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Ranking of Service Quality Solution for Blended Design Teaching Using Fuzzy ANP and TOPSIS in the Post-COVID-19 Era

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Abstract: The blended educational method has become a common way of teaching and learning in the post-COVID-19 era. However, the related research on the selection model for the blended design teaching service quality solution is still an important research gap during this period. Therefore, this study proposed a hybrid method of fuzzy analytic network process (FANP) and technique for order preference by similarity to ideal solution (TOPSIS) to analyse the dimensions, indicators and alternatives of blended design teaching service quality. As for the findings of this research, the dimension of assurance is the most vital factor, followed by responsiveness, reliability and empathy. Meanwhile, this research discovered that the top three significant alternatives are "Employees are trustworthy", "Safe transaction mechanism and environment" and "Personalised needs of customers". Also, we found that dimensions utilised to evaluate the quality of education service are similar whether in the post COVID-19 era, in the COVID-19 epidemic or prior to the COVID-19 pandemic. The main contribution of this study is to establish a multi-criteria decision-making (MCDM) model for the ranking of the blended design teaching service quality index and solution under a fuzzy environment. Finally, the research findings of this study have a guiding role, thereby becoming a guide for the industries related to hybrid design education to maintain good service quality in similar scenarios in the future.

Keywords: blended design teaching; service quality; fuzzy analytic network process (FANP); technique for order preference by similarity to ideal solution (TOPSIS); multi-criteria decision-making (MCDM)

MSC: 68U35

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1. Introduction

Since the outbreak of COVID-19, blended teaching methods have been adopted by many educational institutions in response to the development of the epidemic. Therefore, many related research results were also published during this period. For example, Zhang et al. [1] presented a blended learning study on physical education (PE). They pointed out that it outperformed students with a single learning approach in all aspects when students learned PE through a blended learning approach, thereby demonstrating the practicality and effectiveness of blended approaches to PE learning. Wang et al. [2] revealed that the optimised blended learning model will stimulate the learning motivation of foreign language learners to cultivate their autonomous learning ability, thereby constructing and improving their autonomous learning behaviour. Zhang [3] mentioned that the blended learning approach takes advantage of information and communication technology, which is beneficial to meet needs of students' subject learning, thereby helping them achieve expected learning outcomes. Thus, Zhang [3] believes that a blended learning approach can assist students to progress in their professional studies. Similarly, some studies [4–6] pointed to blended learning as an innovative method that can be used as a solution for disaster-like scenarios in the future.

In the meantime, Rachmadtullah et al. [7] presented a case study of the application of the Moodle application to a blended learning environment, targeting students in the elementary teacher education programme in Indonesia. It illustrated that the use of the Moodle blended learning model for students in the elementary teacher education programme is effective during the COVID-19 pandemic and can be used as a solution to a blended learning approach.

Also, Ożadowicz [8] applied a modified blended learning approach to the higher education environment of engineering. Ożadowicz [8] presented attitudes and choices of engineering students towards blended learning approaches. Moreover, this study demonstrated the experience and reflection of the engineering higher education environment in adopting a blended learning approach and provided recommendations for future related research. Likewise, some research [9–11] provided insights into the effectiveness of the blended learning method in interior design education, exercise science and pre-service biology teacher creative thinking cultivation. These studies demonstrated that blended learning approaches were effective in these areas in exploring alternatives for specific courses to successfully achieve course learning outcomes and provide appropriate instructional continuity in the COVID-19 pandemic.

In addition to the above research results, some researchers [12–16] have also begun to pay attention to the development trend of blended learning research in the post-COVID-19 era. Among them, some studies [12–14] have shown that blended learning is an effective educational and learning strategy for chemical engineering, architectural and art education. Also, Singh et al. [15] proposed an approach for guiding teachers to combine traditional and online instruction, thereby providing students with an engaging learning experience. Similarly, Saboowala et al. [16] provided views and insights on the readiness of in-service teachers for blended learning.

Moreover, several studies [17–23] on the blended education service quality assessment using various methods have been published in recent decades. Among them, Al-Busaidi et al. [20] utilised the SERVQUAL scale to evaluate the key factors of instructors' satisfaction for learning management system in blended learning environment. Beutelspacher et al. [21] proposed a research work of the blended learning platform evaluation using the SERVQUAL scale for the higher education industry. Seo et al. [22] presented a case study using the SERVQUAL scale to assess student perceptions of blended learning approaches in South Korea in the post-COVID-19 era. Similarly, Ho et al. [23] proposed a case study of blended learning service quality using the SERVQUAL scale for higher education institutions in Vietnam after the COVID-19 pandemic. Despite this, the related research using the SERVQUAL scale to measure the blended design teaching service quality is still insufficient in the post-COVID-19 era. Most service providers of design education do not realise that their services can satisfy the consumer or not. Therefore, the service quality evaluation for the blended design education industry is needed to solve this problem and fill the research gap.

In view of this, this research will establish a framework that is based on the SERVQUAL scale for measuring the blended design teaching service quality through expert questionnaires. Afterwards, fuzzy analytic network process (FANP) will be implemented to calculate weights of dimensions and indicators. Finally, technique for order preference by similarity to ideal solution (TOPSIS) will be applied to rank all alternatives, thereby achieving the following research purposes:

1. To construct the evaluation structure based on the SERVQUAL scale for the blended design teaching service quality.
2. To integrate expert consensus for analysing the weight of dimensions and indicators for blended design teaching service quality using FANP.
3. To evaluate and rank alternatives of blended design teaching service quality by applying TOPSIS.
4. To fill in the research gap of blended design teaching service quality in the post-COVID-19 era, thereby providing relevant decision-making suggestions for the blended design education industry.

2. Literature Review

After nearly three years of the COVID-19 pandemic, many scholars [24–27] have begun to pay attention to the characteristics of education in the post-epidemic era due to the gradual easing of the epidemic. For example, some scholars [24,25] argued that virtual education or a blended education method with the help of network technology will be the mainstream education method in the post-COVID-19 era. Similarly, Pham et al. [26] further mentioned that people's recognition of the e-learning advantages is gradually increasing in the post-COVID-19 era. Zhao et al. [27] further added that in the post-COVID-19 era, there are three most obvious educational characteristics, namely student-centred, exploration ability cultivation and purposeful teaching methods. In view of this, features such as IT-assisted classrooms, personalisation and greater educational purpose are hallmarks of education in the post-COVID-19 era.

Meanwhile, consumer satisfaction is one of the most common terms in the business environment. To make customers satisfied with high-quality service, a systematic approach is required to quantify consumer demand into data, thereby establishing a high-quality service quality to meet requirements of customers.

2.1. SERVQUAL Scale

In recent decades, the scale of the service industry has gradually expanded and the impact of service quality on the industry has begun to emerge [28,29]. Many studies [30–34] have shown that the measurement methods of service quality mainly include the definition of service quality, employee training, the dimension of service quality, the importance of service quality and customer satisfaction. Parasuraman et al. [35] first introduced the concept model of service quality in 1985. Then, they proposed a multiple-item scale for service quality measurement called the SERVQUAL scale in 1988 [36]. The SERVQUAL scale is currently one of the most well-known methods for service quality measurement. Afterwards, the SERVQUAL scale was finally summarised as five dimensions and 22 indicators through the improvement and verification by scholars [37–39]. The five main dimensions of the SERVQUAL scale are as follows:

1. Tangibility: the physical facilities used to provide service.
2. Reliability: the ability to properly implement service commitments.
3. Responsiveness: the willingness and ability to help and provide immediate service.
4. Assurance: the knowledge, skills and courtesy required to provide service and the ability to perform tasks satisfactorily.
5. Empathy: the ability to pay special attention to consumers and customisable services.

In the SERVQUAL scale, five dimensions of service quality are examined with 22 indicators. Meanwhile, the customer perception is measured based on fuzzy-like Likert scale [40]. Also, the following equation is utilised to calculate the gap between each dimension of service quality and customer expectations, thereby examining the specific characteristics of different industries and services [41].

$$O_j = \frac{\sum_{i=1}^{n} \left(P_{ij} - E_{ij} \right)}{n_j} \quad (1)$$

j is the SERVQUAL scale dimension, n_j is number of questions in j dimension, P_{ij} is average of perceptions, E_{ij} is average of expectations and O_j is gap between every dimension.

If O_j is positive, the service quality level is higher in dimension than the customer expectations. On the contrary, the service quality level is lower than customer expectations. Accordingly, a reasonable score of service quality level can be calculated by weighting if the weight value of each industry indicator in the SERVQUAL scale is obtained.

Also, the reliability and validity of the SERVQUAL scale have been approved by researchers in various fields [42–52]. Among them, some studies [47–52] proved that the integrated method of the SERVQUAL scale and a multi-criteria decision-making (MCDM) approach are feasible for the measurement of service quality.

In view of this, the SERVQUAL scale will be used to evaluate and assort the demands of customers in this paper.

2.2. Fuzzy Analytic Network Process Model

To choose the best option among the alternatives under discrete conditions, some MCDM methods must be employed. Among them, Analytical Network Process (ANP), proposed by Saaty [53] in 1996, has been confirmed by many studies and is one of the most complete of these techniques in many fields [54–60]. Many scholars [61,62] mentioned that the ANP method asks questions in the form of a network and considers the qualitative and quantitative criteria in question. In the meantime, ANP allows decision makers to involve any relationship in the structure. Accordingly, ANP is very suitable for solving problems with a special relational structure between sub-criteria, alternatives and identified nonlinear links.

