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Article

Investigation, evaluation and countermeasures of the current situation of online physical education in universities during COVID-19: Incorporating biomechanics research

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Abstract: In 2019, a sudden outbreak of novel coronavirus disease swept the world, seriously affecting education and teaching. Most universities around the world have adopted a "learning without classes" model, which is dominated by online teaching. Up to now, this teaching model under the normalization of the epidemic has been popularized all over the world. However, the evaluation of online teaching quality and the weight of influencing factors have become difficult points in measuring teaching quality, that is, the factors and weights affecting online teaching are problems that need to be studied and solved urgently. This study takes online physical education (PE) teaching in Chinese universities as the research object. While traditional research often centers on teaching evaluation methods, this research innovatively integrates biomechanics into the study. By analyzing the relevant research literature, it proposes a weight evaluation method for online PE teaching index in universities based on analytic hierarchy process (AHP)-entropy method-fuzzy comprehensive evaluation method. This method is actually a new teaching evaluation model that combines the subjective and objective weighting method with the fuzzy evaluation method. Integrating biomechanics offers a novel perspective on online PE. It aids in assessing students' exercise effectiveness and optimizing online educational resources. Advanced video analysis and motion capture can precisely measure students' joint angles, limb movement trajectories, and muscle activation patterns during exercises. This enables accurate evaluation of movement standardization. By comparing with optimal biomechanical models, teachers can provide targeted guidance, enhancing exercise effectiveness and reducing injury risks. In teaching video creation, incorporating biomechanical principles helps students understand the scientific basis of movements. For instance, in a basketball shooting tutorial, explaining the arm, wrist, and finger biomechanics can improve students' understanding and performance. Moreover, biomechanical simulation technology can create virtual sports scenes, enriching the online learning experience by allowing students to explore environmental impacts on body mechanics. We applied the method to the weight analysis of online PE teaching index in Chinese universities, and demonstrated that the method has good applicability. More importantly, we have condensed the conclusions of this research into practical countermeasures, and put forward strategies to improve the quality of online PE teaching from the macro level and the subjective research level. This research achieves innovation at the application level, improvement at the theoretical level and focus at the practical level. The research results can help Chinese universities to improve the quality of current online PE teaching, and even provide experience and reference for formulating relevant measures for international online teaching.

Keywords: COVID-19; physical education; AHP-entropy method; fuzzy comprehensive evaluation method; weight evaluation; biomechanics

1. Introduction

As the outbreak spread, similar conditions have been found outside China and other countries outside China. On 5 February 2020, in response to the impact of COVID-19 on the normal university opening and classroom teaching, the Ministry of Education, PRC issued the Guidelines on the Organization and Management of Online University Teaching during the COVID-19 epidemic. The document calls for a government-led, college-led and social participation approach to jointly implement and ensure online teaching at universities during COVID-19 to achieve the goal of "no classroom teaching, no classroom learning". On 1 April 2020, China university physical education steering committee issued "about further COVID-19 during the outbreak of university sports course online teaching guidance", emphasize to Xi Jinping, general secretary of resolutely fight the epidemic war important instructions spirit as the guide, and put forward through the family sports course to ensure that students enjoy fun, enhance physical fitness, improve personality and exercise will. On 15 May 2020, the Ministry of Education, PRC released the book "Online Education from the Fresh to the New Normal", which proposed a new teaching reform model from the perspective of teachers, students, education system and managers. On 2 August 2021, the Ministry of Education of the People's Republic of China and the National Health Commission jointly issued the Notice on Further Strengthening School Health Management under the Regular Prevention and Control of COVID-19, emphasizing the importance of physical education in the normal teaching management during COVID-19. During COVID-19, Chinese universities have realized a full-region, full-coverage, and all-round online teaching model. As of 8 May 2020, 1454 universities across the country have launched online teaching. 1.03 million teachers offered 1.07 million courses online, with a total of 12.26 million lessons; a total of 17.75 million college students participated in online learning, with a total of 2.3 billion person-times. According to the "National Undergraduate Education and Teaching Quality Report (2020)" issued by the Ministry of Education on 17 December 2021, it is pointed out that the scale of online teaching continues to expand. At present, a total of 1.08 million teachers in undergraduate universities across the country have offered 1.1 million courses/17.19 million lessons. The total number of college students studying online is 3.5 billion, and the rate of online courses offered by universities nationwide has reached 91%.

This study takes online physical education (PE) teaching in Chinese universities as the research object. By analyzing the relevant research literature, it proposes a weight evaluation method for the online PE teaching index in universities based on the analytic hierarchy process (AHP)-entropy method-fuzzy comprehensive evaluation method. This method is actually a new teaching evaluation model that combines the subjective and objective weighting method with the fuzzy evaluation method. We applied the method to the weight analysis of the online PE teaching index in Chinese universities, and demonstrated that the method has good applicability. More importantly, we have condensed the conclusions of this research into practical countermeasures, and put forward strategies to improve the quality of online PE teaching from the macro level and the subjective research level. The research contributions are mainly concentrated in three aspects:

(1) By sorting out the current international research literatures on teaching management evaluation and countermeasures, the current situation of online PE teaching in universities during COVID-19 was investigated and analyzed, and the results were given.

(2) The main goal of this paper is to apply a weight evaluation method based on the analytic hierarchy process (AHP)-entropy method-fuzzy comprehensive evaluation method for the online PE teaching index in universities. In other words, the novelty of this paper focuses on the applications and corresponding modifications of the existing methods.

(3) According to (1) and (2), the research gives the experiments first. Then it also puts forward countermeasures and suggestions for improving the quality of online PE teaching in universities.

The rest of this paper is arranged as follows: the second part is the literature review, which mainly summarizes the relevant literature on international and domestic research on teaching models and teaching quality assessment methods during COVID-19; the third part summarizes the research objects and research methods of this paper, which mainly includes literature review method, questionnaire survey method, expert interview method and mathematical statistics method; the fourth part analyzes the current situation of online PE teaching in Chinese universities during COVID-19; the fifth part proposes a quality evaluation method for online PE teaching based on AHP-entropy method - fuzzy comprehensive evaluation method; the sixth part demonstrates the rationality and applicability of the weight evaluation method proposed in this study through an example analysis; the seventh part gives relevant countermeasures and suggestions for improving the quality of online PE teaching in Chinese universities during COVID-19 from the subjective research level and the macro knowledge level; the eighth part is the conclusion.

2. Literature review

This study focuses on the current situation, evaluation and countermeasures of online PE teaching quality in universities under the background of COVID-19. It is necessary to pay close attention on reviewing online teaching issues and related teaching quality evaluation theories and methods during COVID-19. The specific literature review is as follows.

