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Evaluating the quality of simulation teaching in Fundamental Nursing Curriculum: AHP-Fuzzy comprehensive evaluation☆

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ABSTRACT

Background: Simulation has been widely adopted in nursing education, while it is difficult to evaluate the quality of simulation. AHP-Fuzzy comprehensive evaluation could be an effective method based on one a comprehensive and scientific evaluation Index system.
Objectives: To evaluate the quality of simulation teaching in 〈Fundamental Nursing Curriculum〉 with fuzzy comprehensive method, and to provide a scientific evaluation method for the improvement of simulation teaching.
Design: It is a phenomenological research study.
Settings: The study was mainly conducted in one university in China.
Participants: 94 second-year nursing students participated in this study.
Methods: The grade 2015 nursing undergraduate students in Peking university school of nursing as the evaluation subjects were to evaluate the simulation teaching quality on 〈Fundamental Nursing Curriculum〉, Fuzzy Comprehensive Evaluation method was used.
Results: The quality score is 73.55–100 (91.71 ± 6.98) points of 94 students. According to the result of fuzzy comprehensive evaluation, the simulation teaching quality belonging to the "excellent, good, moderate, poor, very poor" of membership degree are respectively "0.6794, 0.2500, 0.00640, 0.0039, 0.0028", and by maximum membership degree of effective inspection, calculate $a = 2.3965$, $1 \leq a < +\infty$.
Conclusions: The application of simulation teaching in 〈Fundamental Nursing Curriculum〉 proves high quality. The fuzzy comprehensive evaluation combining subjective evaluation and objective evaluation proves to be a scientific and feasible methodology in nursing education.

1. Introduction

Simulation has been defined as "A technique that replaces or amplifies real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner" (Onda, 2012). Recent years, there has been a growing tendency to adopt simulation teaching in Nursing Education, since it is able to re-create a vivid clinical situation for students to practice knowledge, clinical skills, critical thinking as well as clinical decisions. Due to its ability to engage students into these vivid clinical situation, simulation could effectively cultivate students' comprehensive ability and builds up their self-confidence, which promote the efficiency and effectiveness in clinical work after they become a registered nurse in the long term (Gamble, 2017; Çelik et al., 2017). Also, a study by the National Council of State Boards of Nursing (NCSBN) shows that scenario simulations can effectively save 50% of clinical practice time (Hayden and Alexander, 2014), and it is a great way to relieve the current demanding of nursing schools and corresponding hospitals. As a result, simulation has been developed rapidly in nursing education world-widely. From 2000 to 2010, the number of nursing schools adopting simulation in the United States has risen from 3% to 87% (Okuda et al., 2009). And in China, the number of literature related to simulation has reached > 1000 so far, reflecting the extensive application of nursing simulation to a certain extent (Wang et al., 2014).

Although simulation is an important teaching method and leads nursing education reform (Nehring and Lashley, 2009), there are lots of factors impacting the quality of simulation. Thus, it is time to highlight the quality of simulation, to ensure it could achieve all the potential

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benefits under current circumstance. Currently, most researchers have focused on the outcomes of high fidelity simulated scenario, such as the ability of clinical knowledge and skills (Khalaila, 2014; Kim and Shin, 2016), critical thinking and risk assessment (Yang and Thompson, 2011), cognitive and psychomotor skills (Shin et al., 2015), building up confidence (Lubbers and Rossman, 2017), teamwork performance (Hallin et al., 2016), leadership (Smith et al., 2015) and so forth. It is worth mentioning that some researchers have paid attention to the quality of simulation. One study demonstrated that low fidelity simulation could not attract students' attention, nor could it improve students' confidence (Basak et al., 2016). One study illustrated that the basic quality of teachers and students is needed to guarantee the quality of simulated teaching (Yang et al., 2016). Other studies have also paid attention to the influencing factors of simulation quality, including design and construction of simulation (Roh and Jang, 2017). According to the literature we have looked into, the evaluation of the influential factors in the preparation and implementation of scenario simulation has been ignored, and there is few standardized evaluation tool or quality index system to evaluate nursing simulation (Nestel et al., 2016). Fuzzy comprehensive evaluation (FCE) is a comprehensive evaluation method based on fuzzy mathematics, which applies fuzzy set theory and fuzzy mathematics calculation method to comprehensively consider the influence of multiple factors (Zadeh, 1965). Meanwhile, FCE adopts the membership degree theory to assess its level with the characteristics of clear results and strong system, which provides a powerful basis for the combination of qualitative and quantitative decision-making. FCE has been widely used in other fields, seldom used in education.