Also, Rahiminezhad et al. [63] proposed a study during the COVID-19 pandemic, mentioning that the biggest advantage of the ANP method is that the internal relationship between decision-making criteria can be considered, which is very suitable for the analysis and calculation of MCDM-related issues during the period of the COVID-19 epidemic. Moreover, Hemmati et al. [64] mentioned that ANP can be expressed verbally to express the decision maker's judgment.

In addition, Sung [65] applied ANP to the evaluation and analysis of design works in 2015. His research results illustrated the feasibility of ANP in the field of design. Wu et al. [66] applied ANP to the evaluation of online course service effectiveness in the post-COVID-19 era. Furthermore, Yao et al. [67] proposed an integrated method of ANP and Fuzzy Delphi in 2022 for the establishment of product design indicator evaluation. The above results, both before and after the COVID-19 pandemic, demonstrated the feasibility of applying the ANP approach to those fields of design and education.

Although ANP can be used to find answers to the above-mentioned problems, unfortunately, it does not provide a good explanation for a problem involving uncertain phenomena or inaccurate answers. Therefore, it is necessary to introduce fuzzy approaches due to the special nature of problems in this paper.

Fuzzy theory and fuzzy logic were proposed by Dr. Lotfi Zadeh in 1965 and 1975, respectively [68,69]. They are regarded by scholars as effective tools for dealing with uncertainty caused by imprecision and ambiguity. For example, Liu et al. [70] mentioned that fuzzy theory uses precise mathematical language to describe the fuzzy phenomenon of the human mental state. Vanegas et al. [71] mentioned that the use of fuzzy theory can bring the results of research statistics closer to the human state of mind largely because human perception variables are often difficult to measure accurately.

Kahraman et al. [72] reported that fuzzy logic is a suitable mean for simulating the uncertainty or imprecision caused by human psychological phenomena. They argued that a relatively new approach to decision analysis research is warranted in the face of problems arising from imprecise psychological phenomena. Therefore, they introduced an integrated method consisting of fuzzy logic and ANP, called Fuzzy ANP (FANP), dealing with the related decision-making problems caused by imprecise psychological phenomena. Furthermore, much research [73–81] reported that that FANP has been widely utilised in the field of decision-making research within these decades and has been proved to have a high degree of reliability and validity in solving decision-making problems.

In addition, we found that many scholars [82–84] have published some research results using fuzzy methods to evaluate service quality or performance in those fields of online distance learning and educational information systems since the COVID-19 pandemic. For example, Hisham et al. [82] proposed a research framework of the stress factors evaluation for online distance learning environment using FANP. They [82] discovered that the most important stress factor is learning environment, followed by time management, lecturer, resources and family members during the period of the COVID-19 pandemic. Hii et al. [83] proposed an evaluation model for e-learning information systems using FANP in the COVID-19 pandemic era. Likewise, Çelikbilek et al. [84] utilised fuzzy methods to prioritise the component of e-learning systems in the COVID-19 era. These research findings demonstrate the feasibility of applying fuzzy methods in the field of education for both blended and non-blended teaching methods which has significant implications for the evaluation methodology of this study.

2.3. The Hybrid Approach of FANP and TOPSIS

TOPSIS was proposed by Huang and Yoon in 1981 [85]. The basic principle is that the alternatives selected by the decision makers are the closest to the positive ideal solution (PIS) and the farthest from the negative ideal solution (NIS) [86]. The so-called positive ideal solution refers to the criterion value with the maximum benefit side or the minimum cost side among the alternatives. In contrast, the criterion value with the minimum benefit side or the maximum cost side is the negative ideal solution [87]. These properties make TOPSIS ideal for evaluating and solving MCDM problems with multiple properties and multiple scenarios [88–90].

Meanwhile, Kim et al. [91] and Shih et al. [92] argued that TOPSIS has the advantages and characteristics of efficient and simple calculation process, considering that the scalar value of the best and worst alternatives and the performance metrics of all alternatives on the attribute can be visualised on the polyhedron, which is very suitable for the MCDM problems of alternative evaluation and ranking.

Also, many scholars [93–96] reported that TOPSIS method is often used together with other methods, such as AHP and ANP, to evaluate and solve MCDM problems in fields of Supply Chain Management, Quality Evaluation, Human Resources and Risk Analysis. Moreover, Chang et al. [97] utilised the integrated method of ANP and TOPSIS to choose the location of Taiwanese service apartment. Zhang et al. [98] used the TOPSIS-Synthetic control method to discuss and recommend higher education development evaluation and improvement policies in the post-COVID-19 era. Nanath et al. [99] integrated ANP and TOPSIS to compare decision-making systems for higher education choice before and after the COVID-19 pandemic.

Furthermore, many scholars [100–104] further proposed a hybrid method of FANP and TOPSIS for MCDM problems within these decades. For example, Sinrat et al. [100] applied this integrated method for the risk management of the supply chain. Kumar et al. [101] proposed a multiple perspectives benchmark framework of software security estimation for hospital management software using fuzzy logic, ANP and TOPSIS. Likewise, some scholars [102–104] proposed some theoretical frameworks and approaches for maintenance plan selection and risk management using the integrated methods of FANP and TOPSIS. Moreover, Chien et al. [105] proposed a case study for the supplier selection of a wind power plant using FANP and TOPSIS. Furthermore, Koochekian et al. [106] proposed a case study of interdisciplinary integration for agricultural higher education students using FANP and TOPSIS in Iran. Koochekian et al. [106] revealed the feasibility of applying a hybrid approach using FANP and TOPSIS to assess interdisciplinary index rankings. The above research results are a significant inspiration for the development and establishment of method and process for this research.

2.4. Summary

The problem becomes one of multiple-criteria decision-making (MCDM) when a decision maker has to consider different criteria to choose between different methods [107,108]. Li et al. [109] mentioned that the well-known advantage of MCDM techniques is that decision makers can assign large weights to risk and return and consider small weights for other criteria. Kou et al. [110] used MCDM techniques for analysis and computation of small samples during the COVID-19 pandemic. They demonstrated the effectiveness of MCDM technology in addressing MCDM-related issues during the COVID-19 pandemic.

Meanwhile, it can be known that FANP and TOPSIS are effective methods for solving MCDM problems in many fields based on the literature review. In the meantime, the hybrid method of FANP and TOPSIS contributes to interdisciplinary research. Also, the feasibility of fuzzy methods for evaluating and solving problems in the field of education has been approved during the period of the COVID-19 pandemic and post-COVID-19 pandemic era.

Moreover, in the FANP model, the evaluation criteria for each alternative are obtained by integrating expert opinions. Therefore, the disadvantage of such models is that they rely on expert experience and are prone to subjective opinions. In view of this, Wang et al. [111] suggested to apply TOPSIS to rank all alternatives in the final stage of such research, thus avoiding interference with the result by the subjective opinion of experts.

Accordingly, this research will be based on the service quality (SERVQUAL) scale to establish a framework for measuring the service quality of blended design teaching through expert interviews. Afterwards, FANP will be implemented to calculate weights of dimensions and indicators. Finally, we will apply TOPSIS to calculate distance of each alternative between positive and negative ideal solutions to discover the potential optimal solution, thereby achieving our main research purposes via employing this hybrid approach.

3. Materials and Methods

In this research, we present an integrated approach of FANP and TOPSIS that is based on the SERVQUAL scale to evaluate the service quality of blended design teaching in the post-COVID-19 era. The process of this research is shown in Figure 1.

3.1. The Construction of Hierarchy and Network Structure

This study first decomposes the problem into evaluation indicators according to ANP and the SERVQUAL scale. Afterwards, we establish the hierarchical structure by grouping indicators to discover the relationship between indicators. Also, Tsai et al. [112] suggested that indicators should be revised by means of expert discussion. Thus, this study uses expert questionnaires to obtain experts' opinions and then revises indicators according to the experts' suggestions, thereby making the expression of indicators conform to meet the particularity of hybrid design teaching in the post-COVID-19 era. Finally, we construct a hierarchical structure of evaluation indicators according to the results of the expert questionnaire.