There are many international studies on the theory and method of teaching quality evaluation. To improve teaching quality continuously, Gao et al. [1] established a teaching quality monitoring system, proposed the basic dynamic AHP to evaluate teaching quality, and analyzed the results, which laid a solid foundation for exploring better teaching quality evaluation methods. Chen et al. [2] proposed a teaching performance evaluation method combining the fuzzy AHP and the fuzzy comprehensive evaluation method, and explained with the practical case application program to make the evaluation results more scientific, accurate and objective. I am very grateful for the above two research results, which provide theoretical experience for my research on the design of online PE teaching quality evaluation methods. Shen et al. [3] adopted the Delphi method and the AHP to jointly construct the evaluation index system of nursing simulation teaching quality, and its weight distribution is

scientific and reliable, which can directly guide high-quality simulation teaching. Yu et al. [4] constructed an evaluation index system from four aspects: teaching effect, content, method and attitude, applied AHP to calculate the weight of each index, and finally used fuzzy mathematics to exploit the rules of teaching quality grade and evaluation index. The author also established the consistency judgment matrix of teaching quality evaluation, and demonstrated the effectiveness and feasibility of this method. The above two studies focus on the construction of the evaluation index system, which can provide a reference for my study to construct the evaluation index system of online PE teaching quality during COVID-19. On the basis of the traditional TOPSIS method and intuitionistic fuzzy sets (IFSs), Liu et al. [5] designed a novel IF-TOPSIS method based on intuition distance to accurately evaluate the quality of PE teaching. Bao et al. [6] proposed an online and offline hybrid teaching quality evaluation method based on mobile edge computing, which effectively evaluated the quality of online and offline hybrid PE teaching. Liu et al. [7] proposed a teaching quality evaluation method based on the dynamic AHP set to improve the teaching quality. According to the evaluation results of the dynamic AHP, it has an important influence on the exploration of better teaching quality evaluation methods. Aiming at the imbalance between qualitative and quantitative evaluation and unscientific teaching evaluation methods in the current teaching quality evaluation of college teachers, Qing et al. [8] reconstructed a new system of teacher evaluation in universities, and used the fuzzy AHP to realize scientific evaluation. The above studies all focus on the improvement and innovation of evaluation methods, which can support the evaluation of teaching quality based on the fuzzy comprehensive evaluation method proposed in this paper. Zhao et al. [9] made a comprehensive evaluation of PE teaching from two aspects of teachers' teaching preparation and practical teaching. Using AHP, the ranking was obtained according to a certain logical relationship through a pairwise comparison to provide a reference for the index. Although her research uses AHP to assign weights, the ideas and logic in it are worth learning from. Ning et al. [10] adopted a variety of methods such as questionnaire method, Delphi method, statistic method, and logical analysis method to establish the evaluation standard of physical quality education. Taking the PE major of a university as an example, the empirical research was carried out on the proposed standard. The highlights mainly focus on the use of a variety of mixed methods for teaching quality evaluation, which has certain novelty. Based on the particle optimization algorithm, Gao [11] divided the factors that affect the quality of university teaching into two categories: "cause and result". On the basis of evaluating the entire system, using AHP, various factors were corrected layer by layer according to its influence on the system. Liu et al. [12] took five universities in a certain province of China as an example to investigate the current situation of PE teaching evaluation, and revealed the existing problems. Luo et al. [13] established the index system in the quality AHP, summarized and selected several indexes that have obvious impact on RG training, and established gymnast physical fitness index system on the basis of these indexes. The author also developed the corresponding software system to provide scientific theoretical basis and practical application basis for the selection and evaluation of gymnasts. Liu et al. [14] summarized the content of the evaluation of college English teaching quality, and clearly put forward the influencing factors. The author also established a perfect

evaluation system of college English teaching quality based on this. Yang et al. [15] studied the multi-attribute fuzzy evaluation of the teaching level of music courses, analyzed the influencing factors, and established a perfect evaluation system. Feng et al. [16] aimed to explore the quality evaluation of PE teaching in universities. The weight of each level index was determined by AHP, and the evaluation method was established by combining the grey system theory and the fuzzy comprehensive evaluation method, and then the evaluation index system was constructed. Liu et al. [17] proposed a college English evaluation index system with students as the main body of evaluation, which was based on language terms, triangular fuzzy numbers and preference selection index method. At the end of the study, the effectiveness and feasibility of the method were illustrated by an example analysis. The above studies focus on the application of evaluation methods in the evaluation of teaching quality of different courses, which provides feasibility demonstrations for the evaluation of online PE teaching quality in my research. Wang et al. [18] designed a distance-based IVIF-CODAS method to evaluate the quality of college English teaching based on the traditional CODAS method and interval-valued intuitionistic fuzzy sets (IVIFSs). Zhao et al. [19] established an optimization model based on the basic idea of traditional TOPSIS, through which the weights of attributes can be determined. The developed procedure was illustrated with an example of evaluating the quality of teaching in a university classroom.

There are relatively few existing studies for online teaching quality during COVID-19. In the context of the epidemic, Lam et al. [20] explored the transformation of PE teaching methods from face-to-face teaching to online teaching, and the decision-making criteria considered in the study were quality management system, information quality, flexibility, learning and teaching, and attractiveness. This study can provide support for our analysis of the current situation of online teaching during COVID-19. Tang et al. [21] applied a comprehensive FCE-AHP assessment in the context of COVID-19. Based on the real cases of online courses, the influencing factors of online course quality were divided into 4 first-level indexes, which were further subdivided into 14 second-level indexes. Several improvements have been made in response to the difficulties encountered with online courses during the COVID-19 epidemic. Hu et al. [22] proposed an evaluation model for the cultivation of innovative talents in universities after the epidemic based on statistical learning theory. A quality evaluation index system for innovation and entrepreneurship talent training in universities was constructed, which consisted of four first-level indexes of environment, teaching links, teachers and students. At the same time, the empirical research was carried out with the fuzzy comprehensive evaluation method. In the context of the Chinese Ministry of Education's promotion of online teaching during COVID-19, Ping et al. [23] emphasized the importance of evaluating the quality of homeschooling. Based on AHP, five indexes of learning users, teaching content, teaching methods, teaching platforms and teaching effects were selected to construct an online evaluation system.

In general, there is currently a lack of international literature on the analysis and evaluation of the current situation of teaching quality during COVID-19, but a large and rich literature focuses on the research on teaching quality evaluation methods, mainly including AHP, fuzzy evaluation method, entropy method, TOPSIS method,

intuitive fuzzy evaluation method, etc., which can provide reference for my study to evaluate the quality of online PE teaching during COVID-19. However, due to the lack of background literature on online teaching studies during the epidemic, we first need to analyze the results of online teaching during COVID-19, so as to propose a scientific and reasonable teaching quality evaluation model, which can contribute to the international research on teaching quality evaluation during COVID-19.

3. Research objects and methods

This study examines the online teaching situation of university students during the epidemic, focusing on the form, content, and satisfaction of online Physical Education (PE) teaching. The research employs a comprehensive methodology to ensure a robust evaluation model. The main research contents include the form of online PE teaching, the content delivered, and the satisfaction of both teachers and students. The research methods are as follows:

1) Literature review method

This paper conducted a thorough literature review by consulting relevant research documents through CNKI, library books, and policy documents from the Ministry of Education and college sports authorities' websites.

2) Questionnaire method

Building upon existing literature, particularly the studies by Guo et al. on "Survey on the Online Teaching Status of PE Courses in Shanxi Province during the Epidemic Prevention Period" and Liu et al. on "Investigation and Countermeasures of PE Risks in Universities During the Epidemic", we formulated the "Online PE Teaching Questionnaire for College Students". This questionnaire was designed following the basic requirements of sociological research to ensure its validity and reliability.

3) Expert interview method

We conducted interviews with over 20 PE teachers from various domestic universities to gather insights on the establishment, content, scheduling, supervision, and satisfaction with online PE teaching.

4) Mathematical statistics method

The data collected were organized and analyzed using mathematical statistical methods to draw relevant conclusions. Charts and graphs were created to visually represent the data analysis.