Thus, our team have focused on working out a quality index system of simulation, “the Evaluation Index system of Nursing Simulation teaching Quality”(Shen et al., 2018), to guide higher quality simulation teaching. With “the Evaluation Index system of Nursing Simulation teaching Quality”, our team adopted the Fuzzy comprehensive evaluation (FCE) to evaluate the quality of simulation teaching in 〈Fundamental Nursing Curriculum〉. This paper is going to describe how to conduct simulation teaching in 〈Fundamental Nursing Curriculum〉, and how to use FCE to analyze the result of “the Evaluation Index system of Nursing Simulation teaching Quality”.

2. Methods

2.1. Conducting simulation teaching in Fundamental Nursing Curriculum

From August 2016 to September 2016, according to the syllabus of Fundamental Nursing Curriculum as well real clinical cases, 〈Fundamental Nursing Curriculum Simulation Manual〉 was designed by Fundamental Nursing teaching group including one associate professor, one advanced practice nurse and two masters majoring in Fundamental Nursing. 〈Fundamental Nursing Curriculum Simulation Manual〉 consists of five single scenarios regarding to single fundamental nursing skills including aseptic techniques, measurement of vital signs, bed making, special oral care and nasal feeding, and one scenario regarding to comprehensive fundamental nursing skill. The single skill scenario training manual includes: learning objectives, scenario introduction, scenario preparation, scenario exercises, tips, considerations and notes, evaluation form and scoring standards; comprehensive scenario simulation exercises include: studying content, scenario introduction and assignments.

Taking the Nursing Simulation Center of Peking University School of Nursing as the teaching base, in accordance with school calendar of 2015–2016 and the arrangement of 〈Fundamental Nursing Curriculum〉, Simulation learning was conducted among second-year nursing students from September 2016 to December 2016: ① Curriculum Preparation: giving away the 〈Fundamental Nursing Curriculum Simulation Manual〉 to students before the start of the curriculum, and emphasizing the manual as an important basis for simulation teaching of 〈Fundamental Nursing Curriculum〉, also the final examination is guided by the scenarios included in this manual. Students can prepare and review the manual during the whole process. At the same time, establishing a class size WeChat group, in order to answer questions about simulation teaching of 〈Fundamental Nursing Curriculum〉. ② Single scenarios simulation teaching process: firstly diving the class into 4–5 groups, secondly students watching teaching video regarding to each fundamental nursing skill, thirdly students practice the fundamental nursing skill based on what they have watched in turn, each team member is required to use the manual as the basis, based on the scenario introduction, setting the simulation scenario, and performing role assignment and scenario drill through the scenario preparation. Fourthly, the team members will debrief, evaluate each other, and the teacher evaluates the performance according to the student scenario simulation exercise. ③ Comprehensive scenario simulation teaching process: The scenario introduction case is distributed to each team member one week before the course. According to the “classroom homework” guidance, the students prepare and rehearse in advance, perform group performances and video recordings in the class, and organize the debrief after the performance. The videos will be distributed to each group so that students can self-evaluate and reflect after class.

2.2. Data collection

General information: including gender, class, age, whether you have participated in simulation teaching, professional outlook, et al.