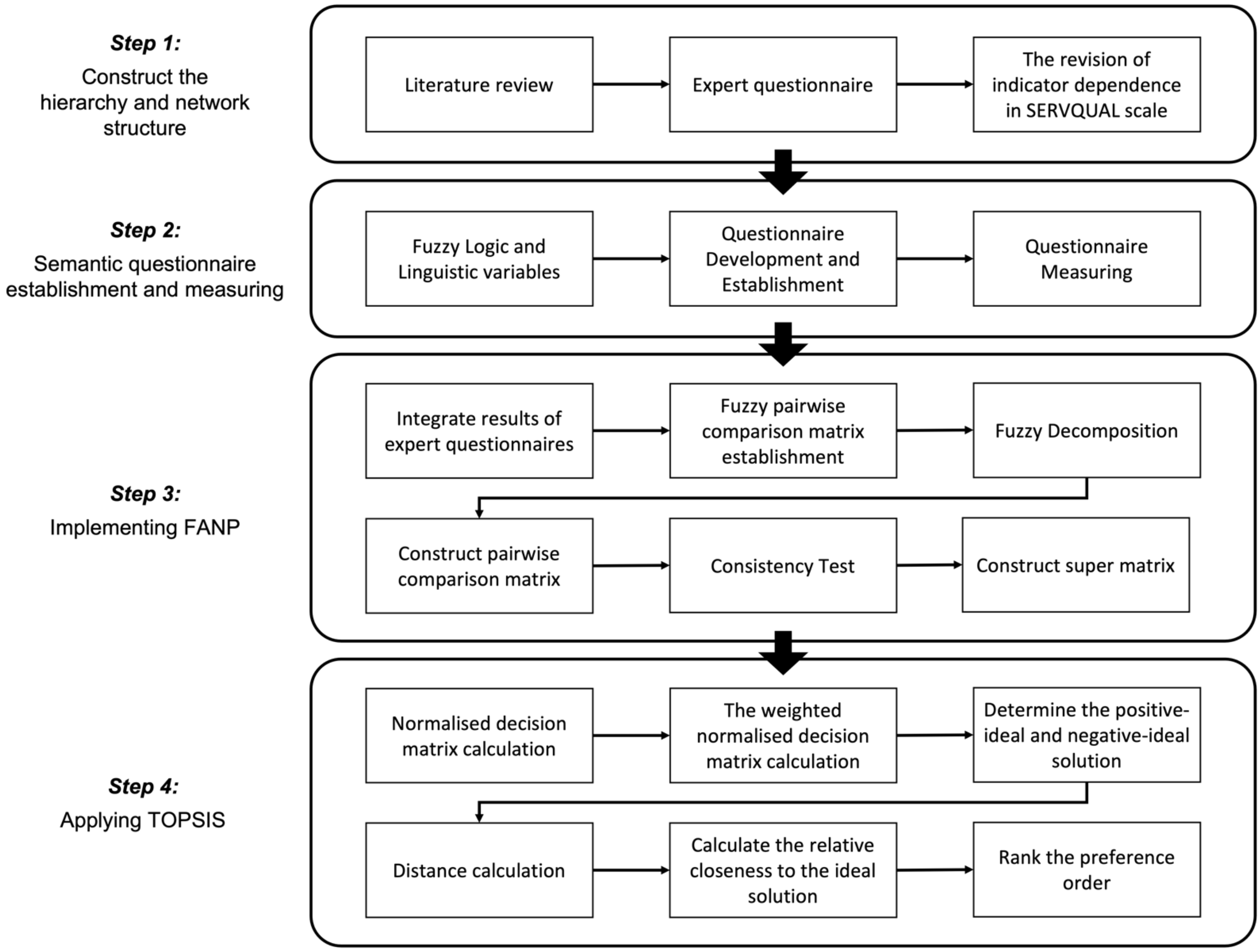

Figure 1. The process of this research.

3.2. Fuzzy Logic and Linguistic Variables

Linguistic variables, such as "Very important", "Somewhat important" and "Unimportant" are often seen as the human mind's natural perception of priorities and judgments about specific options. Herreva and Viedma [113] reported that linguistic variables are useful tools for evaluating service quality performance. However, Zimmermann [114] argued that such linguistic variables related to importance are often ambiguous. He suggested to introduce fuzzy logic to clarify human mental perception when the state of human mental perception is unclear.

Fuzzy logic is an algorithm with fuzzy numbers. In view of this, fuzzy numbers were studied [115–122]. First, many scholars [115–122] reported that the characteristics of fuzzy numbers are generally expressed in mathematical ways to facilitate the practical application of fuzzy numbers. For example, triangular fuzzy number A (a_1, a_2, a_3) given by the following equation is shown in Figure 2.

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-a_1}{a_2-a_1} & , \quad a_1 \leq x \leq a_2 \\ \frac{x-a_3}{a_2-a_3} & , \quad a_2 \leq x \leq a_3 \\ 0 & , \quad \text{otherwise} \end{cases} \tag{2}$$

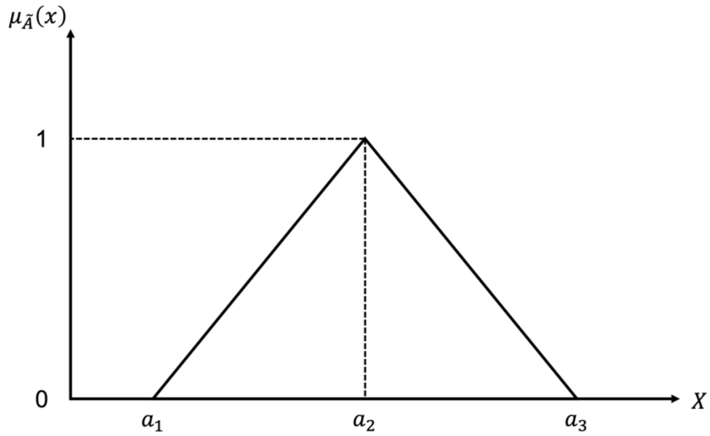

Figure 2. Fuzzy triangular number.

Meanwhile, much research [115–122] mentioned that the most likely value of triangular fuzzy numbers is the crisp value. The crisp value of triangular fuzzy numbers is given by the following equation.

$$A_a = [a_1^\alpha, a_2^\alpha] = [(a_2 - a_1)a - (a_3 - a_2)a + a_3] \quad (3)$$

Also, Buckley [123] considered that the characteristic of triangular fuzzy numbers helps to convert fuzzy linguistic variables into clear and practical numbers, thereby accurately measuring human psychological perception variables. Moreover, Pedrycz [124] proposed a study and proved that the triangular fuzzy number is very suitable for representing the decision maker's relative judgment strength for each criterion or alternative scheme in the hierarchy.

Accordingly, this study uses triangular fuzzy numbers to represent linguistic variable scales. Moreover, a nine-point evaluation scale was suggested by Saaty for ANP [125]. Therefore, we integrate the triangular fuzzy number and the ANP evaluation scale, thereby assessing and measuring human psychological true preferences for specific options. The corresponding fuzzy numbers are provided in Table 1.

Table 1. Fuzzy numbers and scales.

Triangular Fuzzy Number	Linguistic Variables
$\tilde{1} = (1,1,1)$	Equally Preferred
$\tilde{2} = (1,2,3)$	Intermediate
$\tilde{3} = (2,3,4)$	Moderately Preferred
$\tilde{4} = (3,4,5)$	Intermediate
$\tilde{5} = (4,5,6)$	Strongly Preferred
$\tilde{6} = (5,6,7)$	Intermediate
$\tilde{7} = (6,7,8)$	Very Strongly Preferred
$\tilde{8} = (7,8,9)$	Intermediate
$\tilde{9} = (9,9,9)$	Extremely Preferred

3.3. Questionnaire Development and Establishment

As for the questionnaire development, it is necessary to consider the validity of the questionnaire before questionnaire measurement. Therefore, this study rewrites the questionnaire statement based on expert advice and keeps the original representation of dimensions and indicators based on the SERVQUAL scale for retaining high content validity [126]. Then, this study conducts a pre-test and revises the statements according to the pre-test results to see whether the meaning of the questionnaire was clear. Also, this study uses the expert questionnaire method to assess the weight of dimensions and indicators for blended design teaching service quality in the post-COVID-19 era according to the FANP method.

3.4. Questionnaire Measuring

As for the number of expert questionnaires, F. J. Parenté and J. K. Anderson-Parenté [127] suggested that there should be at least ten or more experts. Interestingly, we found that much research [128–137] used small sample size of four to nine to obtain valuable decision-making basis. In the meantime, Darko et al. [138] reported that a large sample size may not be helpful because "cold-called" experts could profoundly affect the result of consistency assessment.

In view of this, ten experts in blended design teaching are selected by this research as the survey objects to avoid the influence of opinions from "cold-called" experts on the consistency evaluation results, thereby achieving our main research objectives.

3.5. Fuzzy Analytic Network Process

3.5.1. Integrate Results of Expert Questionnaires

Since each expert has different cognition of the problem, it is necessary to integrate the expert preference. As for the method of expert opinions integration, Saaty [139] considered that the geometric mean method is not easily affected by extreme values. Therefore, it is very suitable for the synthesisation of expert opinions. Accordingly, this study utilises geometric mean method to generalise results of expert questionnaires.

3.5.2. Fuzzy Pairwise Comparison Matrix Establishment

In this step, a fuzzy pairwise comparison matrix is performed and presented as follows:

$$\widetilde{A^k} = \begin{bmatrix} \widetilde{a_{11}^k} & \widetilde{a_{12}^k} & \cdots & \widetilde{a_{1n}^k} \\ \widetilde{a_{21}^k} & \widetilde{a_{22}^k} & \cdots & \widetilde{a_{2n}^k} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{a_{n1}^k} & \widetilde{a_{n2}^k} & \cdots & \widetilde{a_{nn}^k} \end{bmatrix}, \tag{4}$$

where

$\widetilde{A^k}$ represents the fuzzy pairwise comparison matrix.

$\widetilde{a_{nn}^k}$ is triangular fuzzy mean value for comparing priority pairs among elements.

3.5.3. Fuzzy Decomposition

As for fuzzy decomposition, the process of defuzzification is presented as follows [140–142]:

$$t_{\alpha,\beta}(\bar{a}_{ij}) = \left[\beta f_a(L_{ij}) + (1-\beta) f_a(U_{ij})\right],\ \alpha \in [0,1],\ \beta \in [0,1], \tag{5}$$

where

$$f_a(L_{ij}) = (M_{ij} - L_{ij})\alpha + L_{ij}, \tag{6}$$

$$f_a(U_{ij}) = U_{ij} - (M_{ij} - L_{ij})\alpha \tag{7}$$

where

L_{ij} is the lower bound of the triangular fuzzy number.

M_{ij} represents the median value of the triangular fuzzy number.

U_{ij} is the upper bound of the triangular fuzzy number.