AHP method:

The Analytic Hierarchy Process (AHP) was applied to determine the relative weights of different criteria. We constructed a hierarchical structure model, consisting of a goal layer, criterion layer, and subcriterion layer. Pairwise comparisons were made to determine the weights of each criterion, and a consistency test was conducted to ensure the reliability of the judgments.

Entropy method:

The entropy method was used to calculate the weight of each alternative based on the degree of difference in the data. This method helps to reduce subjective bias in the weight determination process.

Combining AHP and entropy methods:

The weights obtained from the AHP method were combined with the entropy

weights to calculate the final weights for each criterion and subcriterion. This hybrid approach enhances the objectivity and accuracy of the evaluation model.

Data collection method:

We have expanded the description of our data collection method, including the questionnaire design process, sample selection criteria, and the data collection process. The questionnaire was pilottested to ensure clarity and comprehensiveness before fullscale distribution.

Expert selection and scoring process:

We have specified the criteria for expert selection, which includes their professional background, experience in online PE teaching, and publication record in related fields. The scoring process involves a structured approach where experts rate each criterion based on a predefined scale, and these ratings are then aggregated to determine the weights.

Data consistency tests:

We have included detailed information on the results of the consistency tests conducted during the AHP process. Any inconsistencies were addressed by revisiting the pairwise comparisons and adjusting judgments to achieve a consistent matrix.

4. Research status and results: The current situation of online PE teaching in universities during the epidemic

Through the questionnaire method, the current situation of online PE teaching in universities during the epidemic was sorted out as follows:

(1) Attitudes of teachers and students towards online PE teaching

The attitude of teachers and students towards online PE teaching directly determines their behavior. The attitude of PE teachers to online teaching determines whether they can prepare lessons and teach seriously, which directly affects the teaching quality and effect of the whole class. The attitude of students will affect whether they actively participate in the online PE process and whether they are serious about completing teaching tasks. As shown in **Table 1**, 52.66% of the students liked online PE teaching very much, they were able to recognize the importance of online learning during the epidemic, and the importance of physical exercise in fighting the epidemic and mastering study skills; 87.17% of teachers took online PE teaching very seriously and responsibly. Only a small number of teachers did not take it seriously or generally. They felt that it was difficult to teach PE online. Some teachers even thought that PE classes could not be taught online, and felt that the effect of online teaching was poor, so they only sent the content of the exercises to the students so that the students could learn by themselves. Some students attached great importance to the study of cultural classes and neglected physical exercise.

Table 1. Statistical table of teachers and students' preference and attitude towards online PE teaching.

Role	Number of People	Like Very Much/%	Like/%	Average/%	Dislike/%
Teacher	117	87.17	11.11	1.71	0
Student	545	52.66	21.83	14.68	10.83

The motivation of students in online PE classes varies. As shown in **Table 2**:

35.04% of the students believed that the online PE class was for learning the skills of physical exercise; 65.87% of the students were to cope with the final exams after the school started; 74.86% of the students believed that the PE class could be used for rest and decompression. As an adjustment exercise for learning other cultural courses, 21.83% of the students have good physical skills. 96.69% of the students felt that having fun in PE classes was the most important thing, which was also the most important thing in home isolation.

Table 2. Statistical table of students' motivation to participate in online PE classes.

NO.	Motivation	Number	Ratio/%
1	To learn sports skills	191	35.04
2	To cope with the final exams	359	65.87
3	To relieve stress and regulate learning mood	408	74.86
4	To show yourself, attract attentions	119	21.83
5	To entertain the body and mind	527	96.69

(2) The implementation process of online PE teaching

Education authorities in all cities have issued implementation plans for online teaching during the epidemic, requiring full use of existing micro-courses, MOOCs, and high-quality course resources on various national education public platforms. They also called for the full use of "Internet + new media" and other information technologies to carry out online teaching, and the use of national network cloud classrooms to organize students' online teaching. Through consulting relevant literature and conducting questionnaire surveys, it is found that the online PE teaching carried out by universities is diverse, colorful and rich in content. 49.8% of PE teachers used DingTalk to teach; 31.9% used QQ group classrooms; the remaining 18.3% used Chaoxing software, Tencent conference and other platforms. Through online live teaching, teachers teach students various sports skills, spread sports knowledge, share sports games videos, etc. Teachers use the Internet + new media to carry out online teaching activities, explain technical actions to students, at the same time assign homework for students after class, interact with students, answer questions for students online, and check homework. The specific statistics are shown in **Table 3** below.

Table 3. Implementation process of online PE teaching.

	DingTalk	Ratio/%	QQ Group Classroom	Ratio/%	Chaoxing	Ratio/%	Tencent Conference	Ratio/%	Others	Ratio/%
Teacher (117)	58	49.57	37	31.62	2	1.71	18	15.38	2	1.71

(3) Teacher-student interaction and teaching atmosphere in online PE classes

The interaction between teachers and students in PE class can reflect the situation of classroom teaching atmosphere. The better the teacher-student interaction and student-student interaction, the more harmonious the classroom teaching atmosphere. The survey found that the interaction between teachers and students in the process of online PE teaching is not very ideal. The teacher's lectures are brilliant, but the students are indifferent, or it's just the teacher's performance, and the students have

no motivation to learn. Some students even ignore the existence of the classroom and do other things on their own. Whether the teaching atmosphere is active or not directly affects the teaching efficiency. The specific statistics are shown in **Table 4**. During the online PE teaching process, 8.54% of PE teachers thought that the teaching atmosphere was very active; 19.66% thought that it was relatively active; 38.46% thought that it was general; 17.94% thought that it was inactive; and 14.55% thought that it was very inactive. In general, the teaching atmosphere was not active enough. Most teachers believe that although they have been exposed to online teaching, they have no experience in live broadcast, especially when it comes to teaching skills in PE classes, they cannot see the movement practice of students and cannot interact with students.

Table 4. Statistical table of PE teachers and students' evaluation of classroom atmosphere.

Role	Very Active	Ratio/%	Relatively Active	Ratio/%	General	Ratio/%	Inactive	Ratio/%	Very Inactive	Ratio/%
Teacher (117)	10	8.54	23	19.66	45	38.46	21	17.94	18	15.38
Student (545)	16	2.95	158	28.99	271	49.72	72	13.21	28	5.13

(4) Attendance of students in online PE classes

Table 5. Attendance Distribution and Ratios of Students in Different Attendance Categories

Number of Students	Full Attendance	Ratio/%	Attendance over 80%	Ratio/%	Attendance 60%–80%	Ratio/%	Attendance below 60%	Ratio/%
545	134	24.59	298	54.68	104	19.08	9	1.65

The survey found that students' use of the Internet and new media also varied by economic development. Students from disadvantaged families do not have desktops or tablets, only TVs and mobile phones. In some remote areas, the network conditions are poor, and the network is often stuck, making it impossible to play online live classes normally. These will affect the situation of students taking classes online. The specific attendance and attendance rate are shown in **Table 5**. The number of people who can achieve full attendance is 134, accounting for about 1/4 of the total number. And more than 98% of students can achieve passing attendance. But obviously, the attendance rate of online courses still needs to be further improved.

(5) Teachers and students' satisfaction with online PE teaching

In terms of teaching form, content, time, number of online students, and teaching satisfaction, the average value was basically lower than 3 points, especially the number of online students, the satisfaction of teachers and students was lower than 2 points. This shows that teachers and students are less satisfied with online teaching. Due to the different sample sizes of teachers and students, a non-parametric test must be selected when choosing a difference test method, so the Wil-coxon test was selected. The test found that there were significant differences between teachers and students in terms of teaching form, the number of online students, and teaching effects ($P < 0.05$), and the satisfaction of teachers in these three aspects was higher than that of students (the average values of the three satisfactions of teachers were all higher than that of

students), however there was no significant difference in teaching content, teaching time, and teacher-student satisfaction. The specific statistics are shown in **Table 6** below.