The Evaluation Index system of Nursing Simulation teaching Quality Questionnaire: In our study, we have worked out Quality Indicators of Nursing Simulation Teaching via Delphi method and Analytic Hierarchy Process, which has been proved reliable and scientific (Shen et al., 2018). The evaluation questionnaires is based on this Quality Indicators of Nursing Simulation Teaching, setting up: 5 first-level items including simulation instructor, simulation subject, simulation situation, simulation activity and simulation effect, and 14 s-level items as well as 62 third-level items. Each item uses the Likert 5 rating, 1 = completely disagree, 2 = disagree, 3 = general, 4 = consent, 5 = completely agree. The final score is normalized by the actual score × 100 / highest score. The higher the score, the higher the quality of the scenario simulation teaching.

At the end of the semester, after the completion of all the scenario simulation courses, on December 17–19, 2016, researcher interpreted the questionnaires for all students involved in the scenario simulation teaching, and asked them to fill the General information and The Evaluation Index system of Nursing Simulation teaching Quality Questionnaire. Researcher recycled and checked the questionnaires, ensuring no missing.

2.3. Statistical analysis

We input all the data to Microsoft Office Excel © 2013 with two researchers checking, and we used SPSS 17.0 version to analyze the data. Mean and standard deviation (SD) were used to describe the normally distributed continuous variables, like the scores of each item. The adoption rate of open opinions was described and classified and summarized; the overall quality of scenario simulation teaching quality was evaluated by fuzzy comprehensive evaluation method.

2.4. Quality control

The whole process of expert consultation and research is conducted rigorously under the guidance of research groups of the teaching and research department. In the preparation of 〈Fundamental Nursing Curriculum Simulation Manual〉, the research team was aware of the latest literature, teaching objectives and curriculum arrangement and the expert coordination group will modify, discuss and determine to

ensure the reliability of the manual. As for data collection, after the students complete the filling, check whether there is any missing or not to ensure the integrity of the data, as well as carefully double-check and correct to ensure the authenticity of the data.

2.5. Ethical consideration

We applied to Ethics Committees of Peking University, Medical center for human medical ethics review. Through the ethics committee review, our project is in accordance with the relevant provisions of Chinese Ministry of Health Biomedical Research Ethics Review Method for Research Involving Human Being (try out) and the declaration of Helsinki on biology of human trials, thus our research was agreed to be conducted with the decision number PUIRB-2016.V.1.1 on 2016.7.1. After that, we began to conduct our survey, we illustrated all the information related to this study to every participant, and every participants was voluntarily participated in this study with a written informed consent.

3. Results

In this study, a total of 94 students participated, including 38 (40.43%) males and 56 (59.57%) females, aged 18–22 (19.41 ± 0.84) years old. There were 69 (73.40%) people who participated in the simulation teaching.

3.1. Results of simulation teaching quality evaluation questionnaire

The Evaluation Index system of Nursing Simulation teaching Quality Questionnaire scored 73.55–100 (91.71 ± 6.98). First-level item Teacher scored highest (4.77 ± 0.07), followed by Simulation design characteristics (4.61 ± 0.10) and Outcome (4.60 ± 0.05); and second-level item Teacher-attitude scored highest (4.84 ± 0.31), followed by Teacher–knowledge (4.78 ± 0.32) and Teacher-ability (4.70 ± 0.38), and the detailed scores and rankings of first-level and second-level items are shown in Table 1. As for the result of third-level items, the average score of items is 4.59 ± 0.34, detailed information is not listed here owing to the limit of page.