When the diagonal matrix is matching, we have

$$t_{\alpha,\beta}(\bar{a}_{ij}) = \frac{1}{t_{\alpha,\beta}(\bar{a}_{ij})},\ \alpha \in [0,1],\ \beta \in [0,1], i > j \tag{8}$$

3.5.4. Set up the De-Fuzzified Pairwise Comparison Matrix

The de-fuzzified pairwise comparison matrix can be built using $\alpha = [0, 1]$ and $\beta = [0, 1]$ in Equation (5) for calculating the weight of each dimension and indicator. This comparison is made between pairs of indicators. Therefore, the number of comparisons is $\frac{n(n-1)}{2}$ times when there are n metrics to compare. The comparison result after integration is placed in the right-angled triangle area at the upper right of the pairwise comparison matrix. It means that the evaluation value of the main diagonal is 1. Finally, the reciprocal of the evaluation value is put in the upper right corner into the relative position of the lower left corner of the main diagonal to complete the pairwise comparison matrix. The de-fuzzified pairwise comparison matrix is given by the following equation.

$$A = (a_{ij})_{n\times n} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad (9)$$

3.5.5. Consistency Test

After completing the pair comparison matrix, it must be checked for consistency. Therefore, the method of its verification is to use the consistency ratio (*C.R.*) of the pairwise comparison matrix to perform the verification. This ratio compares the degree of consistency with the random objectivity of the data. The consistency ratio (*C.R.*) is defined as follows:

$$C.R. = \frac{C.I.}{R.I.}, \quad (10)$$

where

$C.I.$: Consistency Index,

$R.I.$: Random Index.

When checking the consistency ratio (*C.R.*), it must first find the consistency index (*C.I.*). The consistency index is defined as follows:

$$C.I. = \frac{\lambda max - n}{n-1}, \quad (11)$$

where

λmax: is the maximum value of the matrix,

n is the number of indicators.

As suggested by Saaty [143], when $C.I. \leq 0.1$, it refers to the best acceptable error. When $C.R. \leq 0.1$, it means that the consistency of the matrix is satisfactory. The consistency index generated by the positive reciprocal matrix at different orders is called a random index (*R.I.*). Table 2 shows values of random index.

Table 2. Random indexes (*R.I.*).

The Order of Matrix	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	-	-	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53	1.56	1.57	1.59

3.5.6. The Super Matrix Construction

ANP uses a super matrix to calculate the relative weights between elements to deal with the dependencies between elements in the network structure. A super matrix is composed of many pairwise comparison matrices. Meanwhile, the elements of all clusters are listed on the left and the top of the matrix to form a complete comprehensive matrix, which is called a "super matrix". The super matrix is defined as follows:

$$W = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} w_{11} & w_{12} & w_{13} \\ w_{21} & w_{22} & w_{23} \\ w_{31} & w_{23} & w_{33} \end{bmatrix} \end{array} \quad (12)$$

W is a partition matrix and its items in the matrix are composed of vectors obtained in pairwise comparison matrix. Since W is a column random matrix, the restriction priority of that matrix depends on its reducibility and circularity. If the matrix is irreducible and primitive, the global priority vector is obtained by raising W to the power of the following equation to obtain the limit value [144].

$$\lim_{k \to \infty} W^k \quad (13)$$

Finally, it can be raised to a power large enough to converge, when the super matrix can be assured to be column stochastic. Afterwards, the super matrix will be raised to the limit power which becomes W^{2k+1}, where k is an arbitrarily large number, thereby obtaining all dependencies and the steady-state structures.

3.6. Ranking All Alternatives Using TOPSIS

3.6.1. Normalised Decision Matrix Calculation

In this paper, the decision matrix for m alternatives with n attributes is presented as follows:

$$D = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1j} & \cdots & x_{1n} \\ x_{12} & x_{22} & \cdots & x_{2j} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ x_{i1} & x_{i2} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix}, \quad (14)$$

where

x_{ij} represents the score value of the j^{th} criterion in the i^{th} alternative.

The normalised decision matrix (R) is presented as follows:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1j} & \cdots & r_{1n} \\ r_{12} & r_{22} & \cdots & r_{2j} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ r_{i1} & r_{i2} & \cdots & r_{ij} & \cdots & r_{in} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mj} & \cdots & r_{mn} \end{bmatrix}, \quad (15)$$

r_{ij} can be calculated by the following equation.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad (16)$$

3.6.2. The Normalised Weight Value Calculation

The normalised weight value f_{xy} is calculated by

$$f_{xy} = P_{xy} h_{xy}, x = 1, \ldots, e; y = 1, \ldots, k. \quad (17)$$

where P_j is the weight of x^{tk} criterion and $\sum_{y=1}^{k} p_p = 1$.

3.6.3. Determine the Positive-Ideal and Negative-Ideal Solution

$$D^+ = \{f_1^+, \ldots, f_h^+\} = \left\{ \left(\max_y f_{xy} \middle| x \in A \right), \left(\min_y f_{xy} \middle| x \in A \right) \right\}. \tag{18}$$

$$D^- = \{f_1^-, \ldots, f_n^-\} = \left\{ \left(\min_y f_{xy} \middle| x \in A \right), \left(\max_y f_{xy} \middle| x \in A \right) \right\}. \tag{19}$$

where f_x^+ represents the maximum values of f_{xy} and f_x^- indicates the minimum value of f_{xy}.

3.6.4. Separation Measure Calculation

In this step, the separation of each alternative from positive ideal solution (PIS) is given by

$$Q_x^+ = \left\{ \sum_{y=1}^{k} \left(f_{xy} - f_y^+ \right)^2 \right\}^{\frac{1}{2}}, x = 1, \ldots, e \tag{20}$$

Similarly, the separation from the negative-ideal solution (NIS) is given by

$$Q_x^- = \left\{ \sum_{y=1}^{k} \left(f_{xy} - f_y^- \right)^2 \right\}^{\frac{1}{2}}, x = 1, \ldots, e \tag{21}$$

3.6.5. Determining the Relationship Proximal to the Decision-making Model

$$C_x = \frac{Q_x^-}{Q_x^+ + Q_x^-}, x = 1, \ldots, e \tag{22}$$

3.6.6. Rank the Preference Order

The index values C_x lie between 0 and 1. The larger index value represents the closer to optimal solution for alternatives. Therefore, this research ranks the preference order according to the index values, thereby finding the ideal solution for the blended design teaching industry in the post-COVID-19 era.

4. Results

4.1. The Construction of Hierarchy and Network Structure

A total of ten blended design educating experts were invited by this research to revise and modify statements of dimensions, indicators and alternatives. Among them, five are senior managers in blended design teaching-related industries and five are senior blended design instructors. The details pertinent to these ten experts are shown in Table 3. Then, this study issued 10 expert consultation questionnaires for modifying the statements of indicators of the SERVQUAL scale to the above mentioned ten experts and 10 valid questionnaires were collected. Afterwards, this study developed the questionnaire of blended design teaching service quality based on responses of blended design teaching-related experts.

Table 3. The information about 10 experts.

No.	Given Name	Surname	Job Title	Field	Job Tenure
1	W.-L.	Wang	Senior Human Resources Manager	Digital Media	10
2	W.-H.	Lin	Senior Marketing Manager	Design Education	15
3	J.-Y.	Liao	Senior Curriculum Development Manager	Design Education	12
4	Y.-Z.	Huang	General Manager	Multimedia Design	25
5	Z.-Y.	Huang	Senior Curriculum Development Manager	Design Education	17
6	M.-Z.	Lin	Professor	Multimedia Design	30
7	S.-J.	Chen	Associate Professor	Digital Media	20
8	J.-Y.	Yang	Associate Professor	Industrial Design	23
9	J.	Deng	Assistant Professor	Computer Animation	18
10	P.-W.	Hsiao	Lecturer	Multimedia Design	12

Although the questionnaire was established, a pre-test was still conducted in this study to evaluate the semantic clarity of the questionnaire. According to the results of the pre-test survey, the above ten experts revised statements and added auxiliary descriptions to the semantics of the questionnaires. Afterwards, the evaluation structure of blended design teaching service quality based on the SERVQUAL scale, including five main dimensions, twenty indicators and eight alternatives, was constructed and shown in Figure 3.

