2	39	39
	Unpossess	22	8	37	11	62
C43	Possess	22	27	17	54	20
	Unpossess	33	33	27	31	16
C44	Possess	26	7	26	59	22

Unpossess	32	5	44	11	48

Import the data results into formulas (8) and (9) to calculate the SII and DDI values. First, calculate the weights of A, O, M, and I in the residents' corresponding different needs based on the Kano questionnaire results. Then, use formulas (8) and (9) to determine the resident satisfaction influence coefficients (SII and DDI values), thereby identifying the design attributes corresponding to the design needs. The Kano model classification and SII/DDI values are shown in Table 4. The demand for personalized decoration (C41) in English home learning spaces is not high, making it a non-differentiated type. After excluding the non-differentiated type, the essential attributes are: soundproofing measures (C24), learning materials (C31), network connectivity (C32), and interactive tools (C33). Desired attributes: study schedule (C42), sufficient storage space (C43), flexible space layout (C44). Delight attributes: comfortable seating (C11), appropriate desk and chair height (C12), electronic devices (C13), power outlets (C14), quiet environment (C21), adequate lighting (C22), good ventilation (C23).

Table 4. The analysis results of Kano's demand elements

N	SII	DDI	Kano attribute
C11	0.24	-0.22	A
C12	0.31	-0.7	A
C13	0.52	-0.58	A
C14	0.56	-0.59	A
C21	0.55	-0.6	A
C22	0.31	-0.71	A
C23	0.51	-0.24	A
C24	0.21	-0.78	M
C31	0.44	-0.31	M
C32	0.25	-0.6	M
C33	0.24	-0.47	M
C41	0.56	-0.68	I
C42	0.21	-0.6	O
C43	0.26	-0.38	O
C44	0.41	-0.25	O

In order to more accurately measure the relationship between household needs and household satisfaction, the maximum value of the satisfaction index for modular English home learning spaces is set as T_i, with the calculation formula as follows:

$$T_i = \max(|SII|, |DDI|) \tag{13}$$

The target satisfaction rate is used to assist designers in refining and optimizing the quantitative analysis of quality elements, serving as a critical metric for measuring satisfaction between current conditions and residents' psychological expectations. The target satisfaction rate for demand elements is composed of current satisfaction and target satisfaction. Surveys are conducted among relevant industry professionals, users, and experts to ensure the reliability and professionalism of the questionnaire research. The questionnaire uses a 5-point rating scale from 1 to 5. The arithmetic mean is taken as the current satisfaction value S_0. The survey and statistics determine the satisfaction values that each function should achieve under ideal conditions, and their average is taken as the target satisfaction value S_1. The ratio of S_1 to S_0 in Formula (14) represents the target improvement rate of resident satisfaction V_i for housing. The larger the value of V_i, the greater the gap between the target satisfaction level and the current satisfaction level:

$$V_i = \frac{S_1}{S_0} \tag{14}$$

The self-assessment score for demand importance is a key component of the overall demand importance score in the quality house. During the Kano phase, analyze the types of requirements and add the self-assessment score for requirement importance. Based on the requirements obtained through the affinity diagram method in the previous phase, researchers score each secondary requirement on a 5-point scale, where 1 indicates "very unimportant" and 5 indicates "very important." The arithmetic mean of the survey data, denoted as H_i, represents the self-assessment score for the importance of each requirement in the English home learning space.

The comprehensive importance score of resident needs serves as the final value in the Kano model phase and also plays a bridging role in data support between the Kano and QFD models, providing important references for data inference and subsequent design in the QFD quality house. To refine the importance of resident needs, an adjustment coefficient k is introduced, with different values of k corresponding to different demand attributes. The specific values are as follows:

Essential needs: $k = 0.5$.

Expected new needs: $k = 1$.

Delightful needs: $k = 1.5$.