3.2. Construction of fuzzy comprehensive evaluation model

This study divides "The Evaluation Index system of Nursing Simulation teaching Quality Questionnaire" into four levels, among which A represents the quality of nursing simulation teaching and B represents the first-level items (5 items in total), C stands for the second-level items (14 items in total), and D stands for the third-level index (62 items in total). Therefore, the three-level fuzzy comprehensive evaluation method is adopted. The model construction steps are as follows:

(1) Determining the evaluation factor domain U: U refers to the set of evaluation factors in the comprehensive evaluation. $U = \{u_1, u_2, \ldots u_m\}$, where m is the number of evaluation factors. In this study, the number of third-level items is 62, therefore, the evaluation factor domain $U = \{u_1, u_2, \ldots u_{62}\}$.
(2) Establishment of Judgment Set V: V represents the set of judgment in the comprehensive evaluation, $V = \{v_1, v_2, \ldots v_n\}$, where n is the number of judgment levels, which can be qualitative or quantified values. In this study, the grading is carried out according to the items in "The Evaluation Index system of Nursing Simulation teaching Quality Questionnaire" that can be divided into the 5 grading criteria of "very poor, poor, medium, good, excellent", thus, the judgment set is V = {V1,V2,V3,V4,V5}, in which Vi (i = 1,2,3,4,5) means "very poor, poor, medium, good, excellent" respectively.
(3) Establishment of Membership Matrix: represents the degree of membership of a certain evaluation factor to a certain rating level, and the set of membership factors matrix of multiple factors. In this study, the membership degree matrix is calculated and normalized according to the result of "The Evaluation Index system of Nursing Simulation teaching Quality Questionnaire", which form 14 first-level fuzzy assessment matrixes $??_{11}$, $??_{12}$,..., $??_{53}$, and 5 second-level fuzzy assessment matrixes $??_1$, $??_2$,..., $??_5$, and 1 fuzzy assessment matrixes R.
(4) Determining factor weight vector W: W represents the relative importance degree of the evaluation factor, which is mainly used to weight R. In this study, the weight vector is calculated through Analytic Hierarchy Process, which has been published before (Shen et al., 2018).
(5) Determining Fuzzy operator M: M refers to the analysis of Synthetic Assessment, which is obtained through compound calculation of the single factor weight matrix W and the fuzzy matrix ??. Mathematicians have proposed a lot of fuzzy operators, and commonly used operator models include M(∧,∨), M(∨,●), and M(●,⊕). In this study, we adopted M(●,⊕), since each evaluation factor has an impact on the quality of simulation teaching.
(6) Evaluation result vector B: B represents the result of the comprehensive evaluation, which can be analyzed through 3 common

Table 1
Results of first-level and second-level items (n = 94).

First-level	Score	Rank	Second-level	Score	Rank
Teacher	4.77 ± 0.07	1			
			Attitude	4.84 ± 0.31	1
			Knowledge	4.78 ± 0.32	2
			Ability	4.70 ± 0.38	3
Simulation design characteristics	4.61 ± 0.10	2			
			Technology/method	4.68 ± 0.46	4
			Environment	4.54 ± 0.51	11
Outcomes	4.60 ± 0.05	3			
			Knowledge	4.65 ± 0.44	5
			Ability	4.61 ± 0.45	6
			Emotions	4.54 ± 0.64	10
Educational practices	4.57 ± 0.03	4			
			Preparation	4.60 ± 0.46	7
			Implementation	4.57 ± 0.47	8
			Feedback	4.54 ± 0.49	9
Student	4.34 ± 0.15	5			
			Attitude	4.51 ± 0.54	12
			Ability	4.28 ± 0.63	13
			Knowledge	4.23 ± 0.75	14

methods: Maximum membership principle; Weighted average principle; Fuzzy vector singularity. These three principles could be selected according to research questions and research purposes. For example, while comprehensively evaluating a certain thing, the principle of maximum membership can be used; while comparing or sorting the results of comprehensive, the weighted evaluation principle and the fuzzy vector single value can be selected. This study aims to comprehensively evaluate the quality of nursing simulation teaching, therefore the principle of maximum membership was adopted.

3.3. Validity test of the principle of maximum membership

Due to the ambiguity of the set V, the evaluation based on the principle of maximum membership degree is relatively rough. For this reason, mathematics experts have proposed the maximum membership validity test, and the test index is: $a = (n\beta - 1)/(2\gamma(n - 1))$, n is the number of elements, β is the maximum membership degree in the fuzzy comprehensive evaluation result, and γ is the second largest membership degree in the fuzzy comprehensive evaluation result.

