J. COMBIN. MATH. COMBIN. COMPUT. 127b (2025) 1215--1233

Journal of Combinatorial Mathematics and Combinatorial Computing
www.combinatorialpress.com/jcmcc

Combinatorial Press

A Multimedia Technology-Driven Vocal Music Teaching System Architecture and Effectiveness Assessment Model Based on Fuzzy Comprehensive Evaluation

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ABSTRACT

This paper proposes a vocal music teaching system architecture integrating multimedia technology, aiming to enhance the intuitiveness, interactivity and personalization of vocal music teaching through technical means. The system is equipped with virtual reality and voice interaction technologies to realize the digital presentation of the functional modules of the architecture. In addition, in order to evaluate the teaching effectiveness of the system, a number of evaluation indicators are designed. The fuzzy comprehensive evaluation algorithm is used as the main method, supplemented by hierarchical analysis method, to comprehensively evaluate the teaching effectiveness. Multimedia technology can improve students' vocal ability and mastery of theoretical knowledge, in which the vocal ability is improved by 5.98% to 10.48% compared with the control class, and at the same time, there is a promotion effect on students' positive interest in vocal learning. The students' recognition of the system in terms of technology application, learning interaction experience, learning content and process, and teaching effect ranged from 4.077 to 4.608, with a high degree of recognition. The experts' comprehensive evaluation of the classroom effectiveness of vocal music teaching under the system of this paper is 93.437, which is highly satisfactory. This study not only provides new technical support for vocal music teaching, but also provides a scientific assessment method for teaching evaluation, which is of great significance to improve the level of vocal music teaching.

Keywords: multimedia technology, fuzzy comprehensive evaluation, hierarchical analysis, system architecture, vocal music teaching

1. Introduction

In the information age, the disadvantages of the traditional vocal music teaching mode gradually appear, resulting in the quality of higher vocational vocal music teaching is affected, in order to solve this problem, higher vocational colleges and universities use modern educational technology to reform

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Received 05 August 2024; Revised 20 October 2024; Accepted 15 February 2025; Published Online 16 April 2025.
DOI: 10.61091/jcmcc127b-067

the vocal music teaching mode, in order to improve the quality of higher vocational vocal music teaching [1-3]. Multimedia technology is a product of the development of the information age, and its application in vocals teaching can not only improve the quality of vocals teaching, but also support the development of vocals teaching with the help of Internet resources, searching for teaching-related educational resources through the Internet, providing resource support and technical support for the development of classroom teaching [4-6]. The development of higher vocational vocal music teaching requires a large number of material resources to provide support for classroom teaching, if the traditional teaching mode, teachers need to do a good job in advance of the teaching design, and the required material content into the teaching design [7-9]. However, there is variability in the vocal music teaching classroom, when students have a need to understand a certain knowledge content in vocal music teaching, and the relevant materials are not reflected in the teaching design, it will lead to the development of the course of low-quality and ineffective [10-11]. Therefore, it is necessary to effectively construct the teaching mode of organic combination of multimedia technology and higher vocational vocal music teaching, so as to play the value of the application of multimedia technology [12-13].

On the other hand, the application of multimedia computer technology means to assist the basic skills training in vocal music teaching, the development of this kind of music application system to assist teaching, not only has the potential to provide students with a certain feedback, detection function of the basic skills of self-study opportunities, but also can be relatively objective and accurate assessment of the basic training content of the students' singing learning, thus making it possible for the teacher to pay more attention to the students' artistic aspects of singing [14-16]. Teachers can make general assessments based on student feedback. Students and teachers can communicate with each other in a timely manner through online teaching [17-18].

The article clarifies the development prospect of multimedia technology in vocal music teaching from the perspective of appreciation, singing, score reading and instrumental music teaching. A multimedia technology-driven vocal music teaching system architecture is realized based on virtual reality and voice interaction and other multimedia technologies. The system develops functions such as voice interaction, vocal course design, online vocal practice, etc., to assist the diversified presentation of teaching content and real-time feedback of teaching effect. In terms of the teaching effectiveness evaluation model, the article builds an evaluation index system and adopts a fuzzy comprehensive evaluation method, which can deal with the uncertainty in the evaluation process and make the evaluation results more scientific and accurate.

2. Exploration of the application of multimedia technology in vocal music teaching

2.1. Multimedia teaching

Multimedia technology [19] is a kind of technology and method that enables users to interactively represent a variety of information such as text, graphics, images, audio, animation and video in separate or synthesized forms after specific software and hardware acquisition, production, editing and storage processes.

Multimedia includes a new educational media formed by a large amount of visual and auditory information, which, like traditional teaching methods, can greatly broaden the horizons of teachers and students, and has great attraction to both teachers and students. In the use of multimedia learning can cultivate learners' creativity and imagination, expand the depth of learning, in the use of multimedia learning, students can use listening and watching to really feel the content of learning, which is the teacher's description of the language can not be compared.

2.2. Specific applications

2.2.1. Teaching appreciation. The ability to perceive and appreciate vocal works is the main content of vocal classroom teaching, the use of multimedia teaching tools to hear, observe, experiment and other aspects of the close together, bringing learners a real teaching situation, the knowledge of fun. Vocal music appreciation class in the traditional teaching process requires more teaching aids, and the use of multimedia can be effectively combined with the required vocal clips and video clips, cut out the parts that need to be taught into the library, the computer can be adjusted according to the teacher or the student's needs of the speed of the song, the style and so on.

2.2.2. Teaching singing. Singing is the most practical and fundamental part of vocal music teaching. In the introductory part before the beginning of the classroom, the use of multimedia for the introduction of new songs, multimedia technology can make good use of the computer to simulate the accompaniment, in the need for model singing, can be adjusted in advance to model the audio and accompaniment software, so as to carry out the voice, very expressive model singing, for the students to bring the charm of the singing. In the song melody teaching, the use of multimedia for the rationalization of knowledge, interesting teaching, can largely change the traditional boring teaching methods, so that the boring and abstract teaching more lively and interesting. In the process of sight-singing and ear training, the teacher can first embed the vocal score into the multimedia, the teacher can put the slow accompaniment vocal or model singing vocal into the score, in the vocal accompaniment, the teacher can guide the students to slow sight-singing, during this period, the teacher can guide, guide or correct the students, in addition to the students according to the actual situation of the tutelage respectively.