The comprehensive importance score of resident needs is calculated based on multiple factors, including resident satisfaction values and k values. The formula is as follows:

$$Z_i = H_i * (1 + T_i)^k * V_i \quad (15)$$

Using the detailed data and formulas in the above table, the following values can be calculated: the H_i value, the k value, the S_0 value, the S_1 value, the V_i values, T_i values, and Z_i values. The detailed calculation results for each item are shown in Table 5. These values are convenient for the construction of the QFD quality house, i.e., the right wall of the QFD quality house.

Table 5. Detailed numerical results

	Demand	H_i	k	S_0	S_1	V_i	T_i	Z_i
M	C24	4.97	0.5	4.98	4.81	0.97	0.85	8.92
	C31	4.69	0.5	4.83	4.74	0.98	0.81	8.32
	C32	4.65	0.5	4.59	4.65	1.01	0.7	7.98
	C33	4.59	0.5	4.52	4.63	1.02	0.69	7.91
O	C42	4.53	1	4.18	4.5	1.08	0.67	8.17
	C43	4.46	1	3.8	4.4	1.16	0.67	8.64
	C44	4.4	1	3.79	3.91	1.03	0.64	7.43
A	C11	4.36	1.5	3.43	3.76	1.1	0.64	7.87
	C12	4.05	1.5	3.37	3.67	1.09	0.63	7.2
	C13	3.55	1.5	3.21	3.64	1.13	0.56	6.26
	C14	3.54	1.5	3.17	3.64	1.15	0.55	6.31
	C21	3.26	1.5	3.13	3.52	1.12	0.55	5.66
	C22	3.13	1.5	3.05	3.2	1.05	0.54	5.06
	C23	3.04	1.5	3	3.12	1.04	0.53	4.84

3.3. Derivation of QFD Quality House Design Requirements

By constructing a quality house model, the relationship between resident needs and various design quality elements can be determined, thereby obtaining corresponding weights to facilitate the conversion of resident needs into design requirements for modular English home learning space design.

First, quantify the correlation between secondary resident needs and design requirements. By organizing industry experts and relevant practitioners to grade the association between quality elements and resident needs, the symbol "●" indicates "strong" correlation, with a value of 5. The symbol "○" indicates 'moderate' correlation, with a value of 3. The symbol "▲" indicates "weak" correlation, with a value of 1. A blank space indicates extremely weak or no correlation. Convert the one-sided Kano resident demand data into two-way data that combines target resident demands with design conversion objectives. Finally, the modular English home learning space design is shown in Table 6. The product engineering characteristics are ranked as follows: strong interactivity, modern appearance, fashionable style, easy to clean, space-saving, auxiliary functions, and high-quality materials.

Table 6. Modular English home study space design

	Demand	Style fashion	Modern appearance	Save space	Intermobility	Easy to clean	Auxiliary function	Quality selection
	C24	○	●	○		○	○	●
M	C31			●	●	○		
	C32			●	●	○	▲	○
	C33	○	●	○	●	○	○	●
	C42				○			▲
O	C43	●	●	○	●	○	●	
	C44	●	●	○	●	●	○	
	C11	○	○	○	●	○	○	●
	C12	○	○	○	●	○		●
	C13	○	○		●	○	▲	●
A	C14	○	○	○		○		●
	C21	○	○		●		▲	
	C22	○	○	○	●		▲	
	C23	○	●	○	●		▲	
	w_i	203.17	231.34	176.34	246.35	196.43	122.47	106.44
	Sort	3	2	5	1	4	6	7

3.4. Multifunctional Space Design Results

The preceding section outlined the design of an English home learning space based on Kano-QFD principles, emphasizing the need for strong interactivity, a modern appearance, a fashionable style, ease of cleaning, space efficiency, auxiliary functions, and high-quality materials to enhance service quality. This section presents a multifunctional space design based on the aforementioned research findings.