If $a = +\infty$, the principle of maximum membership is completely valid; If $1 \le a < +\infty$, the principle of maximum membership is very effective; If $0.5 \le a < 1$, the principle of maximum membership is more effective; If $0 < a < 0.5$, the principle of maximum membership is inefficient; If $a = 0$, the principle of maximum membership is completely invalid.

3.4. Results of fuzzy comprehensive evaluation model

3.4.1. Third-level fuzzy comprehensive evaluation

According to the third-level results of "The Evaluation Index system of Nursing Simulation teaching Quality Questionnaire", the percentage method is used to calculate the membership degree, and the fuzzy relation matrix R of the three-level index is obtained. The weight vector of the corresponding evaluation factor has been calculated before (Shen et al., 2018), and the application M(●,⊕) is applied. Owing to the limited space, we only listed one example of the synthesis of the fuzzy matrix, and the detailed results were shown in Fig. 1.

Teacher-knowledge

$$\underline{R}_{11} = \begin{bmatrix} 0 & 0 & 0.0106 & 0.1702 & 0.8191 \\ 0 & 0 & 0 & 0.0957 & 0.9043 \\ 0 & 0 & 0.0638 & 0.2447 & 0.6915 \\ 0 & 0 & 0.0106 & 0.1809 & 0.8085 \end{bmatrix}$$

$$\underline{W}_{11} = [0.2446 \quad 0.6088 \quad 0.0494 \quad 0.0972]$$

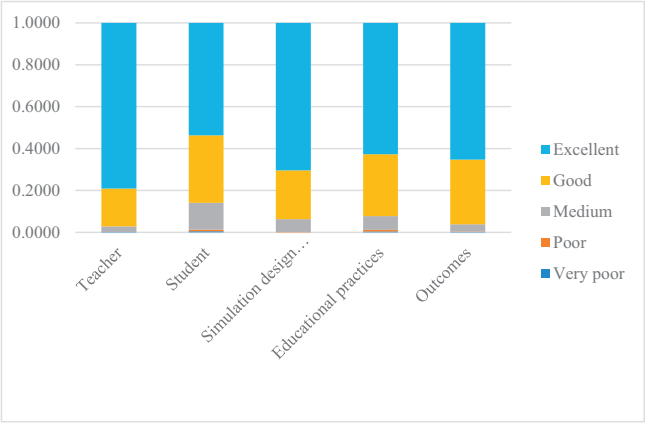

Fig. 2. Result of Second-level fuzzy comprehensive evaluation.

$$B_{11} = \underline{R}_{11} \cdot \underline{W}_{11} = [0 \quad 0 \quad 0.0068 \quad 0.1296 \quad 0.8636]$$

3.4.2. Second-level fuzzy comprehensive evaluation

Based on the weights of the third-level items relating to the second-level items and the results of the first-level comprehensive evaluation, the fuzzy comprehensive evaluation of the second-item is based on the same calculation method and the results were shown in Fig. 2.

3.4.3. First-level fuzzy comprehensive evaluation

In this study, the final results of the First-level fuzzy comprehensive evaluation showed that the subordinates of the quality of the simulation teaching were "excellent: 0.6794, good: 0.2500, medium: 0.0064, poor: 0.0039, and very poor: 0.0028" respectively. Thus, according to the principle of maximum membership, the quality of simulation teaching in 〈Fundamental Nursing Curriculum〉 is "excellent". Among the first-level items, "teacher" and "student" are "excellent"; among the second-level items, "simulation design characteristics-technology or method" and "teacher-ability" are "excellent", indicating that simulation teaching implemented this semester were of high quality.