2.2.3. Teaching music recognition. Teachers can use multimedia to rationally design courseware, active classroom atmosphere for students to play some of the skills and methods of reading music teaching video for students to watch, so that students will be straightforward to understand the knowledge about reading music. Teachers can teach through the multimedia will need to teach the relevant content of the literacy spectrum, the important and difficult to produce a small animation of the vaguely visible, which need to focus on the content of the use of pictures, sound media form inserted into it, so that the production of the courseware sound and emotion, easier for students to accept. In the process of students in the learning process, teachers need to stimulate the desire of students to learn vocal music, to help students master and understand the knowledge they have learned.

2.2.4. Instrumental music instruction. Multimedia is characterized by the synthesis of text, image and sound. It has similar immediacy and can easily stimulate students' interest in learning musical instruments. In the process of teaching, it should be combined with image materials, especially those with the characteristics of sharp contrast and intuition, to set up a relaxing and pleasant learning environment, so as to make the beginners of instrumental music slowly improve the feeling of vocal music, and to eliminate the inferiority complex of the beginners in the initial learning process. In the process of learning instrumental music, teachers should play the background knowledge and video about the relevant instruments at the beginning of teaching, using text, images, video, sound and other media materials to let students understand the background of the instrument, to increase students' interest in learning, and to cultivate students' motivation to learn the instrument.

3. Design of the system architecture for teaching vocal music

In response to the demand analysis, this paper combines the features of virtual reality [20] and intelligent voice interaction [21] in multimedia technology, and develops the architecture of vocal music teaching system based on multimedia technology. The overall system architecture is shown in Figure 1.

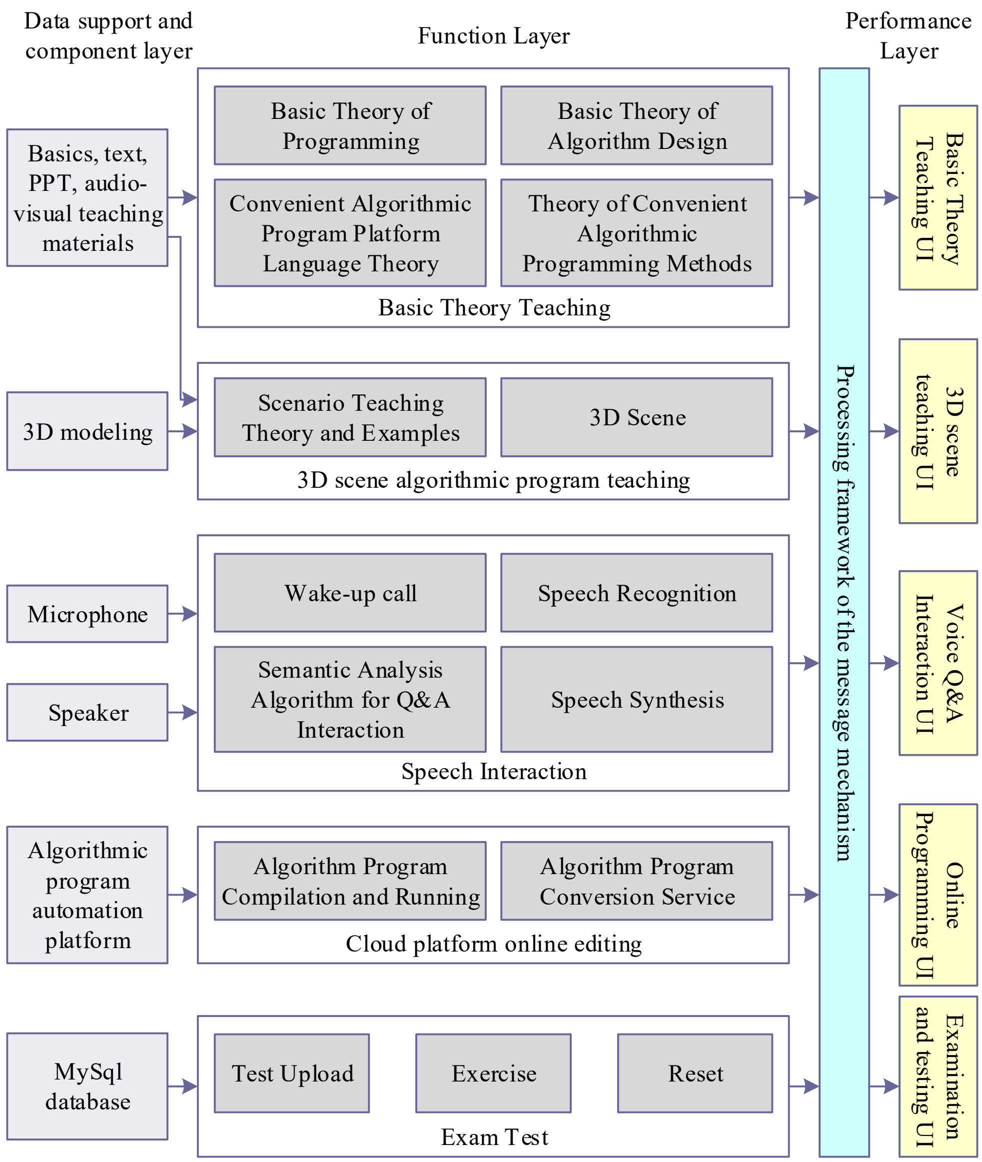

Fig. 1. The overall framework of the multimedia teaching system

1) Expression layer: the interaction layer between users and PC terminals, which is used to display the teaching content and expression of the system, and the users can call the overall functions of the system through this layer.
2) Function layer: the core function module of the system, which plays the role of carrying on the top and starting the bottom, receives requests and commands to the upper layer, calls data and saves to the lower layer, and the module itself completes the corresponding function execution.
3) Data Support and Component Layer: the underlying data and component support of the system, including the basic knowledge materials used in vocal music teaching, the three-dimensional model of vocal music scene teaching, and the MySql database used in the assessment test and login and registration.

3.1. *System functions*

Figure 2 shows the functional module structure of the vocal teaching system. In this section, the design of each module is explained in detail.