3.4.1. Electronic Resource Space

The electronic resource space comprises a search area and a learning and sharing zone. The search area is where residents can access online databases and browse information, equipped with computers for resident use. The Learning and Sharing Space combines learning and recreational functions, with separate dynamic and quiet zones. It features an audiovisual zone, self-study zone, tablet experience zone, self-service space, quiet reflection corridor, and leisure social zone. It also includes a curated book wall showcasing a selection of titles, integrating print and electronic information resources, as well as audio-visual and multimedia content. The space provides integrated facilities, resources, and services.

3.4.2. Leisure and social spaces

The leisure and social space includes areas such as an audiovisual space, a balcony, and a coffee bar. The communication and leisure areas are designed to meet residents' needs for interaction and communication in a digital environment, reflecting the multifunctional communication requirements of home learning spaces. The shared space provides residents with services such as PAD experiences and online browsing. The audiovisual space offers audio and video discs, features a dedicated area for cable TV broadcasts, and is equipped with audio and video playback devices, high-definition TV-computer all-in-one units, and sofas. The living room is equipped with a large color screen, and the shared space also features a small electronic screen for displaying multimedia information or playing academic videos for residents to view. The balcony is an open-air design with green lawns and modern, stylish furniture, allowing residents to study, discuss, or chat there. Additionally, considering that residents may spend extended periods in the facility and often require coffee, beverages, and snacks, a coffee bar is provided. Residents can relax and dine at the coffee bar during their study breaks.

3.4.3. Activity Space

The activity space mainly includes a resident activity center, lecture hall, and exhibition hall, which are used to hold academic conferences, lectures, exhibitions, and other activities on a regular or irregular basis. The resident activity center has a unique design with ample natural light and is equipped with foldable tables and chairs that can be freely arranged to accommodate about 10 people for various English-related activities. Both the resident activity center and lecture hall are equipped with audio, projection, and microphone equipment to provide venues for activities of different sizes.

4. The promotional effect of multifunctional space design on language interaction

This chapter designs a control experiment to investigate the effectiveness of ordinary English home learning spaces and English home learning spaces designed based on Kano-QFD in promoting language interaction.

4.1. Research subjects and methods

Select 20 households that require long-term English learning at home. Ten households (control group) will continue with their previous spatial design, while ten households (experimental group) will undergo spatial adjustments based on an English home learning space designed using the Kano-QFD method.

Through surveys and experiments, the experimental group and control group will engage in English home learning in different living spaces. Finally, quantitative statistical analysis methods (using the data analysis tool SPSS) were employed to describe and analyze the language interaction performance of family members in both groups, focusing on four dimensions: interaction frequency, content depth, content breadth, and feedback quality. This exploration aimed to determine whether the English home learning spaces designed based on Kano-QFD are more conducive to enhancing language interactivity compared to traditional home learning space methods.

4.2. Results and Analysis

The results of the independent samples t-test for pre-test language interactivity among family members in the experimental and control groups are shown in Figure 3. The mean scores for language interactivity among family members in the experimental and control groups were approximately 82.36 and 82.15, respectively, showing homogeneity of variance (Sig. value of 0.855, greater than 0.01). The t-test for equality of means (two-tailed Sig.) yielded a P-value of 0.926 (greater than 0.05), indicating that there was no significant difference in language interactivity between the experimental and control groups prior to the experiment.