3.4.4. Validity test of the principle of maximum membership

In our study, we validated the Fuzzy Comprehensive Evaluation Model adopting the validity test of the principle of maximum membership. And it turned out that the test index a was 2.3965, suggesting that a belongs to $1 \le a < +\infty$ category. Thus, the Fuzzy

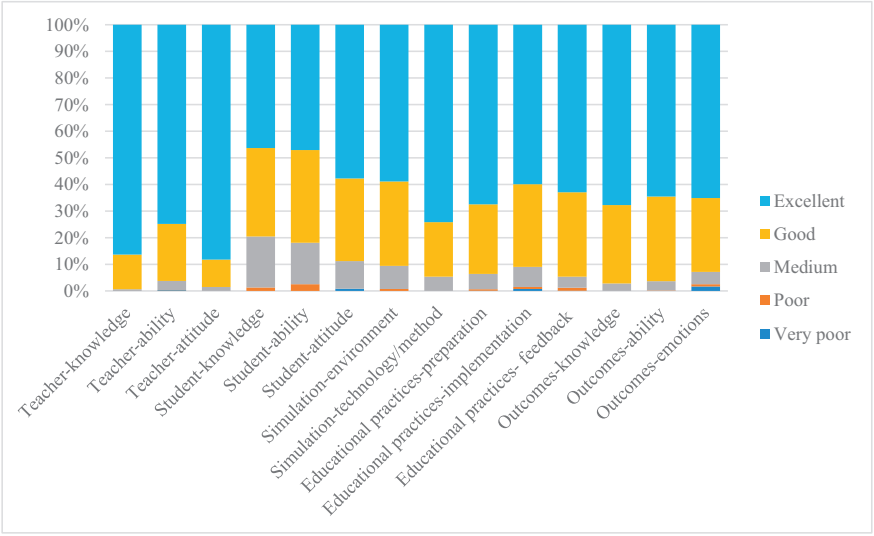

Fig. 1. Result of Third-level fuzzy comprehensive evaluation results.

Comprehensive Evaluation Model has been proved to be credible.

4. Discussion

4.1. The necessity and feasibility of AHP-fuzzy comprehensive evaluation

Simulation teaching quality itself is a vague concept, which could be influenced by many uncertain factors. While the evaluation results are generally determined by subjective judgment, indicating that accurate and quantitative research is often difficult and fuzzy (Çelik et al., 2017). The fuzzy set of mathematics can quantitatively describe these uncertain factors. Therefore, it is necessary to use fuzzy comprehensive evaluation to evaluate the influencing factors of simulation teaching quality, which can present the qualitative results and subjective feelings in a quantified form through fuzzy operations, and to a certain extent avoid the probability that the evaluation results affected by subjective emotions. In our study, we adopted fuzzy comprehensive evaluation to evaluate the quality of simulation teaching, considering each influencing factor on the overall teaching quality. AHP-fuzzy comprehensive evaluation could provide an effective methodological reference for the quality evaluation of nursing teaching. Although AHP-fuzzy has been seldom used in nursing education, while it has been widely used in environment research (Liu et al., 2016), health service (Zhai et al., 2017), transport research (Zou et al., 2014), psychological burden (Wei and Liu, 2018), et al. The AHP-fuzzy comprehensive evaluation method uses AHP to obtain the weight value of each index. And the steps of the AHP-fuzzy comprehensive evaluation model are clear and intuitive, and some calculations can be calculated by Excel or Yaahp analytic software. The matrix operation in fuzzy comprehensive evaluation can be performed by means of programming tools. Thus, the feasibility of AHP-fuzzy comprehensive evaluation is strong, can provide scientific methodological reference for nursing teaching and clinical nursing quality evaluation, and further improve the objectivity and credibility of the evaluation results.