Table 6. Statistical table of teachers and students' satisfaction on online teaching.

	Role	Number	Average Value	Standard Deviation	Wilcoxon Test Value	*P*
Teaching Form	Teacher Student	117 545	2.81 2.28	1.313 1.204	4.028[a]	0.000
Teaching Content	Teacher Student	117 545	3.04 2.90	1.464 1.417	−1.447[b]	0.148
Teaching Time	Teacher Student	117 545	2.09 2.03	1.022 0.960	−1.147[b]	0.251
Number of Online Students	Teacher Student	117 545	1.64 1.67	1.133 1.133	−3.653[b]	0.000
Teaching Effect	Teacher Student	117 545	2.49 2.41	0.877 0.982	−2.843[a]	0.004

(6) Statistics on the supervision and assessment of online PE classes by school leaders

Through the investigation of this study, it is found that all universities have carried out online teaching evaluation, and the evaluation methods include inspecting online class group, student cadre supervision and so on. Through the survey of PE teachers, it is found that 6.83% thought that school leaders attached great importance to online PE teaching; 16.23% thought that they attached importance to it; 43.59% thought that it was general; 33.33% thought that they didn't pay attention. In general, it was believed that school leaders did not pay much attention to PE teaching. The main reason is that school leaders and even many teaching administrators think that online PE teaching is difficult to implement. In their minds, they all believe that PE can only be practiced on the playground. Some leaders attach great importance to the teaching of professional courses, while PE is only a course without examination in many schools, so they do not pay much attention to PE teaching. The specific statistical results are shown in **Table 7** below.

Table 7. School leaders' emphasis on online PE teaching.

	Great Importance	Ratio/%	Importance	Ratio/%	General	Ratio/%	Neglect	Ratio/%
Teacher (117)	8	6.83	19	16.23	51	43.59	39	33.33

5. Evaluation of online PE teaching quality based on AHP-entropy method-fuzzy comprehensive evaluation method (AHPE-FCE)

To take the advantages of single fuzzy comprehensive evaluation methods, entropy and Analytic Hierarchy Process (AHP) methods are always used to calculate the comprehensive weights. Particularly, AHP is for evaluation criterion weights subjectively, while entropy method is for objective weights. Hence, in this study, both AHP and entropy methods are adopted. Together they can effectively make up for each other's shortcomings.

AHP transforms multi-objective, multi-criteria, and difficult-to-quantify

decision-making problems into multi-level single-objective problems. It has been widely used in different fields. The main implementation steps of AHP are as follows: (1) According to the nature of the problem and the goal to be achieved, the decision-related factors are classified into layers; (2) Following the evaluation scale of the AHP, each 2 factors are scored by comparison, and a judgment matrix is established; (3) The corresponding eigenvalues and eigenvectors are obtained from the judgment matrix; (4) Check the consistency. If the consistency check requirements are met, the normalized vector is the weight; if the consistency check requirements are not met, the judgment matrix needs to be adjusted and recalculated. The problem that needs to be decided is divided into the target layer - the criterion layer—the scheme layer from top to bottom by the AHP, and the hierarchical structure model is used to express the relationship between these factors and the degree of mutual influence. The specific analysis steps of this method are as follows:

(1) Build a hierarchical structure model

First, establish an index system for evaluating the quality of online PE teaching, as shown in **Table 8** below.

Table 8. Online PE teaching quality index system.

First-level Index	Second-level Index	Third-level Index	Meaning of Third-level Index
Online PE teaching quality evaluation X_1	Teaching interaction Y_{11}	Affinity Z_{111}	Making students feel close in online teaching
		Communication skills Z_{112}	Be able to express the teaching content well in online teaching
		Listening ability Z_{113}	Listening to students' demands in online teaching
	Information literacy Y_{12}	Integration ability for IT and curriculum Z_{121}	Multi-resource integration and innovation ability of online teaching
		Ability to use IT tools Z_{122}	Proficient use of online teaching tools
		Network resource utilization and development capabilities Z_{123}	The level of network resource use in online teaching
	Professional character Y_{13}	Professional emotion Z_{131}	Professional attitudes such as Moral education
		Career pursuit Z_{132}	Higher-level pursuits around careers
	Teaching ability Y_{14}	Teaching design Z_{141}	Design of teaching content and teaching objectives
		Teaching implementation Z_{142}	Ability to carry out teaching activities
		Teaching research and reform Z_{143}	Ability to think and innovate on teaching problems
	Knowledge Y_{15}	educational knowledge Z_{151}	Pedagogy-related theory
		PE subject knowledge Z_{152}	Level of expertise in PE
		IT knowledge Z_{153}	Theoretical and practical knowledge of IT
	Basic information of students Y_{16}	Learning motivation Z_{161}	Students' enthusiasm for online learning
		Learning target Z_{162}	Online Learning Objective of Students
		Learning habit Z_{163}	Learning habits of students in online classes

(2) Construct a pairwise comparison judgment matrix A

The value of the judgment matrix reflects the decision-maker's understanding of the relative importance of the factors. Generally, 1–9 and its reciprocal are used to express importance. The evaluation scale table of the AHP method is shown in **Table 9** below.

Table 9. AHP evaluation scale table.

Comparison standard	Meaning
1	Factor i are as important as factor j
3	Factor i are slightly more important than factor j
5	Factor i are significantly more important than factor j
7	Factor i are strongly more important than factor j
9	Factor i are extremely more important than factor j
2, 4, 6, 8	compromises between the comparison criteria of above two-factor
Reciprocal	Standard Values compared by factor i and j

(3) Calculate the combined weight vector

Calculate the maximum eigenvalue of the judgment matrix A and its corresponding eigenvector, as shown in Equation (1):

$$AW = \lambda_{max} \tag{1}$$

where, A is the judgment matrix, λ_{max} is the maximum eigenvalue of the judgment matrix, and W is its corresponding eigenvector.

(4) Consistency check

The relative weight of the index obtained according to the eigenvector corresponding to the largest eigenvalue with respect to the influence of the upper-level index needs to be checked for consistency, and the consistency index CI is calculated, as shown in Equation (2):

$$CI = \frac{\lambda_{max}}{n - 1} \tag{2}$$

where, CI is the consistency index and n is the number of indexes.

The calculation of the consistency check discriminant CR is shown in Equation (3).

$$CR = \frac{CI}{RI} \tag{3}$$

where, CR is the consistency check discriminant, RI is the average random consistency index, and RI is only related to n. When $CR < 0.1$, it is considered that the consistency check of the judgment matrix A is qualified, and the result is credible. When $CR \geq 0.1$, the judgment matrix A needs to be adjusted until the consistency check is qualified. Finally, when the judgment matrix A has satisfactory consistency, the eigenvector W corresponding to the largest eigenvalue λ_{max} is the weight corresponding to the evaluation result, also known as the subjective weight W obtained based on AHP.

Based on AHP, the analysis of the importance of each index is more logical and more credible, but the judgment of the relative importance of each index is subjective,

which will affect the evaluation result of the index weight. The entropy method uses the size of the entropy value of the index itself to determine its weight. By determining the reliability of the data itself through the entropy weight, the weight obtained by the AHP can be corrected and the subjectivity brought by the AHP itself can be reduced. After the entropy method is introduced, the calculation of the index weight can improve the reliability of the evaluation model, so in the research of the combination of the AHP and the entropy method, we also call it the subjective and objective weighting method.