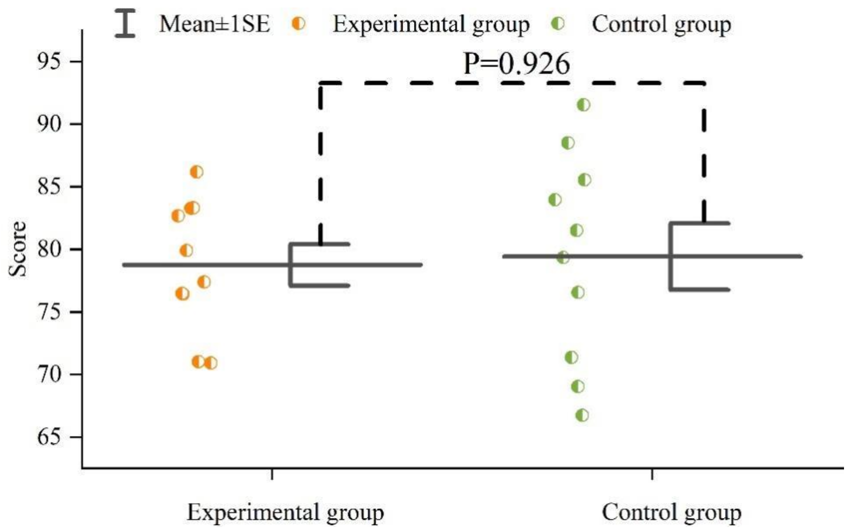

Figure 3. Test results of the previous test

An independent samples t-test was conducted on the pre-test data for the four dimensions of language interactivity among family members in the experimental and control groups. The test results are shown in Table 7. The P (two-tailed Sig.) values were all greater than 0.05, indicating that there were no significant differences between the two groups in terms of the four dimensions of language interactivity among family members: interaction frequency, content depth, content breadth, and feedback quality.

Table 7. Test results of the independent sample t in front of each dimension

Dimension	Group	N	M	Sig.	T	Mean difference	P
Interactive frequency	Experimental group	10	24.22	0.456	2.463	-0.05	0.963
	Control group	10	24.17				
Content depth	Experimental group	10	24.11	0.363	0.164	-0.02	0.863
	Control group	10	24.09				
Content span	Experimental group	10	23.25	0.164	0.563	0.04	0.912
	Control group	10	23.29				
Feedback quality	Experimental group	10	10.78	0.642	0.253	-0.18	0.967
	Control group	10	10.6				

Four months later, an independent samples t-test was conducted on the post-test data of language interactivity among family members in the experimental and control groups. The test results are shown in Figure 4. The mean values of language interactivity among family members in the experimental and control groups were approximately 93.65 and 85.61, respectively. There was no homogeneity of variance (Sig. value = 0.000, less than 0.01), and the t-test for equality of means (two-tailed Sig.) yielded a P-value of 0.000 (less than 0.05), indicating a significant difference in language interactivity between the experimental and control groups after the intervention. Comparing the means of the two groups, it is evident that the improvement in language interactivity levels was more pronounced in the experimental group.

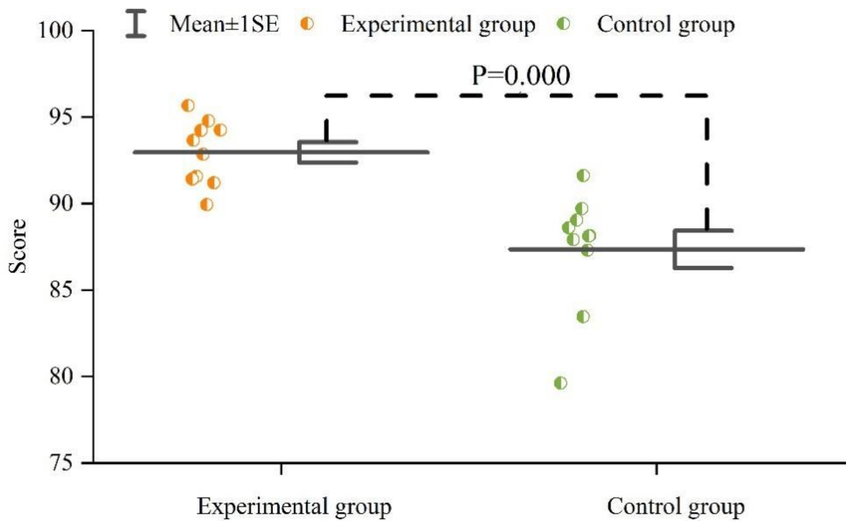

Figure 4. The rear data independent sample t test

An independent samples t-test was conducted on the post-test data for the four dimensions of language interactivity among family members in the experimental and control groups. The test results are shown in Table 8. The P (two-tailed Sig.) values for all four dimensions were less than 0.05, indicating that there were significant differences between the two groups in terms of the four dimensions of language interactivity among family members: interaction frequency, content depth, content breadth, and feedback quality.