4.2. Multi-level fuzzy comprehensive evaluation model provides important information for discovering weak links in simulation teaching

The simulation teaching quality evaluation system is complex, involving Teachers, Students, Simulation design characteristics, Educational practices and Outcome. And the “Evaluation Index system of Nursing Simulation teaching Quality” constructed in this study included 5 first-level items, 14 second-level items and 62 third-level items, making it difficult to put into practice to some extent. Since the fuzzy comprehensive evaluation can carry out multilevel evaluation, and the evaluation process is recyclable, the comprehensive evaluation result of the previous level can be used as input data for the comprehensive evaluation of the next level. Therefore, this study applied a multilevel fuzzy comprehensive evaluation model, which can not only maintain the analysis of each level, but provides a strong basis for overall analysis. On the one hand, the nursing teaching managers and supervisory departments could select teachers with high teaching ability; On the other hand, through targeted analysis of the subordinate categories of each level, it is found that promising factors could be maintained, and less promising factors could be strengthened and improved. Moreover, with the results, reasonable suggestions for teaching reform are made to clarify the key directions of reform and balance the distribution of resources and manpower.

4.3. Maximum membership provides a basis for evaluating the quality of simulation teaching

The transition between the objective things and the differences under the co-dimensional conditions also determines the objective attributes of the existence of fuzzy phenomena and ambiguities. This property is precisely the basis of fuzzy mathematics and fuzzy systems in the perspective of Philosophical. Therefore, in fuzzy mathematics, the concept of “degree of membership” is introduced to describe the intermediate transition of differences. With its own life experience, human beings have a set of evaluation criteria for each fuzzy concept. Fuzzy mathematics believes that the interconnection between things, the boundaries of their degree of attribution are sometimes not clear, such as the quality of “good” and “bad”, the boundaries between “good” and “bad” are relatively vague. The degree of Maximum membership can indicate the degree to which something belongs to another thing, and is usually expressed as a percentage. The nature of the fuzzy comprehensive evaluation determines that the final evaluation result is a fuzzy vector value rather than an exact point value.

In this study, the comprehensive evaluation result of the most important indicator of the first-level item “teacher” is $B_1 = [\blacksquare(0.0015\& 0.0006\&0.0270\&0.1805\&0.7903)]$, that is, the degree of “excellent” is at the level of 79.03%, and the degree of “good” is at the level of 18.05%; and the comprehensive evaluation result of “student” is $B_2 = [\blacksquare(0.0050\&0.0078\&0.1280\&0.3230\&0.5362)]$, that is the degree of “excellent” is at the level of 53.62%, and the degree of “good” is at the level of 32.30%. According to the principle of maximum membership degree, the evaluation grades of both are subordinate to “excellent”. In the same way, the second-level item “Simulation design characteristics-technology or method” and “teacher ability” also belongs to “excellent”, since the degree of “excellent” was 58.92% and 74.86%, respectively. The results of fuzzy comprehensive evaluation scientifically describe the intermediate transition state of each level or item. Through the maximum membership degree, the evaluation criteria of teaching quality evaluation could be improved, and the relationship between qualitative analysis and quantitative analysis could be established to ensure the fuzzy evaluation, providing a comprehensive and scientific method to evaluate teaching quality.

5. Conclusion

The quantitative research trend of humanities and social sciences has effectively promoted the wide application of the theory of fuzzy mathematics processing in such disciplines. Such disciplines often involve complex things related to people, as well as various influencing factors, making it difficult to list them one by one in the research process. In our study, we tried to evaluate the simulation teaching quality in 〈Fundamental Nursing Curriculum〉 with fuzzy comprehensive evaluation methods. Based on the weight distribution of “Evaluation Index system of Nursing Simulation teaching Quality”, it turns out the simulation teaching quality in 〈Fundamental Nursing Curriculum〉 was excellent, indicating that the 〈Fundamental Nursing Curriculum Simulation Manual〉 we designed was worthy spreading in larger scale and the way we conducted simulation teaching is also worthy applying in different schools. Also, based on our knowledge, it is the first time to adopt fuzzy comprehensive evaluation in nursing education, and as a result, fuzzy mathematics could effectively solve the ambiguity and complexity phenomenon involved in teaching quality, indicating the AHP-fuzzy comprehensive evaluation could be widely used in nursing education.

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