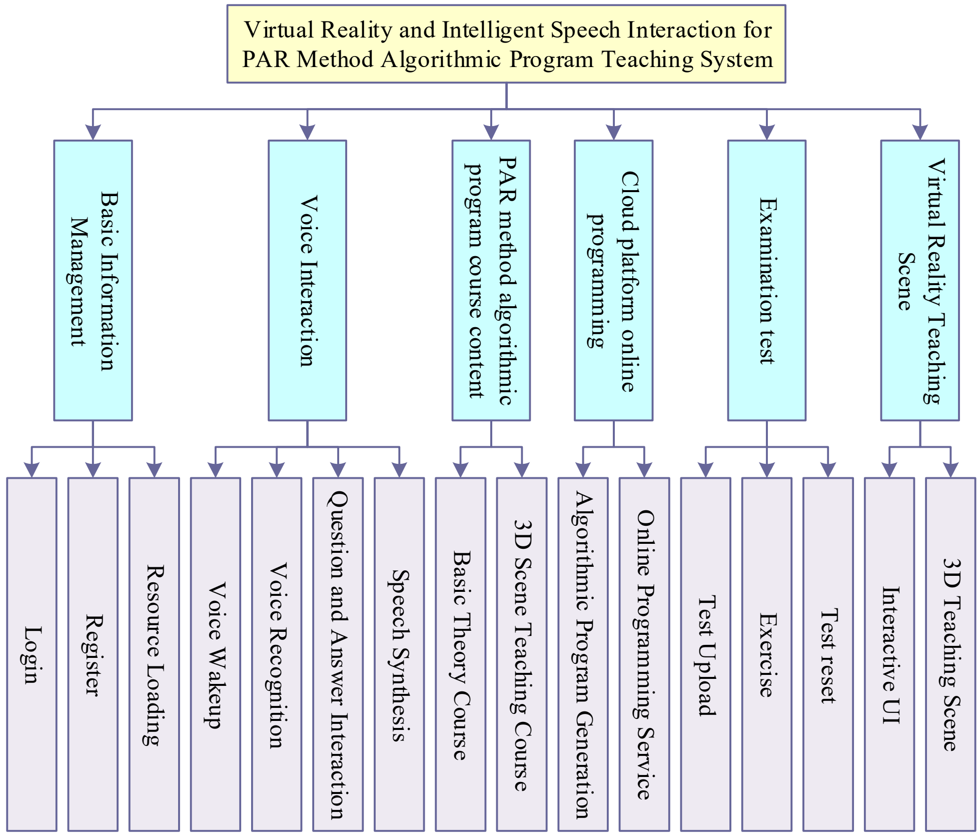

Fig. 2. Multimedia teaching system function structure

3.1.1. Basic information management module. This module serves as the entrance to the teaching system and contains user login, registration, and loading of teaching resources. Users can get the right to use the system only through login.

Login function: Users need to enter their account password, the system determines whether the account information exists in the database and loads the corresponding teaching resources for the users.

Registration function: Fill in the account password, the system detects whether the account information exists or not, if not, the data will be saved in the database.

Resource loading: When users enter the system, they need to load the corresponding teaching resources, such as teaching scenes, multimedia videos, animations, texts, etc. A 0%-100% loading progress bar will be constructed for display.

3.1.2. Voice interaction module. Voice Interaction Module is to act as a virtual learning assistant, realizing human-machine voice Q&A interaction, providing users with real-time knowledge Q&A in the field of vocal music, and improving the Q&A interactivity of the teaching system.

A set of lightweight intelligent voice interaction service module is designed by adopting the dynamic maximum matching algorithm based on the dictionary improvement, combined with the Xunfei AIUI engine. Including voice wake-up, voice recognition, Q&A interaction, voice synthesis, etc., of which Q&A interaction is the core.

3.1.3. Vocal program. This system combines intelligent voice interaction, online vocal music and assessment test to build and complete the whole virtual reality vocal music teaching system. Under the environment of virtual reality system, it provides immersive vocal course learning, three-dimensionalization of the vocal teaching environment, and real-time voice Q&A, which makes it easier for users to devote themselves to the process of vocal course learning, and enhances the degree of users' interest in learning, as well as human-computer interaction, in order to achieve better teaching results.

3.1.4. Online Vocal Exercises on Cloud Platforms. Cloud platform online vocal practice module mainly plays a role in singing practice after vocal teaching. The core functions of the whole module include real-time pitch detection, range expansion, customized practice plans, personalized experience and so on.

3.1.5. Appraisal test module. The assessment and testing module, as the last part of the teaching process, can well test and evaluate the learning mastery effect of the user, reflecting the weakness of the user's knowledge in a timely manner, and checking the leakage and making up for the deficiencies. Core design requirements:
1) Provide test questions to test the learning effect.
2) Judge the answers submitted by users, calculate the correct rate, and save them in the database.
3) Administrators can upload test questions, and reset and clear test questions.
4) Users can view the results of the test, the answer process can also view the answer prompts.

3.1.6. VR Interactive Side UI and Scenery. The display of UI modules in the Unity3D platform is designed to improve the operational interactivity of the system, allowing users to learn both basic theoretical knowledge and immersive learning through 3D scenes.

3D models (e.g., multimedia blackboards, 3D showcases, characters) are created in 3dsMax software. Development of the scene of the virtual reality algorithmic program teaching system in Unity3D. The creation of the scene covers the following three main steps:

Step 1: Solid model creation.

Step 2: Texture mapping of the model.

Step 3: Model integration.

3.2. System database design

Due to the difference between this multimedia teaching system and the traditional system, most of the teaching resources and model data information will be built in the system, only a small part of the information needs to be stored in the database, so this section will be the design of the database E-R diagram for this part.

For the user login and registration as well as the assessment and testing module business process, the correlation between the data entities is analyzed. Figure 3 shows the E-R relationship between the user and the system. Among them, the user information entity can choose different test questions, and each test question entity is associated with multiple specific question entities, and the evaluation results entity is associated with the user entity and the test question entity, and there are multiple results for different users.