Table 8. Test results of the independent sample t after each dimension

Dimension	Group	N	M	Sig.	T	Mean difference	P
Interactive frequency	Experimental group	10	28.22	0.863	4.613	-3.26	0.000
	Control group	10	24.96				
Content depth	Experimental group	10	26.11	0.524	3.564	-1.53	0.000
	Control group	10	24.58				
Content span	Experimental group	10	25.25	0.421	4.312	-0.62	0.000
	Control group	10	24.63				
Feedback quality	Experimental group	10	14.07	0.152	3.542	-2.63	0.000
	Control group	10	11.44				

The results of the paired sample t-test for pre- and post-tests of language interactivity among family members in the experimental and control groups are shown in Table 9. From the mean values of the data, the pre-test mean values for language interactivity among family members in the experimental and control groups were very similar, but the post-test mean values after the experiment showed an increase of 11.35 in the experimental group and only 3.46 in the control group compared to the pre-test values.

Table 9. Test results of the matching sample t of the language interactivity

Group		N	M	SD	T	P
Experimental group	Pretest	10	82.36	9.635	-16.352	0.000
	Posttest	10	93.65	8.635		
Control group	Pretest	10	82.15	13.635	-6.521	0.000
	Posttest	10	85.61	15.634		

The results of the paired sample t-test for each dimension of family member language interactivity in the experimental group before and after the experiment are shown in Table 10. The P (two-tailed Sig.) values for the paired sample t-test for the four dimensions before and after the experiment were all 0.000 (less than 0.05), indicating a significant difference.

Table 10. Test results of the different experimental group of the experimental group

Dimension		N	M	SD	T	P
Interactive frequency	Pretest	10	24.22	2.635	4.613	0.000
	Posttest	10	28.22	3.652		
Content depth	Pretest	10	24.11	2.593	3.564	0.000
	Posttest	10	26.11	3.964		
Content span	Pretest	10	23.25	2.415	4.312	0.000
	Posttest	10	25.25	3.695		
Feedback quality	Pretest	10	10.78	2.485	3.542	0.000
	Posttest	10	14.07	3.529		

In summary, compared with traditional home learning spaces, English home learning spaces designed based on Kano-QFD have a better promotional effect on improving the level of language interaction among family members.

5. Conclusion

The study designed a quality optimization model for home-based English learning spaces based on the Kano-QFD framework to maximize the satisfaction of residents' needs for home-based English learning. Through questionnaire data, 15 demand elements were identified. The Kano model was used to determine the types of design attributes, and the SII and DDI values were calculated. The identified and categorized resident needs included essential attributes (soundproofing measures, learning materials, internet connectivity, interactive tools), expected attributes (learning schedules, sufficient storage space, flexible spatial layout), and delight attributes (comfortable seating, appropriate desk and chair heights, electronic devices, power outlets, quiet environment, adequate lighting, and good ventilation). Based on the Kano-QFD model, a multifunctional English home learning space was designed using the weighted values of the identified demand elements. The language interaction outcomes of family members in this space were compared with those in a traditional home learning space. After the experiment, the language interaction scores of family members in the English home learning space designed using the Kano-QFD model improved by 11.35 points, significantly higher than those in the traditional home learning space. The home learning space service quality optimization model proposed in this paper, based on Kano-QFD, can maximize the satisfaction of home-based English learning needs.

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