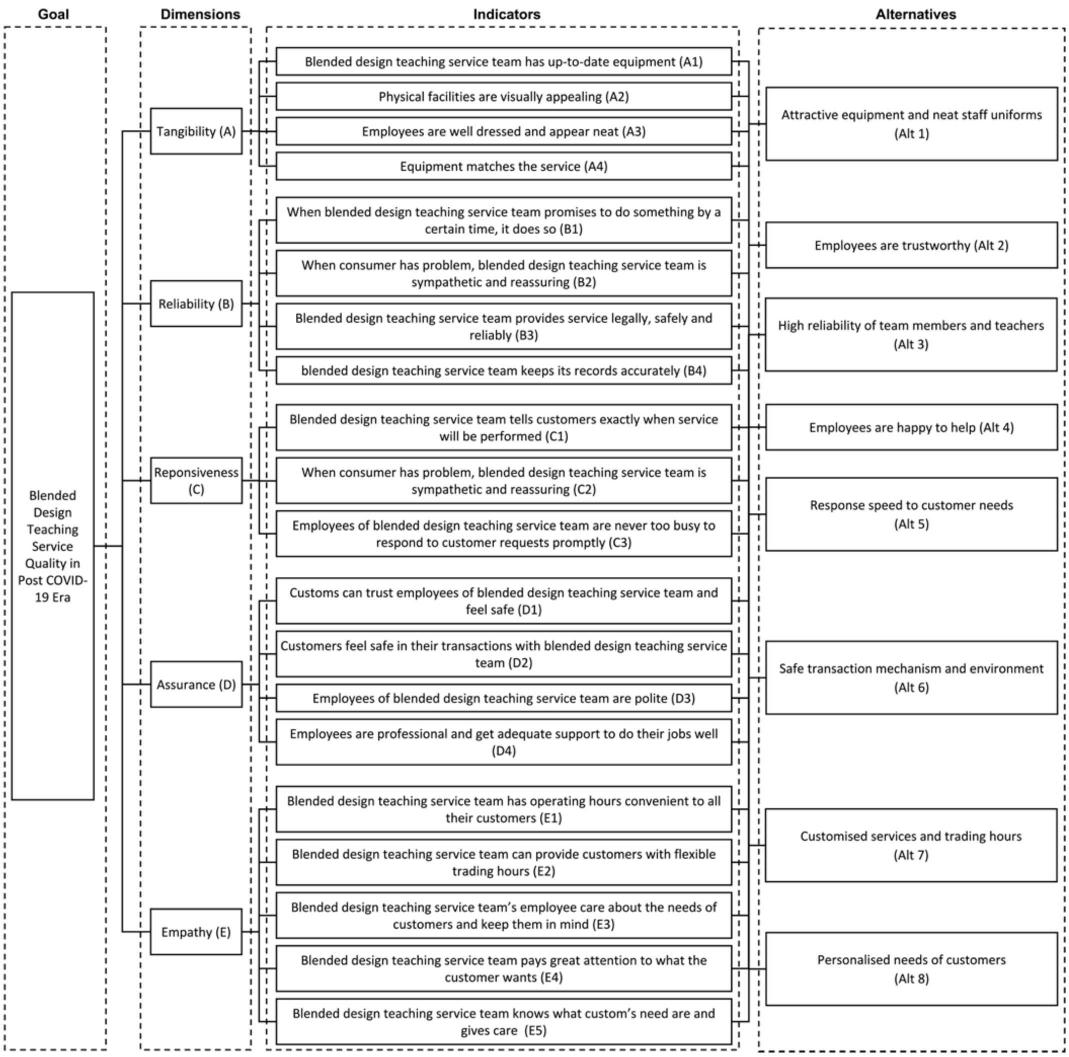

Figure 3. The evaluation structure of blended design teaching service quality.

Meanwhile, views of each expert were summarised on the interdependence of various indicators through relevant questionnaires in this study. While most expert-approved correlations ensure interdependence among indicators, it is possible to overlook some correlated indicators. On the contrary, this study can select indicators with low expert recognition. However, this will lead to a substantial increase in the degree of dependence among indicators, thereby increasing the number of questions in the comparison questionnaire. For example, the questions in the questionnaire will exceed 50, if it has more than six experts who reach a consensus on the dependence of indicators.

In view of this, this study adopts the dependence of the approval of more than nine out of ten experts to prevent too many questions being added to the questionnaire, and the network relationship of the indicators can be retained. It means that the dependency of all indicators is determined by most experts. For example: more than nine out of ten experts believe that A4 has an impact on E1, which means that the two indicators A4 and E1 are related.

Finally, this research summarised opinions of all experts into the hierarchy and network structure for the service quality evaluation of blended design teaching in the post-COVID-19 era, as shown in Figure 4.

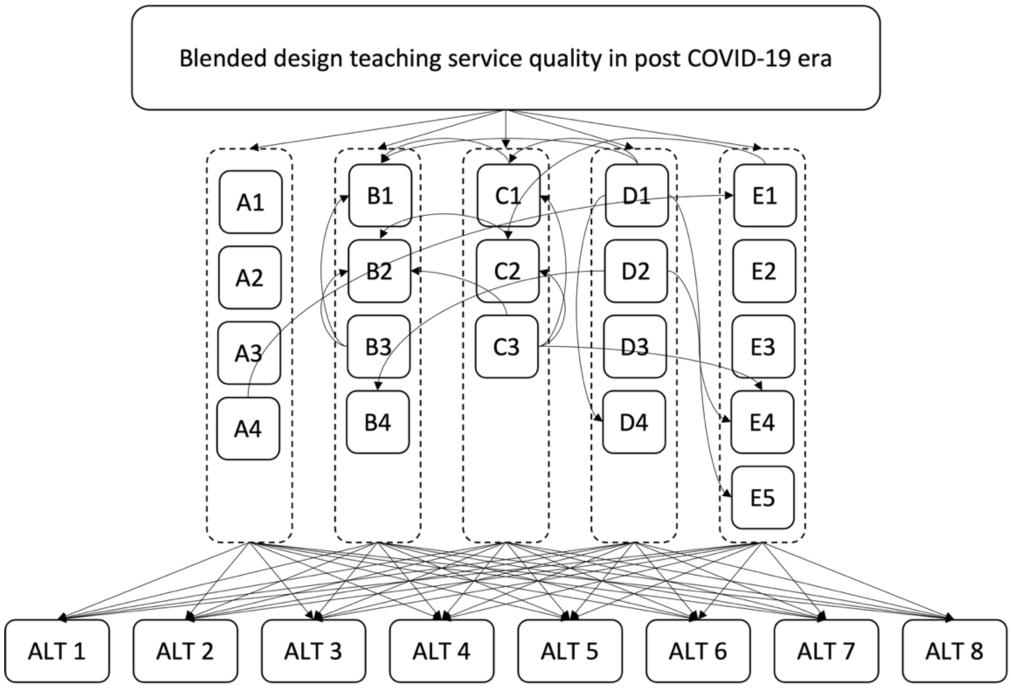

Figure 4. The hierarchy and network structure of this research.

4.2. Questionnaire and Analysis

4.2.1. Questionnaire Measurement

This research issued a total of 15 fuzzy semantic pairwise comparison questionnaires to experienced experts of blended design education from 15 July 2022 to 31 August 2022. A total of ten valid questionnaires was obtained with a recovery rate of 66.67%. Then, we integrated all perspectives of experts using geometric mean method, and a fuzzy pairwise comparison matrix for all criteria from the FANP model was established.

4.2.2. Numerical Analysis of the FANP Model

Table 4 revealed the fuzzy pairwise comparison matrix of five dimensions.

Table 4. The fuzzy pairwise comparison matrix of dimensions from FANP model.

Dimensions	Tangibility (A)	Reliability (B)	Responsiveness (C)	Assurance (D)	Empathy (E)
Tangibility (A)	(1,1,1)	(1/8,1/7,1/6)	(1/9,1/8,1/7)	(1/9,1/8,1/7)	(1/5,1/4,1/3)
Reliability (B)	(6,7,8)	(1,1,1)	(1/3,1/2,1)	(1/3,1/2,1)	(1,2,3)
Responsiveness (C)	(7,8,9)	(1,2,3)	(1,1,1)	(1,1,1)	(1,2,3)
Assurance (D)	(7,8,9)	(1,2,3)	(1,1,1)	(1,1,1)	(2,3,4)
Empathy (E)	(3,4,5)	(1/3,1/2,1)	(1/3,1/2,1)	(1/4,1/3,1/2)	(1,1,1)

This study utilises $\alpha = 0.5$ and $\beta = 0.5$ during the defuzzification [145–147]. The process of fuzzy decomposition for dimensions between tangibility (A) and reliability (B) is as follows:

$$t_{0.5,0.5}(\overline{a_{A,B}}) = \left[0.5 \times \frac{1}{6} + (1-0.5) \times \frac{1}{7}\right] = \frac{1}{7}$$

$$f_a(L_{A,B}) = \left(\frac{1}{7} - \frac{1}{8}\right) \times 0.5 + \frac{1}{8} = \frac{1}{7}$$

$$f_a(U_{A,B}) = \frac{1}{6} - \left(\frac{1}{7} - \frac{1}{8}\right) \times 0.5 = \frac{1}{6}$$

$$t_{0.5,0.5}(\overline{a_{B,A}}) = 7$$

The remaining calculations of other dimensions, including responsiveness, assurance and empathy, are similar to the above calculation. The de-fuzzified pairwise comparison matrix of five dimensions from the FANP model is shown in Table 5.

Table 5. The de-fuzzified pairwise comparison matrix of five dimensions from FANP model.

Dimensions	Tangibility (A)	Reliability (B)	Responsiveness (C)	Assurance (D)	Empathy (E)
Tangibility (A)	1	1/7	1/8	1/8	1/4
Reliability (B)	7	1	1/2	1/2	2
Responsiveness (C)	8	2	1	1	2
Assurance (D)	8	2	1	1	3
Empathy (E)	4	1/2	1/2	1/3	1

The maximum individual value (AM) is calculated as follows:

$$AM_1 = \left(1 \times \frac{1}{7} \times \frac{1}{8} \times \frac{1}{8} \times \frac{1}{4}\right)^{\frac{1}{5}} = 0.2235$$

$$AM_2 = \left(7 \times 1 \times \frac{1}{2} \times \frac{1}{2} \times 2\right)^{\frac{1}{5}} = 1.2847$$

$$AM_3 = (8 \times 2 \times 1 \times 1 \times 2)^{\frac{1}{5}} = 2$$

$$AM_4 = (8 \times 2 \times 1 \times 1 \times 3)^{\frac{1}{5}} = 2.1689$$

$$AM_5 = \left(4 \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{3} \times 1\right)^{\frac{1}{5}} = 0.8027$$

$$\sum AM = 0.2235 + 1.2847 + 2 + 2.1689 + 0.8027 = 6.4799$$

The calculation of weight (ω) for each dimension is shown in Table 6.

Table 6. The calculation of weight for five dimensions.

Dimensions	The Calculation of Weight (ω)
Tangibility (A)	$\frac{0.2335}{6.4799} = 0.0345$
Reliability (B)	$\frac{1.2847}{6.4799} = 0.1983$
Responsiveness (C)	$\frac{2}{6.4799} = 0.3086$
Assurance (D)	$\frac{2.1689}{6.4799} = 0.3347$
Empathy (E)	$\frac{0.8207}{6.4799} = 0.1237$

The calculation of normalised matrix is shown in Table 7.