Since the contents of the indexes are not identical and are not comparable, the indexes are normalized to eliminate the influence of different dimensions. There are no negative indexes in this study, and the range is adopted to normalize the indexes, as shown in Equation (4).

$$Y_{ij} = \frac{B_{ij} - \left(B_{ij}\right)_{min}}{\left(B_j\right)\left(B_j\right)_{min_{max}}} \tag{4}$$

where, i is the evaluator number; j is the evaluation index number; Y_{ij} is the data of the i -th evaluator under the j -th evaluation index after normalization; and B_{ij} is the data of the i -th evaluator under the j -th evaluation index in the original data. $\left(B_{ij}\right)_{min}$ is the minimum value in the original evaluation data set, $\left(B_j\right)_{max}$ is the maximum value in the evaluation index of row j; and $\left(B_j\right)_{min}$ is the minimum value in the evaluation index of row j.

Since there are percentage variables in the indexes, in order to avoid the weight of 0, the indexes with a normalized value of 0 are calculated as 0.01. The proportion P_{ij} of the i -th evaluator under the j -th index is calculated, as shown in Equation (5).

$$P_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{n} Y_{ij}} \tag{5}$$

Then, the index entropy value is calculated as shown in Equation (6).

$$e_j = -\frac{1}{ln\, n} \sum_{i=1}^{m\sum_{ij}} P_{ij} ln \tag{6}$$

where, e_j is the entropy value of the j -th evaluation index and m is the number of evaluators.

Finally, the entropy weight of the index is calculated as shown in Equation (7).

$$S_j = \frac{1 - e_j}{\sum_{j=1}^{n} 1 - e_j} \tag{7}$$

where, S_j is the entropy weight of the j -th evaluation index, which can also be called the objective weight obtained based on the entropy method.

The subjective weight W calculated based on the AHP and the objective weight S_j obtained based on the entropy method are comprehensively calculated to obtain the comprehensive weight, as shown in Equation (8).

$$C_j = \frac{W_j S_j}{\sum_{j=1}^{n} W_j S_j} \tag{8}$$

where, C_j is the comprehensive weight of the j -th evaluation index; and W_j is the subjective weight of the j -th index calculated based on the AHP.

When there are many uncertain factors in the system, the fuzzy comprehensive evaluation method is often adopted for evaluation. This method is supported by fuzzy mathematical theory. The whole evaluation process will involve three key points: (1) system factor set; (2) system evaluation set; (3) system single factor evaluation set.

After the index weights in each factor set are determined, the fuzzy subsets of the weights of the factor sets can be determined according to the index weights, and then quantitatively measured by the expert scoring method. The index quantification criteria in this paper are shown in **Table 10** below.

Table 10. Index quantification criteria.

Qualitative Index Description	Quantitative Index Value
Worse	0–59
Poor	60–69
General	70–79
Good	80–89
Better	90–100

In the evaluation process, experts score each index of the evaluation object, quantify the score based on the fuzzy principle, and then obtain the evaluation set of the index according to the membership principle. Now suppose that there are five experts to score the index, one expert scores 50, the corresponding index quantification result is worse, two experts score it as poor, and two experts score it as general, then an evaluation set of this index can be obtained. Finally, a fuzzy relation matrix R is constructed for the evaluation set of each index.

The fuzzy comprehensive evaluation model is shown in Equation (9).

$$B = C \circ R \tag{9}$$

where, B is the fuzzy comprehensive evaluation value set; C is the comprehensive index weight set; R is the fuzzy relation matrix set; and $\circ$is the fuzzy operation symbol.

There are two main definitions of the fuzzy operation symbol $\circ$. The first is the main factor determination type, and the second is the weighted average type. This paper adopts the second one, which can conduct a more comprehensive evaluation than the first one.

After fuzzy operation, the final evaluation result can be obtained according to the maximum membership principle.

6. Case analysis: It is recommended to take a university as an example to evaluate online PE teaching

Regarding the weight evaluation of online PE teaching in universities during

COVID-19, five experts from the Chinese Institute of Social Sciences were found to sort and score the importance of 17 indexes. The decision matrix obtained is shown in **Table 11** below. The AHP decision matrix is obtained by experts scoring, and the credibility of experts are judged from five aspects: seniority, education, major, experience and professional title. The specific standard weights are shown in **Tables 12** and **13** below.

Table 11. Expert scoring weight table.

Consideration	**Weight** r	**Level**	**Score** s
Seniority	3	> 30	0.8
		15–30	0.6
		< 15	0.4
Education	2	PhD	0.8
		Master	0.6
		Bachelor	0.4
Major	2	PE	0.8
		Pedagogy	0.6
		Sociology	0.4
Experience	2	Experience in PE teaching	0.8
		No experience in PE teaching	0.4
Professional Title	1	Professor	0.8
		Associate Professor	0.6
		Lecturer	0.4

The equation for calculating expert credibility is as follows:

$$R = \frac{\sum_{i=1}^{5} r_i s}{\sum_{i=1}^{5} r_i} \tag{10}$$

where R represents the credibility of experts.

Table 12. Decision matrix S_1 for online PE weight evaluation based on AHP.

	Z_{111}	Z_{112}	Z_{113}	Z_{121}	Z_{122}	Z_{123}	Z_{131}	Z_{132}	Z_{141}	Z_{142}	Z_{143}	Z_{151}	Z_{152}	Z_{153}	Z_{161}	Z_{162}	Z_{163}
Z_{111}	(0.0,0.0)	(0.5,0.4)	(0.8,0.1)	(0.5,0.4)	(0.5,0.2)	(0.6,0.3)	(0.6,0.2)	(0.4,0.4)	(0.4,0.4)	(0.5,0.4)	(0.5,0.2)	(0.8,0.2)	(0.7,0.2)	(0.5,0.4)	(0.9,0.1)	(0.5,0.4)	(0.8,0.1)
Z_{112}	(0.5,0.2)	(0.0,0.0)	(0.5,0.4)	(0.7,0.3)	(0.8,0.1)	(0.4,0.4)	(0.5,0.2)	(0.6.0.4)	(0.6.0.4)	(0.5,0.2)	(0.8,0.1)	(0.7,0.2)	(0.0,0.0)	(0.5,0.2)	(0.4,0.3)	(0.5,0.2)	(0.5,0.5)
Z_{113}	(0.7,0.1)	(0.6,0.2)	(0.0,0.0)	(0.5,0.4)	(0.0,0.0)	(0.0,0.0)	(0.8,0.1)	(0.5,0.4)	(0.5,0.4)	(0.4,0.2)	(0.8,0.1)	(0.5,0.4)	(0.5,0.2)	(0.4,0.2)	(0.5,0.2)	(0.4,0.2)	(0.5,0.5)
Z_{121}	(0.5,0.4)	(0.5,0.2)	(0.5,0.4)	(0.0,0.0)	(0.8,0.2)	(0.2,0.7)	(0.8,0.1)	(0.7,0.3)	(0.7,0.3)	(0.0,0.0)	(0.4,0.4)	(0.5,0.2)	(0.9,0.1)	(0.0,0.0)	(0.8,0.1)	(0.0,0.0)	(0.0,0.0)
Z_{122}	(0.6,0.4)	(0.8,0.1)	(0.4,0.3)	(0.5,0.4)	(0.0,0.0)	(0.5,0.1)	(0.4,0.5)	(0.6,0.4)	(0.5,0.4)	(0.4,0.3)	(0.6.0.4)	(0.4,0.2)	(0.6,0.4)	(0.4,0.3)	(0.8,0.1)	(0.4,0.3)	(0.4,0.4)
Z_{123}	(0.7,0.1)	(0.8,0.1)	(0.5,0.2)	(0.4,0.3)	(0.7,0.2)	(0.0,0.0)	(0.8,0.2)	(0.8,0.2)	(0.8,0.1)	(0.6,0.2)	(0.5,0.4)	(0.0,0.0)	(0.6,0.4)	(0.7,0.3)	(0.4,0.4)	(0.6,0.2)	(0.6,0.4)

Table 12. (*Continued*).