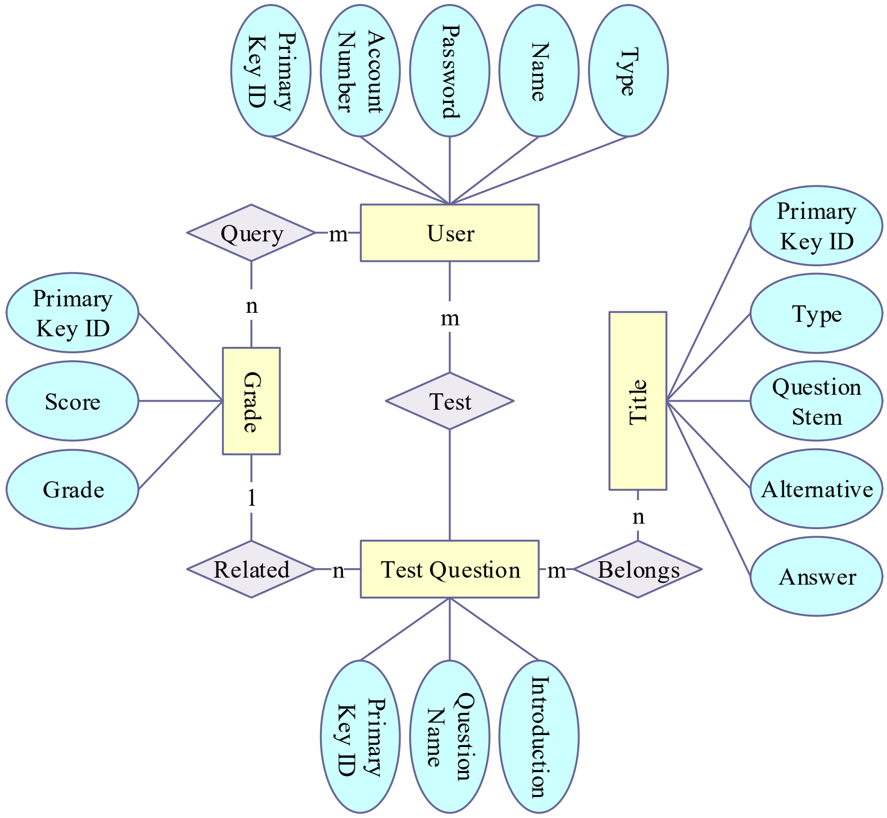

Fig. 3. User and system E-R relations

3.3. Analysis of effectiveness based on teaching experiments

3.3.1. Effectiveness of teaching vocal ability and theory. In this section of the experiment, two classes in the vocal arts program of the class of 2023 in an art college were selected for the study. The control class and the experimental class both consisted of 50 students, and were taught by the same vocal teacher using the traditional vocal music teaching mode as well as the multimedia technology-driven teaching mode, respectively. Prior to the teaching experiment, students in both classes were given the same pre-test to ensure that there were no significant differences in vocal level (appreciation, singing, score reading, instrumental music, in order of vocal ability 1-4) and theoretical scores between the two groups of students, so as to ensure that the results of the experiment were comparable. The experimental period was from September to December 2023, a total of 12 weeks, with a total of 4 vocal lessons per week.

Table 1 shows the significant tests of the test results of each index in the two classes. Figures 4 and 5 show the statistical results before and after the experiment of vocal ability as well as theory scores of the students in the two classes, respectively. Combined with the charts, the average level of students in the experimental class and the control class in each vocal ability as well as theoretical knowledge before the experiment is basically the same, and the P-value is in the range of 0.602~0.789, which is greater than 0.05. This indicates that there is no significant difference between the experimental class and the control class in basic vocal ability as well as theoretical test. In contrast, after the experiment, there were different degrees of gaps between the two classes in each vocal ability as well as theoretical knowledge, and the average scores of the tests of the students in the experimental class were higher than those of the control class. Specifically, the average vocal ability test of the students in the experimental class is 5.98%~10.48% higher than that of the students in the control class, while the difference in theory scores between the two classes is 6.56 points, and the p-value of each index is less than 0.05. It means that after the experiment, the experimental group and the control group have a significant difference in vocal ability as well as theoretical knowledge. Lateral verification of the application of multimedia technology significantly improve the efficiency and quality of vocal music teaching.

Table 1. Significant inspection of the results of each index of the two classes

	Class	Appreciate	Sing	Spectral spectrum	Musical instrument	Theory
Pre	CK(Mean)	66.64	70.2	75.56	64.76	80.44
	T(Mean)	67.04	70.4	76.2	64.98	80.92
	P value	0.602	0.652	0.724	0.746	0.789
Post	CK(Mean)	68.26	73.96	77.62	67.58	83.18
	T(Mean)	72.76	79.92	82.26	74.66	89.74
	P value	0.025	0.037	0.022	0.031	0.011