Table 7. Normalised matrix calculation.

Dimensions	Tangibility (A)	Reliability (B)	Responsiveness (C)	Assurance (D)	Empathy (E)
Tangibility (A)	1×0.0345	$1/7 \times 0.1983$	$1/8 \times 0.3086$	$1/8 \times 0.3347$	$1/4 \times 0.1239$
Reliability (B)	7×0.0345	1×0.1983	$1/2 \times 0.3086$	$1/2 \times 0.3347$	2×0.1239
Responsiveness (C)	7×0.0345	2×0.1983	1×0.3086	1×0.3347	2×0.1239
Assurance (D)	8×0.0345	2×0.1983	1×0.3086	1×0.3347	3×0.1239
Empathy (E)	4×0.0345	$1/2 \times 0.1983$	$1/2 \times 0.3086$	$1/3 \times 0.3347$	1×0.1239

The calculation of maximum eigenvector (W_1) is shown in Table 8.

Table 8. The calculation of maximum eigenvalue for five dimensions.

Dimensions	A	B	C	D	E	Total	ω	W_1
A	0.0345	0.0283	0.0386	0.0418	0.0310	0.1742	0.0345	$0.1742/0.0345 = 5.0502$
B	0.2415	0.1983	0.1543	0.1674	0.2478	1.0092	0.1983	$1.0092/0.1983 = 5.0901$
C	0.2760	0.3965	0.3086	0.3347	0.2478	1.5636	0.3086	$1.5636/0.3086 = 5.0661$
D	0.2760	0.3965	0.3086	0.3347	0.3716	1.6875	0.3347	$1.6875/0.3347 = 5.0461$
E	0.1380	0.0991	0.1543	0.1116	0.1239	0.6269	0.1239	$0.6269/0.1239 = 5.0604$

After that, the numbers of main dimensions are 5; we get $n = 5$. Therefore, λ_{max} and $C.I.$ are calculated as follows:

$$\lambda_{max} = \frac{(5.0502 + 5.0901 + 5.0661 + 5.0461 + 5.0604)}{5} = 5.0617$$

$$C.I. = \frac{\lambda_{max} - n}{n - 1} = \frac{5.0617 - 5}{5 - 1} = 0.0154$$

For $C.R.$, with $n = 5$, we have $R.I. = 1.12$.

$$C.R. = \frac{C.I.}{R.I.} = \frac{0.0154}{1.12} = 0.0138$$

The calculation result of de-fuzzified pairwise comparison matrix between five dimensions is shown in Table 9.

Both $C.I.$ and $C.R.$ are less than 0.1. It means that the data in de-fuzzified pairwise comparison matrix for five dimensions is consistent. Afterwards, the calculation method of the de-fuzzified pairwise comparison matrix for the remaining indicators and alternatives is analogous to the above calculation method. Finally, $C.I.$ and $C.R.$ values for remaining dimensions, indicators and alternatives are shown in Tables 10 and 11.

Table 9. The pairwise comparison matrix of five dimensions from FANP model.

Dimensions	Tangibility (A)	Reliability (B)	Responsiveness (C)	Assurance (D)	Empathy (E)	Weights
Tangibility (A)	1	1/7	1/8	1/8	1/4	0.0345
Reliability (B)	7	1	1/2	1/2	2	0.1983
Responsiveness (C)	8	2	1	1	2	0.3086
Assurance (D)	8	2	1	1	3	0.3347
Empathy (E)	4	1/2	1/2	1/3	1	0.1239
					Total	1
			$C.I. = 0.0154,\ C.R. = 0.0138$			

Table 10. *C.I.* and *C.R* values for other dimensions and indicators.

	Compare Respect to	Group	Pairwise Comparison	*C.I.*	*C.R.*
Dimensions	C		B and C, B and E, C and E	0.0268	0.0462
	D		B and C, B and D, B and E, C and D, C and E, D and E	0.0270	0.0300
Indicators	Goal	A	A1 and A2, A1 and A3, A1 and A4, A2 and A3, A2 and A4, A3 and A4	0.0034	0.0038
		B	B1 and B2, B1 and B3, B1 and B4, B2 and B3, B2 and B4, B3 and B4	0.0382	0.0424
		C	C1 and C2, C1 and C3, C2 and C3	0.0000	0.0000
		D	D1 and D2, D1 and D3, D1 and D4, D2 and D3, D2 and D4, D3 and D4	0.0131	0.0145
		E	E1 and E2, E1 and E3, E1 and E4, E1 and E5, E2 and E3, E2 and E4, E2 and E5, E3 and E4, E3 and E5, E4 and E5	0.0138	0.0123
	B3	B	B1 and B2	0.0000	0.0000
	C3	C	C1 and C2	0.0000	0.0000

Table 11. *C.I.* and *C.R* values for all alternatives.

	Compare Respect to	Group	Pairwise Comparison	*C.I.*	*C.R.*
Indicators	A1		All Alternatives	0.0137	0.0097
	A2		All Alternatives	0.0251	0.0178
	A3		All Alternatives	0.0242	0.0171
	A4		All Alternatives	0.0525	0.0372
	B1		All Alternatives	0.0529	0.0375
	B2		All Alternatives	0.0260	0.0184
	B3		All Alternatives	0.0119	0.0084
	B4		All Alternatives	0.0022	0.0015
	C1		All Alternatives	0.0025	0.0018
	C2		All Alternatives	0.0067	0.0048
	C3		All Alternatives	0.0291	0.0206
	D1		All Alternatives	0.0212	0.0150
	D2		All Alternatives	0.0457	0.0324
	D3		All Alternatives	0.0808	0.0573
	D4		All Alternatives	0.0656	0.0465
	E1		All Alternatives	0.0112	0.0079
	E2		All Alternatives	0.0455	0.0322
	E3		All Alternatives	0.0076	0.0053
	E4		All Alternatives	0.0301	0.0213
	E5		All Alternatives	0.0333	0.0236

Since both *C.I.* and *C.R.* are less than 0.1, this means the result of the consistency tests is acceptable.

After passing consistency test, the weight of all indicators in the FANP model was calculated using Super Decisions software, as shown in Table 12.

Table 12. The weight of all indicators in FANP model.

Indicators	Description	Weight
A1	Blended design teaching service team has up-to-date equipment	0.0028
A2	Physical facilities of blended design teaching service team are visually appealing	0.0025
A3	Employees of blended design teaching service team are well-dressed and appear neat	0.0095
A4	Equipment matches the service	0.0042
B1	When blended design teaching service team promises to do something by a certain time, it does so	0.1000
B2	When consumer has problem, blended design teaching service team is sympathetic and reassuring	0.1643
B3	Blended design teaching service team provides service legally, safely and reliably	0.0561
B4	Blended design teaching service team keeps its records accurately	0.0954
C1	Blended design teaching service team tells customers exactly when service will be performed	0.0609
C2	Employees of blended design teaching service team are always willing to help customers and provide prompt service	0.0733
C3	Employees of blended design teaching service team are never too busy to respond to customer requests promptly	0.0793
D1	Customers can trust employees of blended design teaching service team and feel safe	0.0232
D2	Customers feel safe in their transactions with blended design teaching service team	0.1396
D3	Employees of blended design teaching service team are polite	0.0145
D4	Employees are professional and get adequate support to do their jobs well	0.0323
E1	Blended design teaching service team has operating hours convenient to all their customers	0.0107
E2	Blended design teaching service team can provide customers with flexible trading hours	0.0054
E3	Blended design teaching service team's employees care about the needs of customers and keep them in mind	0.0147
E4	Blended design teaching service team pays great attention to what the customer wants	0.0889
E5	Blended design teaching service team knows what customer's needs are and gives care	0.0223

4.2.3. Numerical Analysis of the TOPSIS Model

The TOPSIS model is applied for ranking alternatives in this research. The decision matrix in the TOPSIS model is shown in Table 13.

Table 13. Decision matrix for each alternative with respect to each indicator.

Indicators	Alternatives							
	ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	ALT 7	ALT 8
A1	2.35	1.32	1.64	1.00	3.10	1.32	1.25	1.00
A2	1.78	1.32	1.89	1.00	2.93	1.32	1.15	1.00
A3	1.64	1.74	1.00	1.15	2.93	1.52	1.00	1.00
A4	5.07	2.55	1.15	1.15	1.15	1.32	4.57	1.00
B1	4.74	5.77	3.18	1.32	3.78	2.00	2.76	1.15
B2	1.52	5.98	3.32	1.32	3.32	2.00	2.17	7.00
B3	1.32	3.93	3.32	1.32	3.06	5.53	1.52	1.15
B4	1.32	5.32	4.64	1.32	4.32	5.45	2.00	4.79
C1	1.15	5.98	3.95	5.00	4.18	5.59	4.18	4.00
C2	1.32	4.11	4.13	5.38	3.00	5.67	1.64	4.00
C3	1.52	5.77	3.95	5.38	5.93	5.29	1.52	1.52
D1	1.74	4.46	3.95	2.77	4.74	5.76	1.52	1.64
D2	1.15	4.11	4.13	5.72	5.00	5.66	1.52	1.52
D3	1.15	1.41	4.64	4.37	4.13	4.68	1.64	1.43
D4	1.32	1.62	3.95	4.57	1.89	5.91	1.52	1.00
E1	1.52	1.62	3.57	1.15	2.00	4.63	5.30	3.78
E2	1.15	1.62	5.33	1.00	1.15	4.40	6.58	3.57
E3	1.52	3.37	3.78	1.00	1.15	1.32	1.00	4.79
E4	1.32	3.00	5.14	1.00	1.15	1.52	1.00	4.79
E5	2.35	3.00	1.15	2.93	1.74	1.15	1.00	4.79

The normalised weight matrix in the TOPSIS model is shown in Table 14.