	Z_{111}	Z_{112}	Z_{113}	Z_{121}	Z_{122}	Z_{123}	Z_{131}	Z_{132}	Z_{141}	Z_{142}	Z_{143}	Z_{151}	Z_{152}	Z_{153}	Z_{161}	Z_{162}	Z_{163}
Z_{131}	(0.3,0.4)	(0.4,0.5)	(0.8,0.1)	(0.5,0.2)	(0.6,0.4)	(0.4,0.3)	(0.0,0.0)	(0.7,0.2)	(0.5,0.5)	(0.9,0.1)	(0.7,0.3)	(0.4,0.3)	(0.6,0.2)	(0.2,0.7)	(0.6.0.4)	(0.9,0.1)	(0.5,0.4)
Z_{132}	(0.3,0.5)	(0.0,0.0)	(0.0,0.0)	(0.8,0.1)	(0.5,0.3)	(0.5,0.3)	(0.6,0.4)	(0.0,0.0)	(0.5,0.5)	(0.5,0.3)	(0.2,0.7)	(0.6,0.2)	(0.5,0.2)	(0.5,0.1)	(0.5,0.4)	(0.5,0.3)	(0.7,0.3)
Z_{141}	(0.0,0.0)	(0.7,0.2)	(0.8,0.2)	(0.0,0.0)	(0.6,0.3)	(0.7,0.1)	(0.6,0.4)	(0.5,0.4)	(0.0,0.0)	(0.8,0.1)	(0.5,0.1)	(0.9,0.1)	(0.8,0.1)	(0.6,0.4)	(0.7,0.3)	(0.8,0.1)	(0.5,0.4)
Z_{142}	(0.7,0.2)	(0.5,0.3)	(0.3,0.7)	(0.8,0.2)	(0.4,0.4)	(0.5,0.4)	(0.6,0.2)	(0.4,0.3)	(0.4,0.4)	(0.0,0.0)	(0.6,0.4)	(0.5,0.3)	(0.8,0.1)	(0.0,0.0)	(0.9,0.1)	(0.5,0.4)	(0.6,0.4)
Z_{143}	(0.6,0.3)	(0.6,0.3)	(0.7,0.3)	(0.3,0.7)	(0.0,0.0)	(0.6,0.4)	(0.5,0.2)	(0.5,0.2)	(0.6.0.4)	(0.7,0.3)	(0.0,0.0)	(0.8,0.1)	(0.4,0.5)	(0.9,0.1)	(0.4,0.3)	(0.8,0.1)	(0.7,0.1)
Z_{151}	(0.4,0.4)	(0.5,0.3)	(0.9,0.1)	(0.7,0.3)	(0.2,0.7)	(0.7,0.1)	(0.8,0.1)	(0.8,0.1)	(0.5,0.4)	(0.5,0.3)	(0.9,0.1)	(0.0,0.0)	(0.5,0.4)	(0.5,0.3)	(0.5,0.2)	(0.5,0.5)	(0.3,0.7)
Z_{152}	(0.0,0.0)	(0.7,0.1)	(0.6,0.4)	(0.9,0.1)	(0.5,0.1)	(0.3,0.4)	(0.8,0.1)	(0.0,0.0)	(0.7,0.3)	(0.5,0.4)	(0.5,0.3)	(0.0,0.0)	(0.6,0.4)	(0.8,0.1)	(0.8,0.1)	(0.5,0.5)	(0.7,0.3)
Z_{153}	(0.2,0.7)	(0.5,0.4)	(0.7,0.1)	(0.5,0.4)	(0.6,0.4)	(0.3,0.5)	(0.4,0.5)	(0.8,0.2)	(0.5,0.4)	(0.6,0.4)	(0.8,0.1)	(0.8,0.2)	(0.5,0.4)	(0.4,0.3)	(0.8,0.1)	(0.0,0.0)	(0.9,0.1)
Z_{161}	(0.5,0.1)	(0.6,0.4)	(0.3,0.4)	(0.4,0.3)	(0.6,0.3)	(0.0,0.0)	(0.5,0.4)	(0.3,0.7)	(0.6,0.4)	(0.7,0.1)	(0.4,0.3)	(0.3,0.7)	(0.6,0.4)	(0.5,0.2)	(0.0,0.0)	(0.6,0.4)	(0.8,0.2)
Z_{162}	(0.6,0.4)	(0.7,0.1)	(0.3,0.5)	(0.5,0.2)	(0.5,0.4)	(0.7,0.2)	(0.6,0.4)	(0.7,0.3)	(0.7,0.1)	(0.3,0.4)	(0.5,0.2)	(0.7,0.3)	(0.6,0.4)	(0.8,0.2)	(0.5,0.4)	(0.0,0.0)	(0.7,0.2)
Z_{163}	(0.9,0.1)	(0.3,0.4)	(0.0,0.0)	(0.8,0.1)	(0.2,0.6)	(0.6,0.4)	(0.5,0.4)	(0.9,0.1)	(0.3,0.4)	(0.8,0.2)	(0.8,0.2)	(0.9,0.1)	(0.3,0.4)	(0.7,0.3)	(0.6,0.4)	(0.6,0.4)	(0.0,0.0)

Table 13. Decision matrix S_2 for online PE weight evaluation based on entropy method.