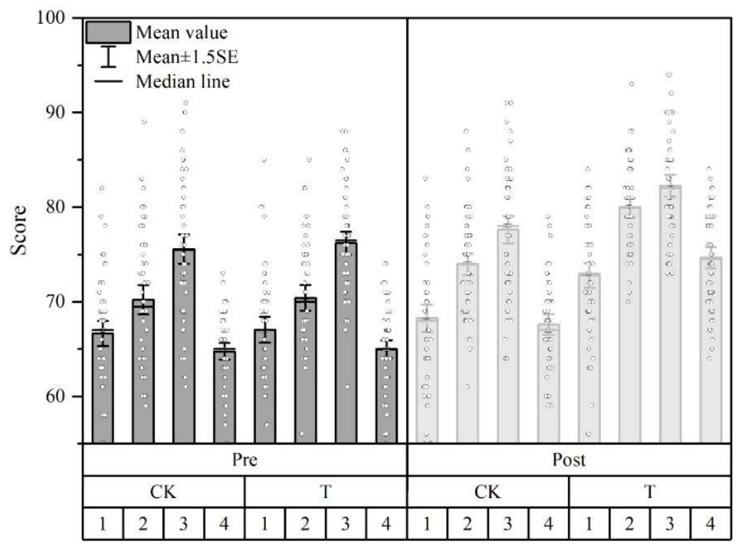

Fig. 4. The students' ability to test the vocal ability of the students

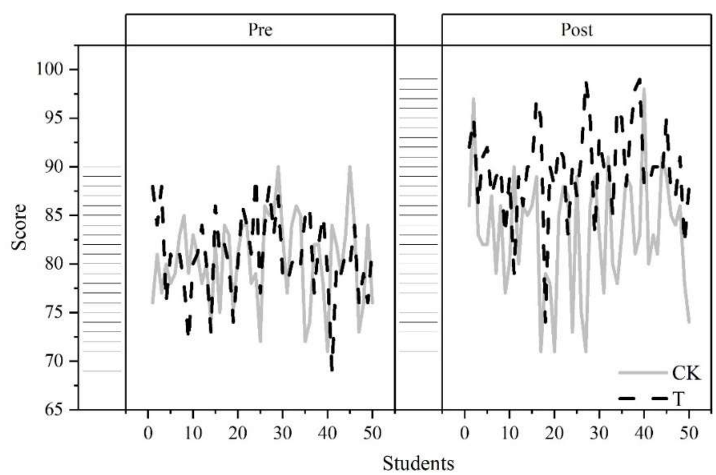

Fig. 5. The students' theoretical knowledge test results

3.3.2. Comparative analysis of learning interest before and after the experiment. In a large number of surveys and experimental studies, it has been found that students' interest in exercise is positively correlated with the learning effect of vocal music. In this study, a questionnaire was administered to the students in the experimental class before and after the experiment to investigate the extent to which the system of this paper had an impact on the students' teaching and learning in vocal music. Again, the questionnaire utilized the 5-point scale described above for the quantitative evaluation of students' remaining learning interest.

Figure 6 shows the data statistics of students' vocal learning interest indexes before and after the experiment in the experimental class. As can be seen from the figure, in the negative interest indexes, the mean value of the experimental group before the experiment is 3.01, and the mean value of the experimental group after the experiment is 2.05, and the experimental group's negative interest in the post-experimental period is significantly lower than that in the pre-experimental period. In the index of positive interest, the mean value of the experimental group before the experiment is 2.98, and the mean value of the experimental group after the experiment is 4.04. In the index of vocal attention and vocal practice, the mean value of the experimental group after the experiment is also improved, and the difference between before and after the experiment is 1.12, and 1.22, respectively. it can be seen that in the three indexes, namely, positive interest, vocal attention, and vocal practice, the interest of the experimental group in vocal learning after the experiment is significantly higher than that before the experiment, which indicates that the introduction of multimedia technology in vocal teaching can be a good way to improve the interest of vocal learning after the experiment. The introduction of multimedia technology in vocal music teaching can significantly improve students' interest in learning vocal music.

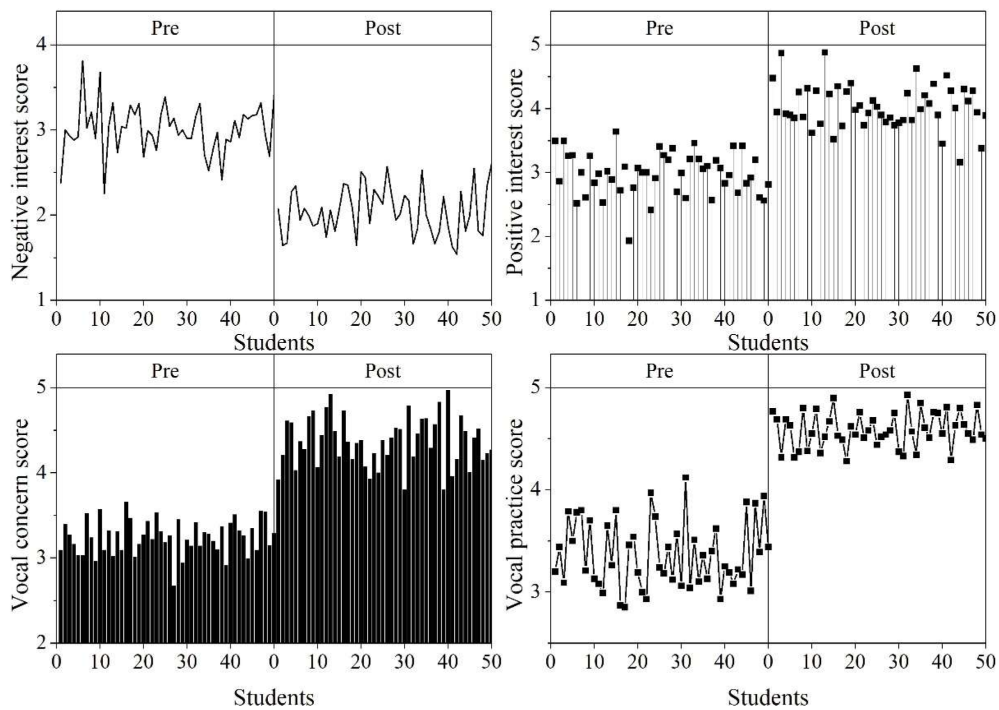

Fig. 6. Student music learning interest index data statistics

3.3.3. Multimedia Teaching System Recognition Survey. In order to have a more in-depth and comprehensive understanding of the effectiveness of the multimedia technology-driven to the vocal classroom produced, this section designed a questionnaire on the application of multimedia technology, the learning interaction experience, the learning content and process as well as the recognition of the teaching effect. The questionnaire mainly targets the students (50 students) in the experimental class of the above-mentioned multimedia vocal music teaching system, and through these four parts of the survey to understand the students' feelings and learning effects after practice. In order to achieve a visual presentation of student recognition, the questionnaire was analyzed using a 5-level scale, i.e., ratings 1-5, which represents the degree of student recognition from shallow to deep.

Figure 7 presents the results of the student survey on the four levels of endorsement. The figure depicts the ratings of 50 students on the level of endorsement of multimedia technology application, learning interactive experience, learning content and process, and teaching effectiveness. The results show that for the different dimensions of endorsement, the students rated above 3.5. The average recognition ratings of the four dimensions were 4.384, 4.608, 4.077 and 4.437, with the highest average ratings and a more concentrated distribution of ratings in the interactive learning experience. It indicates that the multimedia teaching system for vocal music provides a highly immersive learning environment for students, promotes multi-sensory learning in vision, hearing and even touch, and improves that experience of students' interaction. In addition, it was found that the recognition of the learning content and process was relatively low, which may be due to the insufficient vocal music learning resources recorded in the system, resulting in the students' learning content as well as the process did not meet the expectation level.