Table 14. Normalised weight matrix in TOPSIS model.

Indicators	Alternatives							
	ALT 1	**ALT 2**	**ALT 3**	**ALT 4**	**ALT 5**	**ALT 6**	**ALT 7**	**ALT 8**
A1	0.0018	0.0004	0.0009	0.0000	0.0028	0.0004	0.0003	0.0000
A2	0.0010	0.0004	0.0012	0.0000	0.0025	0.0004	0.0002	0.0000
A3	0.0031	0.0036	0.0000	0.0007	0.0095	0.0026	0.0000	0.0000
A4	0.0042	0.0016	0.0002	0.0002	0.0002	0.0003	0.0037	0.0000
B1	0.0817	0.1008	0.0462	0.0039	0.0598	0.0193	0.0366	0.0000
B2	0.0058	0.1287	0.0576	0.0000	0.0576	0.0196	0.0245	0.1636
B3	0.0016	0.0252	0.0208	0.0016	0.0183	0.0561	0.0035	0.0000
B4	0.0000	0.0666	0.0579	0.0000	0.0523	0.0954	0.0119	0.0605
C1	0.0000	0.0527	0.0318	0.0437	0.0344	0.0616	0.0344	0.0323
C2	0.0000	0.0349	0.0373	0.0539	0.0223	0.0726	0.0042	0.0356
C3	0.0000	0.0700	0.0419	0.0666	0.0760	0.0793	0.0000	0.0000
D1	0.0009	0.0117	0.0103	0.0053	0.0136	0.0232	0.0000	0.0005
D2	0.0000	0.0668	0.0711	0.1091	0.0919	0.1396	0.0088	0.0088
D3	0.0000	0.0006	0.0127	0.0117	0.0109	0.0145	0.0018	0.0010
D4	0.0018	0.0029	0.0164	0.0199	0.0050	0.0323	0.0029	0.0000
E1	0.0010	0.0010	0.0062	0.0000	0.0022	0.0096	0.0107	0.0068
E2	0.0001	0.0005	0.0042	0.0000	0.0001	0.0036	0.0054	0.0025
E3	0.0020	0.0092	0.0108	0.0000	0.0006	0.0012	0.0000	0.0147
E4	0.0069	0.0430	0.0889	0.0000	0.0032	0.0112	0.0000	0.0814
E5	0.0079	0.0118	0.0009	0.0114	0.0044	0.0009	0.0000	0.0223

4.3. Research Results

4.3.1. Fuzzy Analytic Network Process (FANP)

As for the ranking of dimensions and indicators in the FANP model, it was ordered by overall weight. The overall weight and ranking of dimensions and indicators in the FANP model are shown in Figures 5 and 6.

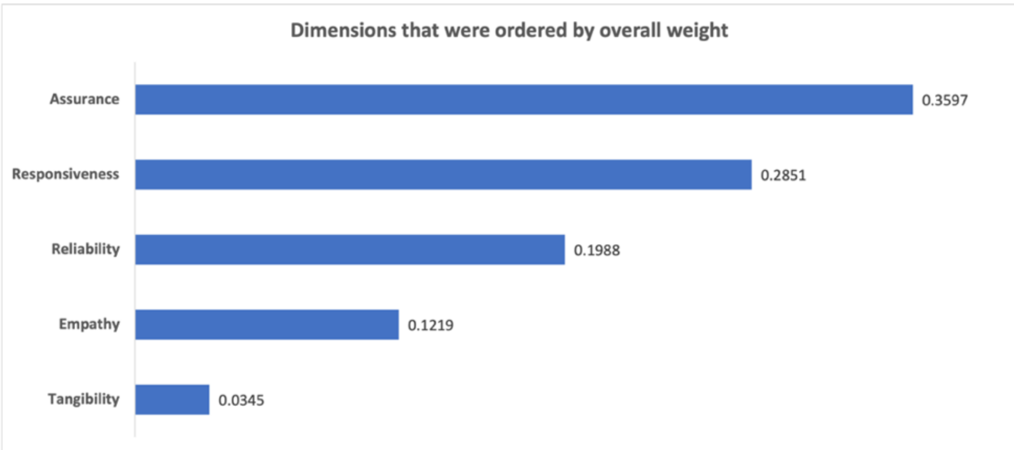

Figure 5. The overall weight and ranking of dimensions in FANP model.

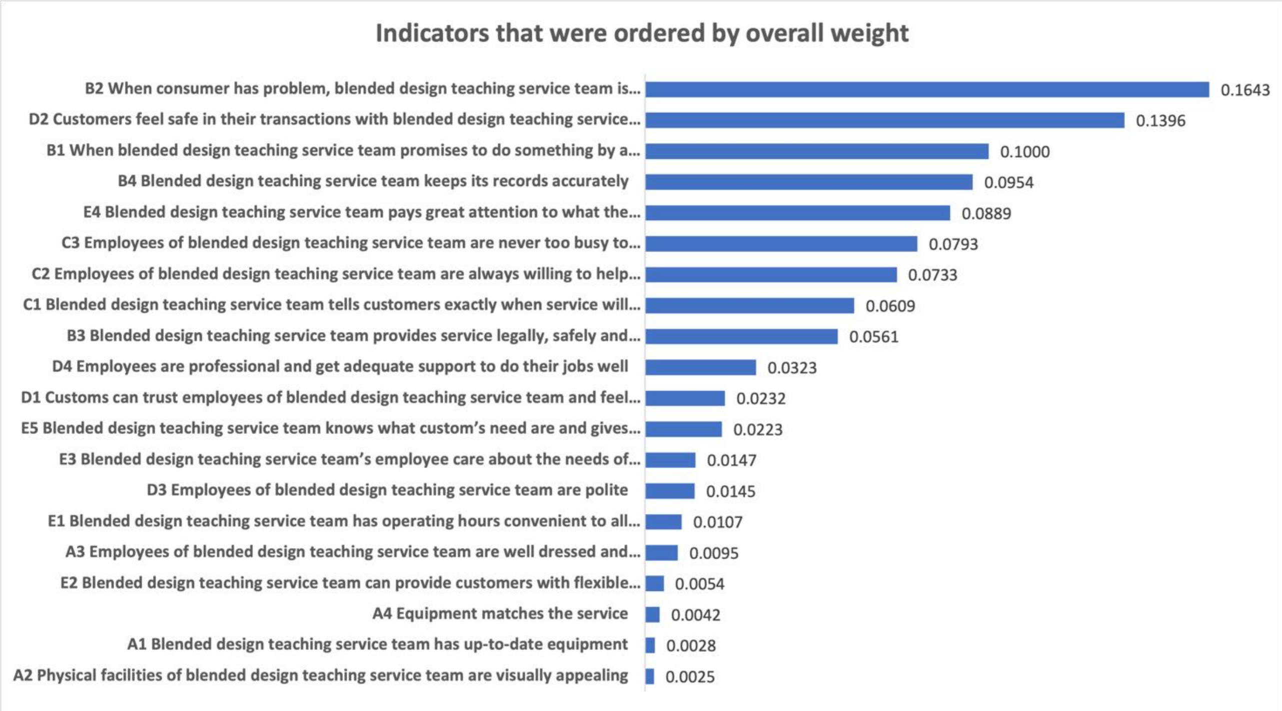

Figure 6. The overall weight and ranking of indicators.

As shown in Figure 5, the dimensions were ordered by overall weights as assurance (0.3597), responsiveness (0.2851), reliability (0.1988), empathy (0.1219) and tangibility (0.0345).

As shown in Figure 6, the top three important indicators were ordered by overall weights as "When consumer has problem, blended design teaching service team is sympathetic and reassuring" (B2, 0.1643), "Customers feel safe in their transactions with blended design teaching service team" (D2, 0.1396) and "When blended design teaching service team promises to do something by a certain time, it does so" (B1, 0.1).

The overall weights of indicators ranked fourth to fifth are "Blended design teaching service team keeps its records accurately" (B4, 0.0954) and "Blended design teaching service team pays great attention to what the customer wants" (E4, 0.0889).

The sixth to eighth important indicators are "Employees of blended design teaching service team are never too busy to respond to customer requests promptly" (C3, 0.0793), "Employees of blended design teaching service team are always willing to help customers and provide prompt service" (C2, 0.0733) and "Blended design teaching service team tells customers exactly when service will be performed" (C1, 0.0609).

4.3.2. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

As for the ranking of all alternatives, it was determined by the geometric distance from positive ideal solution (PIS) and negative ideal solution (NIS). All alternatives are ranked according to the geometric distance closest to PIS as ALT 2 (0.0566), ALT 3 (0.0877), ALT 5 (0.0985), ALT 6 (0.1100), ALT 8 (0.1288), ALT 4 (0.1449), ALT 7 (0.1673) and ALT 1 (0.1792).

All alternatives are ranked according to the geometric distance farthest from NIS as ALT 2 (0.1523), ALT 6 (0.1421), ALT 8 (0.1257), ALT 5 (0.1208), ALT 3 (0.1196), ALT 4 (0.1175), ALT 1 (0.0469) and ALT 7 (0.0374).

The geometric distance of all alternatives from PIS and NIS is shown in Figure 7.