	Z_{111}	Z_{112}	Z_{113}	Z_{121}	Z_{122}	Z_{123}	Z_{131}	Z_{132}	Z_{141}	Z_{142}	Z_{143}	Z_{151}	Z_{152}	Z_{153}	Z_{161}	Z_{162}	Z_{163}
Z_{111}	(0.5,0.5)	(0.8,0.1)	(0.0,0.0)	(0.0,0.0)	(0.7,0.3)	(0.6,0.4)	(0.6,0.4)	(0.6.0.4)	(0.4,0.2)	(0.7,0.2)	(0.6,0.2)	(0.7,0.3)	(0.8,0.1)	(0.5,0.4)	(0.6,0.4)	(0.4,0.3)	(0.5,0.4)
Z_{112}	(0.0,0.0)	(0.8,0.1)	(0.4,0.3)	(0.4,0.3)	(0.2,0.7)	(0.8,0.2)	(0.6,0.4)	(0.5,0.4)	(0.0,0.0)	(0.0,0.0)	(0.5,0.2)	(0.9,0.1)	(0.4,0.4)	(0.5,0.2)	(0.7,0.2)	(0.6,0.2)	(0.5,0.2)
Z_{113}	(0.4,0.4)	(0.4,0.5)	(0.6,0.2)	(0.6,0.2)	(0.5,0.1)	(0.7,0.2)	(0.6,0.2)	(0.7,0.3)	(0.4,0.3)	(0.5,0.2)	(0.8,0.1)	(0.8,0.2)	(0.6.0.4)	(0.4,0.2)	(0.8,0.2)	(0.9,0.1)	(0.4,0.2)
Z_{121}	(0.6,0.4)	(0.8,0.2)	(0.9,0.1)	(0.9,0.1)	(0.6,0.4)	(0.0,0.0)	(0.5,0.2)	(0.9,0.1)	(0.6,0.2)	(0.9,0.1)	(0.8,0.1)	(0.7,0.2)	(0.5,0.4)	(0.0,0.0)	(0.7,0.1)	(0.5,0.3)	(0.0,0.0)
Z_{122}	(0.5,0.4)	(0.0,0.0)	(0.5,0.3)	(0.5,0.3)	(0.0,0.0)	(0.5,0.4)	(0.8,0.1)	(0.4,0.3)	(0.9,0.1)	(0.4,0.3)	(0.7,0.3)	(0.0,0.0)	(0.7,0.3)	(0.4,0.3)	(0.7,0.3)	(0.8,0.1)	(0.4,0.3)
Z_{123}	(0.7,0.3)	(0.6,0.4)	(0.8,0.1)	(0.8,0.1)	(0.9,0.1)	(0.4,0.3)	(0.8,0.1)	(0.5,0.2)	(0.5,0.3)	(0.5,0.2)	(0.2,0.7)	(0.0,0.0)	(0.9,0.1)	(0.6,0.2)	(0.0,0.0)	(0.0,0.0)	(0.6,0.2)
Z_{131}	(0.5,0.4)	(0.6,0.4)	(0.7,0.3)	(0.0,0.0)	(0.5,0.3)	(0.5,0.2)	(0.4,0.5)	(0.8,0.1)	(0.8,0.1)	(0.7,0.2)	(0.5,0.1)	(0.7,0.2)	(0.4,0.3)	(0.9,0.1)	(0.5,0.4)	(0.0,0.0)	(0.9,0.1)
Z_{132}	(0.6,0.4)	(0.6,0.2)	(0.5,0.4)	(0.7,0.3)	(0.8,0.1)	(0.8,0.1)	(0.5,0.4)	(0.8,0.1)	(0.0,0.0)	(0.6,0.4)	(0.6,0.4)	(0.6,0.4)	(0.5,0.2)	(0.5,0.3)	(0.6,0.4)	(0.8,0.2)	(0.5,0.3)
Z_{141}	(0.7,0.1)	(0.5,0.2)	(0.8,0.1)	(0.5,0.3)	(0.4,0.3)	(0.0,0.0)	(0.6,0.4)	(0.0,0.0)	(0.7,0.3)	(0.7,0.2)	(0.0,0.0)	(0.9,0.1)	(0.8,0.1)	(0.8,0.1)	(0.7,0.1)	(0.3,0.7)	(0.8,0.1)
Z_{142}	(0.3,0.4)	(0.8,0.1)	(0.5,0.5)	(0.5,0.4)	(0.5,0.2)	(0.5,0.2)	(0.5,0.4)	(0.5,0.4)	(0.5,0.3)	(0.8,0.2)	(0.9,0.1)	(0.5,0.3)	(0.8,0.1)	(0.9,0.1)	(0.3,0.4)	(0.7,0.3)	(0.0,0.0)
Z_{143}	(0.6,0.3)	(0.8,0.1)	(0.5,0.5)	(0.6,0.4)	(0.8,0.2)	(0.8,0.2)	(0.5,0.2)	(0.5,0.2)	(0.5,0.4)	(0.7,0.1)	(0.5,0.3)	(0.5,0.4)	(0.0,0.0)	(0.4,0.3)	(0.4,0.3)	(0.9,0.1)	(0.8,0.2)
Z_{151}	(0.4,0.4)	(0.4,0.5)	(0.0,0.0)	(0.7,0.1)	(0.2,0.7)	(0.8,0.2)	(0.8,0.1)	(0.8,0.1)	(0.5,0.2)	(0.7,0.3)	(0.8,0.1)	(0.4,0.3)	(0.5,0.4)	(0.5,0.2)	(0.5,0.2)	(0.5,0.5)	(0.3,0.7)

Table 13. (*Continued*).

	Z_{111}	Z_{112}	Z_{113}	Z_{121}	Z_{122}	Z_{123}	Z_{131}	Z_{132}	Z_{141}	Z_{142}	Z_{143}	Z_{151}	Z_{152}	Z_{153}	Z_{161}	Z_{162}	Z_{163}
Z_{152}	(0.0,0.0)	(0.0,0.0)	(0.4,0.4)	(0.3,0.4)	(0.5,0.1)	(0.7,0.2)	(0.8,0.1)	(0.0,0.0)	(0.8,0.2)	(0.0,0.0)	(0.4,0.3)	(0.5,0.2)	(0.6,0.4)	(0.8,0.1)	(0.8,0.1)	(0.5,0.5)	(0.7,0.3)
Z_{153}	(0.2,0.7)	(0.5,0.3)	(0.6.0.4)	(0.5,0.4)	(0.6,0.4)	(0.0,0.0)	(0.4,0.5)	(0.8,0.2)	(0.5,0.4)	(0.6,0.4)	(0.5,0.2)	(0.8,0.1)	(0.5,0.4)	(0.0,0.0)	(0.8,0.1)	(0.0,0.0)	(0.9,0.1)
Z_{161}	(0.5,0.1)	(0.5,0.4)	(0.5,0.4)	(0.4,0.3)	(0.6,0.3)	(0.0,0.0)	(0.5,0.4)	(0.3,0.7)	(0.6,0.4)	(0.7,0.1)	(0.8,0.2)	(0.0,0.0)	(0.6,0.4)	(0.9,0.1)	(0.0,0.0)	(0.6,0.4)	(0.8,0.2)
Z_{162}	(0.6,0.4)	(0.6,0.4)	(0.7,0.3)	(0.5,0.2)	(0.5,0.4)	(0.7,0.2)	(0.6,0.4)	(0.7,0.3)	(0.7,0.1)	(0.3,0.4)	(0.7,0.3)	(0.8,0.2)	(0.7,0.1)	(0.5,0.3)	(0.5,0.4)	(0.0,0.0)	(0.7,0.2)
Z_{163}	(0.9,0.1)	(0.7,0.1)	(0.5,0.4)	(0.8,0.1)	(0.2,0.6)	(0.6,0.4)	(0.5,0.4)	(0.9,0.1)	(0.3,0.4)	(0.8,0.2)	(0.8,0.2)	(0.3,0.7)	(0.3,0.4)	(0.8,0.1)	(0.6,0.4)	(0.6,0.4)	(0.0,0.0)