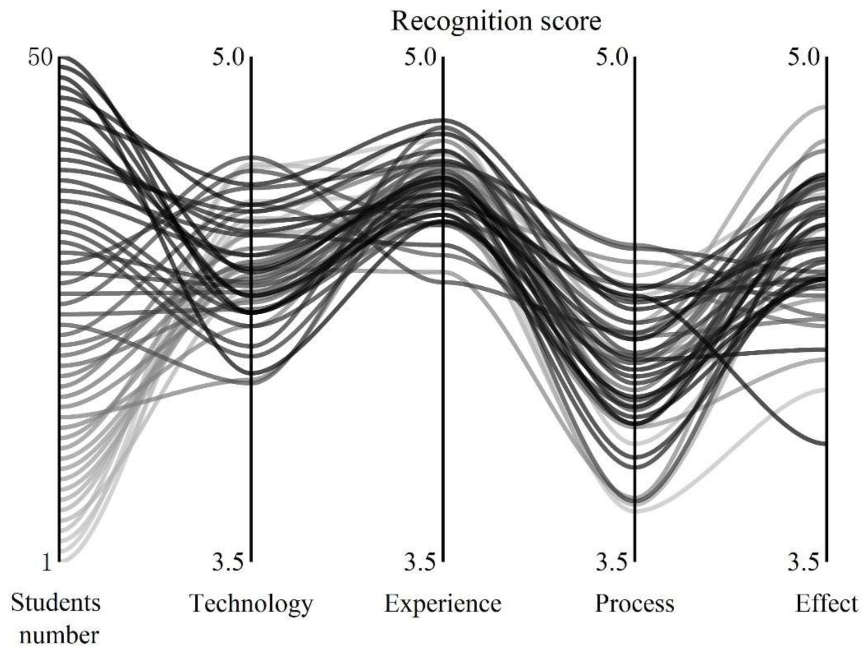

Fig. 7. The students' survey results of four levels of recognition

4. Evaluation of the effectiveness of vocal music teaching based on fuzzy algorithm

4.1. Vocal Music Teaching Effectiveness Evaluation Index System

In this section, a large amount of relevant literature was reviewed for the establishment of the evaluation index system of vocal music teaching effectiveness, and two expert opinions were solicited through questionnaires. On the basis of the statistical analysis of the results of the first round of expert consultation and the modification opinions put forward by the experts, the content of some indicators was modified, and the evaluation index system of vocal music teaching based on multimedia technology was redesigned. After the second expert consultation questionnaire was returned, the mathematical and statistical analysis of the experts' assignment of each indicator was conducted, and it was considered that all the indicators were in line with the principles and standards of the indicator design of this study and the consistency of the experts' opinions was remarkable, so no more repetition of the expert consultation was carried out, and the final multimedia technology-based vocal music teaching effectiveness evaluation indicator system was established as shown in Table 2.

Table 2. The evaluation index system of vocal music teaching

Primary indicator	Secondary indicator	Tertiary indicator
Classroom preparation	Teaching design	Textbook study
		Study affective analysis
		Target setting
		Process arrangement
	Teaching case	Formal specification
		Accurate statement
Classroom teaching	Organizational management	Organizational specification
		Reasonable regulation
	Situation creation	Contact experience
		Multiple perception
		Wake up
	Instructional guidance	Problem guidance
		Interest
		Cooperative learning
		Exploration innovation
	Student interaction	Classroom atmosphere
		Experience sharing
	Evaluation feedback	Reasonable evaluation
		Incentive channel
Classroom teaching effect	Knowledge comprehension rate	Knowledge
		Theoretical application
	Skill control rate	Skill master
		Professional level
	Music level expression	Music
		Ability
	Student subjective performance	Internal psychological subjective description
		Subjective performance of external behavior
Classroom teaching reflection	Teaching journal	After class
		Periodic finishing
	Teaching reflection	Problem reflection
		Case study

4.2. *Application of hierarchical analysis*

In the framework of AHP hierarchical analysis [22] through the evaluation matrix method to assign weights to indicators at all levels. Assuming that there are n indicators related to the lower level of a higher level indicator, the importance of this indicator relative to this higher level indicator can be calculated by using judgment matrix, which can be expressed as judgment matrix A:

$$A=\left(a_{ij}\right)_{m\times n},(i=1,2,\ldots,n;\ j=1,2,\ldots,n) \tag{1}$$

Where: a_{ij} for i indicators and j indicators to get the judgment value, $a_{ij}>0$, $a_{ii}=0$, and $a_{ij}=1/a_{ji}$

1) Consistency test of judgment matrix: consistency test, is to test whether the random consistency ratio CR of a certain level of indicators is less than 0.1, when $\mathrm{CR}=\mathrm{CI}/\mathrm{RI}<0.10$, that is, it is considered that the results of the index sorting has a more reasonable consistency. Among them, $CI=\lambda_{\max}-n/n-1$, RI is the average random consistency indicator.

2) Solve each comparison judgment matrix: Hierarchical analysis method determines the weights of the indicators by obtaining the eigenvalues and eigenvectors of the judgment matrix, and the eigenvectors corresponding to the largest non-zero eigenvalues are the weight vectors of the indicators.

3) Total ranking of indicators: the eigenvalues and eigenvectors are obtained from the judgment matrix that has passed the consistency test, and the eigenvector corresponding to the largest eigenvalue is the relative importance of the corresponding indicator to the upper indicator, and the weights of the indicators can be obtained after the normalization process.

4) Establishment of comprehensive evaluation model: Assuming that there are t evaluation indicators, the comprehensive evaluation model is constructed as follows:

$$V=\sum_{i=1}^{t} w_i y_i \tag{2}$$

Where: V is the overall assessed value of the social evaluation of the project.
V_i is the weight of each indicator.
Y_t The i th evaluation indicator C, the value after standardization.