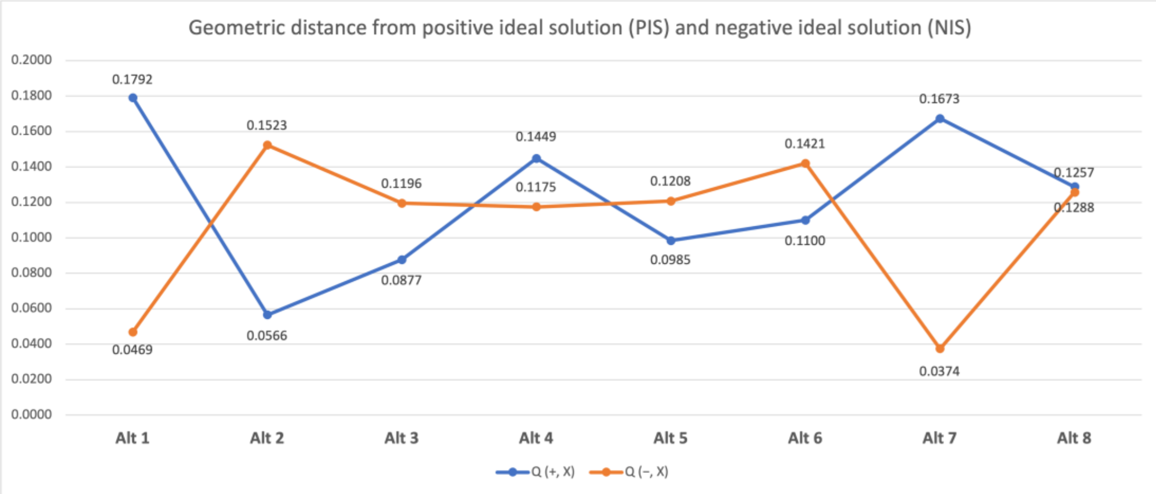

Figure 7. Geometric distance of all alternatives from PIS and NIS.

The optimal solution ranking based on the index value C_x in the TOPSIS model is shown in Figure 8.

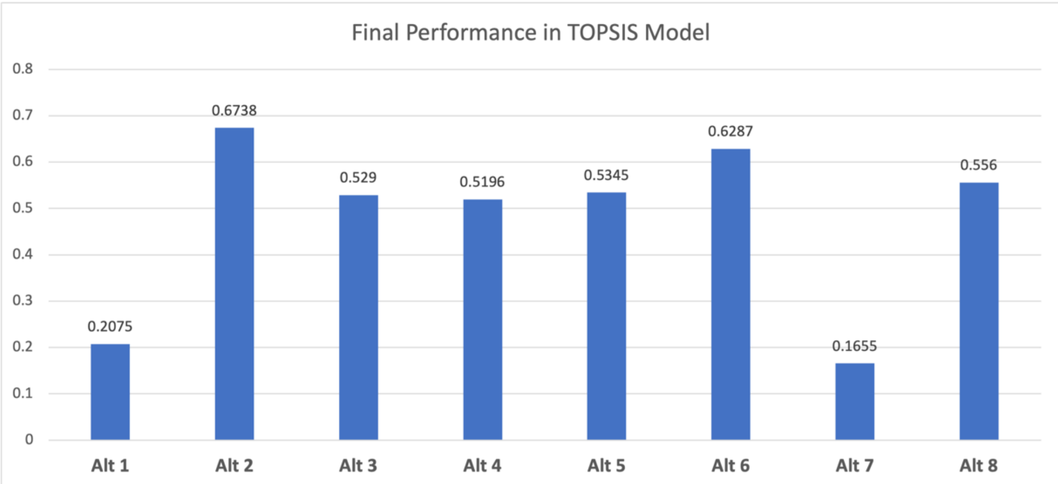

Figure 8. The final performance in TOPSIS model.

Finally, the larger index value C_x means that the alternative is closer to the optimal solution in the TOPSIS model. Accordingly, the alternative ordering based on index value C_x is "Employees are trustworthy" (ALT 2, 0.6738), "Safe transaction mechanism and environment" (ALT 6, 0.6287), "Personalised needs of customers" (ALT 8, 0.556), "Response speed to customer needs" (ALT 5, 0.5345), "High reliability of team members and teachers" (ALT 3, 0.529), "Employees are happy to help" (ALT 4, 0.5196), "Attractive equipment and neat staff uniforms" (ALT 1, 0.2075) and "Customised services and trading hours" (ALT 7, 0.1655).

5. Discussions

5.1. Discussion and Suggestions

As for the ranking of dimensions in the FANP model, the most important dimension is assurance. Thus, we suggest that service providers of blended design teaching should give top priority to the necessary items required to provide services, such as professional knowledge and trustworthiness for providing good service quality in the post-COVID-19 era.

The second to fourth important dimensions in the FANP model are responsiveness, reliability and empathy. It means that the willingness of service providence, the capability of high reliability and individual need of customer should be paid attention by blended design teaching service providers for maintaining good service quality in the post-COVID-19 era.

As for the ranking of indicators in the FANP model, the most significant indicator that was ordered by overall weight is “When consumer has problem, blended design teaching service team is sympathetic and reassuring”, followed by “Customers feel safe in their transactions with blended design teaching service team” and “When blended design teaching service team promises to do something by a certain time, it does so”. Meanwhile, the fourth and fifth important indicators in the FANP model are “Blended design teaching service team keeps its records accurately” and “Blended design teaching service team pays great attention to what the customer wants”.

Interestingly, the top three alternatives that were ordered by index value in the TOPSIS model are “Employees are trustworthy”, “Safe transaction mechanism and environment” and “Personalised needs of customers”. In view of this, the characteristics of reassuring and consideration, staff with trustworthy principles, the safe transactional environment and customised consumer needs should be given the highest priority by blended design teaching service providers in the post-COVID-19 era. Thus, we suggest that blended design teaching service providers should make consumers feel considerate and reassured. In the meantime, the service providers of blended design teaching should establish a safe transaction mechanism and pay attention to the principle of keeping promises and individual needs of customers.

Also, the sixth and eighth important indicators in the FANP model are “Employees of blended design teaching service team are never too busy to respond to customer requests promptly”, “Employees of blended design teaching service team are always willing to help customers and provide prompt service” and “Blended design teaching service team tells customers exactly when service will be performed”. At the same time, the alternatives ranked fourth to sixth in the TOPSIS model are “Response speed to customer needs”, “High reliability of team members and teachers” and “Employees are happy to help”. Accordingly, we suggest that the hybrid design education service team should instantly respond to customer needs. In the meantime, the well-qualified teachers and helpful staff are also important factors in providing high-quality service of blended design teaching in the post-COVID-19 era.

Finally, whether in the model of FANP or TOPSIS, the dimension and alternative ranked last are equipment factors. This means that the service equipment of the blended design teaching industry is relatively less important in the post-COVID-19 era.

Matzler et al. [148] proposed factor structures of customer satisfaction in 2002, which are basic factor, performance factor and excitement factor. They considered that the basic needs of customers must be identified and fulfilled. In this study, assurance was found to be the most important dimension in the FANP model by analysing the feedback from expert questionnaires. Meanwhile, the two most vital alternatives in the TOPSIS model are “Employees are trustworthy” and “Safe transaction mechanism and environment”. Also, the indicators in order of weight in the assurance dimension are “Customers feel safe in their transactions with blended design teaching service team” and “Employees are professional and get adequate support to do their jobs well”. This means that consumers’ basic needs include security of the transaction environment, professionalism and trustworthy employees.

Moreover, Kim et al. [149] and Uppal et al. [150] proposed some research works before the period of the COVID-19 pandemic. They pointed out that the dimensions in the SERVQUAL scale, such as reliability, responsiveness, assurance and empathy, play an important role in the evaluation of online learning and e-learning satisfaction. Furthermore, Sumi [151] and Ma et al. [152] mentioned that the dimensions and indicators in the SERVQUAL scale are feasible for evaluating the service quality of the online teaching industry during the period of the COVID-19 pandemic.

Interestingly, the results of the above-mentioned research are very similar to the results of the present study. Therefore, the dimensions and indicators used to assess the quality of education services are consistent, whether in the post-COVID-19 era, during the COVID-19 pandemic or before the COVID-19 pandemic.

In view of this, service providers of blended design teaching should address basic consumer needs, such as trusted employees and a safe transactional environment to deliver high-quality service in the post-COVID-19 era.

5.2. Research Limitations

This research method combines FANP and TOPSIS. In the hierarchy and network structure, more than nine out of 10 experts agree on the relationship. There is a certain consensus. In the pairwise comparison of the importance of the indicators, the value of C.I. and C.R. is used to verify their progression. In the decision matrix of TOPSIS, 10 experts evaluated the indicators and plans. The research results are based on the opinions of the experts. This is the limitation of this research and the research methods of ANP and TOPSIS, so this research is specially commissioned by rich-experienced experts filling the questionnaire.

6. Conclusions

Based on the SERVQUAL scale, this study establishes the hierarchical and network structure of service quality in blended design education. Afterwards, weights of all indicators are calculated using the FANP method. Finally, all alternatives are ranked using TOPSIS.

The contribution of this research is to propose a hybrid research approach of FANP and TOPSIS for the service quality evaluation of blended design teaching in the post-COVID-19 era under fuzzy environment. Meanwhile, the top three alternatives in this study are "Employees are trustworthy", "Safe transaction mechanism and environment" and "Personalised needs of customers". This represents factors such as trustworthiness of staff, transactional security and individual needs of customers, which are key elements for a blended design education team to maintain high service quality in the post-COVID-19 era.

Also, this study has an indicative role for the hybrid design education industry to provide good service quality in the post-COVID-19 era. Finally, the research findings of this study provide the guidance for the blended design teaching industry to maintain good service quality in future related scenarios.

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