According to Equations (1)–(9), the index importance of the online PE weight obtained from the matrix S_1 and S_2 can be used to calculate the real matrix $D = (D_{ij})_{m\times n}$:

$$\mathrm{D} = \begin{Bmatrix} 0.735 & 1.226 & 0.986 & 1.234 & 1.098 & 1.657 & 1.546 & 1.786 & 2.567 \\ 1.268 & 1.124 & 0.345 & 1.267 & 1.121 & 0.678 & 1.789 & 1.567 & 2.675 \\ 0.642 & 1.198 & 0.657 & 1.789 & 0.567 & 1.106 & 2.234 & 1.235 & 0.999 \\ 1.688 & 3.068 & 0.953 & 1.902 & 0.679 & 1.204 & 2.567 & 0.694 & 1.567 \\ 0.992 & 0.998 & 0.486 & 1.923 & 1.235 & 2.222 & 2.765 & 1.689 & 1.643 \\ 0.235 & 3.556 & 2.456 & 1.231 & 1.953 & 2.395 & 2.103 & 0.694 & 1.567 \\ 2.456 & 2.454 & 1.245 & 2.456 & 2.067 & 2.432 & 2.041 & 1.694 & 1.754 \\ 0.981 & 0.567 & 1.654 & 0.567 & 0.694 & 1.029 & 0.776 & 0.875 & 0.979 \\ 2.565 & 0.465 & 1.903 & 0.668 & 2.456 & 0.532 & 0.909 & 0.532 & 1.234 \end{Bmatrix}.$$

Combined with the weight calculation equation in Equation (11), the ranking results of the index importance of the teaching weight can be calculated as follows:

$$M = [Z_{111}, Z_{112}, Z_{113}, Z_{121}, Z_{122}, Z_{123}, Z_{131}Z_{132}, Z_{141}, Z_{142}, Z_{143}, Z_{151}, Z_{152}, Z_{153}, Z_{161}, Z_{162}, Z_{163}]$$
$$= [1.265,1.064,1.243,1.217,1.098,1.198,1.345,1.146,1.143,1.156,1.785,1.423,0.985,1.324,1.306,1.257,1.224] \quad (11)$$

7. Countermeasures and suggestions

From the conclusions of the sixth part of this study, it can be seen that the index weights of online PE teaching quality evaluation during COVID-19 are ranked as follows: the first is teaching research and reform, the second is educational knowledge, the third is professional emotion, the fourth is IT knowledge, the fifth is students' learning motivation, the sixth is teacher affinity, the seventh is students' learning target, the eighth is teachers' listening ability, the ninth is students' learning habits in online classes, the tenth is integration ability for IT and curriculum, the eleventh is teachers' network resource utilization and development capabilities, the twelfth is teaching implementation, the thirteenth is teachers' career pursuit, the fourteenth is teaching design, the fifteenth is teachers' ability to use IT tools, the sixteenth is teachers' communicate skills, and the seventeenth is teachers' PE subject knowledge. Therefore, in order to improve the quality of online PE teaching during COVID-19, from the perspective of teachers, attention should be paid to the difference from the original offline teaching mode. The form and content of PE teaching need further

research and reform, and the online PE teachers must have a wealth of educational knowledge, including IT knowledge, etc. It is also very important to pay attention to the cultivation of teachers' professional emotions. From the perspective of students, the key factor is to cultivate students to establish a perfect learning goal, clarify their learning motivation, and develop good online learning habits. Specifically, the countermeasures for online PE teaching during COVID-19 are as follows:

(1) Make targeted teaching plan, improve teaching content, and adjust online teaching time reasonably

To cultivate students' enthusiasm for sports activities and form a lifelong sports awareness, online PE teaching should fully consider the richness of content. Considering the actual situation of freshmen and sophomores, students can be guided to carry out diversified exercises at home during the epidemic. In the future, teachers should also be encouraged to discover the practice tips for each project under space constraints, so that when conducting online teaching, according to the specific situation of online sports teaching, teachers can choose the content of sports practice and set up unique learning and practice methods for each project. Of course, when choosing the content of online PE teaching, more consideration should be given to the venue, students' abilities, etc. Teachers should give full play to the resources of students, reasonably determine the content, and ensure the effectiveness of the whole activity.

(2) Optimize the teaching live broadcast platform to provide hardware guarantee for teaching

Relying on the online interactive live broadcast platform, the technical support system is the lifeline. It is very necessary to have a professional network technical support team. Engineers need to pay close attention to network conditions and user opinions, solve various problems in time, and ensure the normal progress of live courses. In terms of technical details, continuous improvement is required to enhance the convenience and applicability of the interaction between the platform and users. We should develop new technologies continuously to achieve more powerful functional support, expand interactive functions, and improve user experience and satisfaction.

(3) Carry out IT training for PE teachers to improve their' information literacy

Combined with the assessment results of PE teachers' IT application ability, training programs are implemented in a targeted manner. Training courses are formulated to strengthen weak abilities, so as to achieve the optimal training results. First of all, from the analysis results, it can be seen that the overall ability of teachers to apply IT to teaching methods is slightly poor. Therefore, when developing the training system, the breadth and intensity of training in this area should be strengthened. Secondly, different provinces and cities can adjust training content and courses according to local conditions. The ability with a lower compliance rate can arrange more training content and courses, and the ability with a higher compliance rate can appropriately delete the training content. We should improve weak abilities, so as to achieve balanced development of the abilities of teachers in the same province and city, and at the same time narrow the gap between teachers' IT application abilities in different provinces and cities.

(4) Improve the online teaching evaluation and supervision system and enhance

the quality of online PE teaching

Effective supervision and feedback are implemented in the teaching process. The purpose of teaching is to support student learning. PE not only imparts movement skills and concepts, but also equips students with knowledge and principles related to sports. We should improve the supervision mechanism to ensure the quality of teaching. For online teaching, the supervision teams at the school and college levels should carry out online supervision work normally. They should be familiar with the online teaching process of teachers and go deep into the platform and classroom. They should also supervise, evaluate and guide teachers' online teaching work, sort out and guide the problems between teachers and students in the process of online teaching and learning, ensure the quality of online teaching, and realize the smooth operation of online teaching.

8. Conclusion and discussion

In this paper, we delve into the challenges of online Physical Education (PE) teaching in universities during the COVID-19 pandemic, with a particular focus on the situation in China. We conducted a status survey, evaluated the teaching quality weights, and proposed strategies for online teaching. Our study has led to the following conclusions:

8.1. Current status and analysis

By reviewing international and domestic research on online PE teaching, teaching quality evaluation, and teaching status during the pandemic, we analyzed the current state of online PE teaching in China. Our study investigated seven key areas, including the attitudes of teachers and students towards PE teaching, the implementation process of online PE classes, teaching content and duration, teacher-student interaction and classroom atmosphere, and student attendance. This comprehensive analysis has provided a solid foundation and valuable background data for our core research on the quality evaluation of online PE teaching.

8.2. Methodology for teaching quality improvement

To enhance the quality of online PE teaching, we introduced a hybrid weighting method that combines subjective and objective elements based on the AHP-entropy method. This approach corrects for the deviation caused by the differences between subjective and objective evaluations and integrates the fuzzy comprehensive evaluation method to calculate the weights of online PE indices. Utilizing this method, we derived ranking results from the 17 constructed online PE indices, revealing that teaching research and reform, educational knowledge, teachers' professional passion, and IT proficiency are critical factors in the analysis of PE teaching quality.

8.3. Conclusions and recommendations

Based on the conclusions of this paper, we provided specific recommendations and implementation plans for improving the quality of online PE teaching during COVID-19 from both a subjective research perspective and a macro-policy standpoint. Our findings can assist Chinese universities in developing relevant online teaching

policies and offer a reference for the quality evaluation of online teaching in international universities. Due to COVID-19 situation, many researchers have focused on its related research in recent years, especially on some management issues of government and its influence on education [24,25]. For future works, we will also focus on this field and would like to pay more attention to the novel form of education under COVID-19. For this study, more comparative analysis with other state-of-the-art works needs to be added to prove the rationality and effectiveness of the proposed method in the future. In addition, more practical datasets could be added to this study to verify the performance.

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