4.3. Application of fuzzy integrated evaluation method

4.3.1. Fuzzy evaluation algorithm model. Let $U=\{u_1,u_2,\ldots,u_n\}$ be n kinds of factors and $V=\{v_1,v_2,\ldots,v_m\}$ be m kinds of evaluation their elements can be subjectively specified by people according to the actual problem needs. People do not absolutely affirm or deny the m evaluations, so the fuzzy comprehensive evaluation [23] should be a fuzzy subset on V :

$$B=\left(b_1,b_2,\ldots\ldots,b_m\right)\in T\left(V\right) \tag{3}$$

where $b_j=(j=1,2,\ldots,m)$ reflects the position of the j nd evaluation v_j in the comprehensive evaluation (i.e., v_j the degree of affiliation to the fuzzy set B : $B\left(v_j\right)=b_j$). The comprehensive evaluation B depends on the weight of each factor, which should be a fuzzy subset $A=\left(a_1,a_2,\ldots,a_n\right)\in T(U)$ on U , and:

$$\sum_{n}^{1} a_i=1 \tag{4}$$

where a_i denotes the weight of factor 1. Thus, once the weights A are given, a composite evaluation B can be obtained accordingly.

Thus, according to the above theoretical account, a fuzzy transformation from U to V needs to be established T . If for each factor u_i , a separate evaluation $f\left(u_i\right)$ is made, this can be seen as a fuzzy mapping from U to V , i.e.:

$$f:U\to R(V)u_i\mapsto f\left(u_i\right)\in T(V) \tag{5}$$

From f a fuzzy linear transformation T_f from U to V can be induced, and we can then view T_f as a mathematical model of the comprehensive evaluation B obtained from the weights A .

4.3.2. Steps for fuzzy integrated evaluation. When n is large in the factor set $U=\{u_1,u_2,\ldots,u_n\}$ of a thing, each component a_i in the weight vector $A=\{a_1,a_2,\ldots,a_n\}$ often becomes small, thus affecting the evaluation results. Here, the steps and methods of second-level fuzzy comprehensive evaluation are explained as follows:

1) The factors in factor set U are grouped into a number of subsets $U_i=\{u_{i1},u_{i2},\ldots,u_{in}\}$ according to certain commonalities (here $i=1,2,\ldots,k$, $u_{i1},u_{i2},\ldots,u_{in}$ are both factors of U) such that $i=1,2,\ldots,k$, $u_{i1},u_{i2},\ldots,u_{in}$ are both factors of U) such that:

$$\bigcup_{i=1}^{k} u_i = u \ And \ U_i \cap U_j = \phi(i \neq j)(i,j=1,2,\ldots,k) \tag{6}$$

2) Select evaluation set $V=\{v_1,v_2,\ldots,v_m\}$, where $v_j(j=1,2,\ldots,m)$ represents the j rd level of evaluation.

3) First-level evaluation

The n_i factors in U_i are evaluated as single factors, and the degree of affiliation of each factor to each evaluation level is determined. Regardless of the method of single-factor evaluation, a fuzzy mapping from U to V is given:

$$\begin{gathered} f :\to T(V) \\ u_i \to (v_i) = R_i = (r_{i1}, r_{i2} \ldots, r_{im}) \to T(V), (i=1,2,\ldots,n) \end{gathered} \tag{7}$$

Then a fuzzy relation $R(f) \in T(U \times V)$ can be induced from the fuzzy mapping f, i.e:

$$R_f(u_i,u_j) = f(u_i)(u_j) = r_{ij} \tag{8}$$

Therefore, based on the above mapping relationships, a one-factor evaluation matrix R_f consisting of the one-factor evaluations of each factor in u_i is obtained, and R_f can be represented by a fuzzy matrix $R \in []_{n\times m}$:

$$R = (R_1, R_2, \cdots R_n)^T = (r_{ij})_{n\times m} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{nm} \end{bmatrix} \tag{9}$$

Where the i nd row R_i in R reflects the degree of affiliation of the i th factor of the evaluated object to the ranks in the evaluation set: the j th column reflects the degree to which each factor of the evaluated object takes the j th rank in the evaluation set, respectively. Determine the weights $A_i = (a_{1i}, a_{2i}, \ldots, a_{ni})$ of the n_i factors in U_i, where:

$$\sum a_{ni} = 1 \tag{10}$$

Then, a fuzzy synthesized evaluation of U_i

Make a fuzzy transformation:

$$f : T(U) \to T(V), A \to f(A) = A \circ R = B \in T(V) \tag{11}$$

Here "$\circ$" represents the generalized synthetic operation, and $B=(b_1,b_2,\ldots,b_m)$ is the fuzzy comprehensive evaluation of things.

In this paper, according to the needs of the actual problem, the $M(\vee,\wedge)$ model is selected to find

$b_j(j=1,2,\ldots,m)$, the formula is as follows:

$$b_j = \vee_{i=1}^{n}\left(a_i \wedge r_{ij}\right)(j=1,2,\ldots,0) \tag{12}$$

The largest of these $a_i \wedge r_{ij}$ counterparts is the main factor that determines the extent to which this thing has rank v_j qualifications.

4.3.3. Integrated secondary evaluation. A comprehensive evaluation (second level evaluation) of the things represented by U is obtained from $B_1,B_2,\ldots,B_k$. The one-factor evaluation matrix for $U=\{u_1,u_2,\ldots,u_k\}$ is:

$$B=\begin{bmatrix} B_1 \\ B_2 \\ \cdots \\ B_k \end{bmatrix}=\begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1m} \\ b_{21} & b_{22} & \cdots & b_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ b_{k1} & b_{k2} & \cdots & b_{km} \end{bmatrix} \tag{13}$$

If the weight vector of $u_1,u_2,\ldots,u_k$ is:

$$A=\left(a_1,a_2,\ldots,a_k\right) \tag{14}$$

Then the overall evaluation of the things represented by U is:

$$B=A\circ R=\left(b_1,b_2,\cdots,b_m\right) \tag{15}$$

Modeled after the two-level integrated evaluation method, three or more levels of integrated evaluation can be used for complex matters with more factors.

4.3.4. Determination of evaluation findings. For the comprehensive evaluation results, whether it is a one-level, two-level or multi-level fuzzy comprehensive evaluation, an evaluation conclusion is made based on the evaluation results.

First, $b_1,b_2,\ldots,b_m$ is normalized to get:

$$B=\left[\frac{b_1}{\sum_{j=1}^{m} b_j},\cdots,\frac{b_m}{\sum_{j=1}^{m} b_j}\right]=\left(b_1',b_2',\ldots b'_m\right) \tag{16}$$

Then, the fuzzy comprehensive evaluation results are evaluated according to the maximum affiliation method.

Maximum affiliation method: if $b_k' = \max\left(b_1', bi_2, \cdots b_m'\right)$, the evaluation of this thing can be judged as V_k. Fuzzy distribution method: that is, $B=\left(b_1,b_2,\ldots,b_m\right)$ is taken as the result of the comprehensive evaluation of this thing.

4.4. Evaluation of teaching effectiveness based on fuzzy algorithm

Based on the indicators obtained above, these indicators were distributed to 10 experts, who scored them according to their listening and tallied the scores. The weighted score of the three-level indicators of expert evaluation can be obtained, which contains 31 three-level indicators. And according to the scoring results, the fuzzy evaluation algorithm was utilized to rate the overall effectiveness of multimedia technology-driven vocal music teaching in terms of appropriateness. The suitability rating based on fuzzy evaluation is divided into: very suitable (90-100 points), suitable (80-89 points), general (70-79 points), unsuitable (60-69), and very unsuitable (<60 points).

The results of the experts' ratings of the three-level indicators are shown in Figure 8, and it can be seen from the data in the figure that the experts' ratings of the indicators corresponding to each of the three-level indicators are better, and the ratings of each of the experts are above 85 points. After statistics, the average rating of each three-level indicator was obtained between 91.123 and 93.023. Calculated according to the hierarchical analysis method, the weights of the evaluation indicators at all levels are shown in Table 3. As can be seen from the table, the difference between the weights of the three-level indicators is small, and the sum is 1. The weights of Classroom preparation, Classroom teaching, Classroom teaching effect, Classroom teaching reflection are respectively 19.32%, 41.98%, 25.82% and 12.88% respectively, which shows that the classroom teaching stage in the vocal music teaching promoted by multimedia technology has been emphasized by experts.

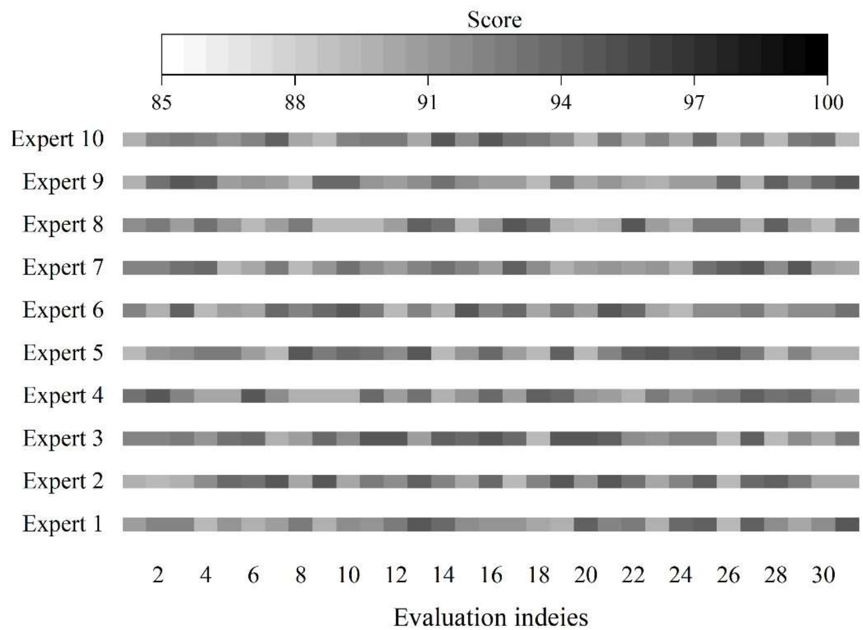

Fig. 8. The results of experts' scores on tertiary indicators

Table 3. Evaluation index weight at all levels

Primary indicator	Weight	Secondary indicator	Weight	Tertiary indicator	Weight	Score
Classroom preparation	19.32%	Teaching design	12.9%	Textbook study	3.31%	91.152
				Study affective analysis	3.34%	92.096
				Target setting	3.35%	92.452
				Process arrangement	3.33%	91.795
		Teaching case	6.42%	Formal specification	3.32%	91.456
				Accurate statement	3.32%	91.53
Classroom teaching	41.98%	Organizational management	6.43%	Organizational specification	3.33%	91.933
				Reasonable regulation	3.31%	91.172
		Situation creation	9.69%	Contact experience	3.32%	91.701
				Multiple perception	3.34%	92.07
				Wake up	3.35%	92.351
		Instructional guidance	12.94%	Problem guidance	3.32%	91.517
				Interest	3.37%	92.885
				Cooperative learning	3.35%	92.423
				Exploration innovation	3.33%	91.833
		Student interaction	6.49%	Classroom atmosphere	3.36%	92.703
				Experience sharing	3.34%	92.208
		Evaluation feedback	6.44%	Reasonable evaluation	3.31%	91.261
				Incentive channel	3.35%	92.366
Classroom teaching effect	25.82%	Knowledge comprehension rate	6.44%	Knowledge	3.30%	91.123
				Theoretical application	3.35%	92.321
		Skill control rate	6.44%	Skill master	3.34%	92.204
				Professional level	3.31%	91.288
		Music level expression	6.49%	Music	3.31%	91.263
				Ability	3.37%	93.023
		Student subjective performance	6.48%	Internal psychological subjective description	3.32%	91.676
				Subjective performance of external behavior	3.37%	92.885
Classroom teaching reflection	12.88%	Teaching journal	6.46%	After class	3.33%	91.742
				Periodic finishing	3.34%	92.232
		Teaching reflection	6.43%	Problem reflection	3.31%	91.336
				Case study	3.31%	91.876

According to the expert evaluation indicators of the questionnaire survey statistics, screening, certification of the expert evaluation indicator items obtained. Fifty expert evaluation questionnaire copies were selected to evaluate the content of the questionnaire on the suitability of the indicators. Ratings from 1 to 5 represent "very inappropriate", "inappropriate", "average", "suitable", and "very suitable". Complete the summary statistics of the evaluation suitability survey results submitted by experts.

The results of the research on the appropriateness of multimedia technology for teaching and learning are shown in Figure 9. Statistically, most of the 50 experts indicated that the suitability of the system in this paper was "suitable" and "very suitable", with the number of both accounting for 76% to 90% of the total.

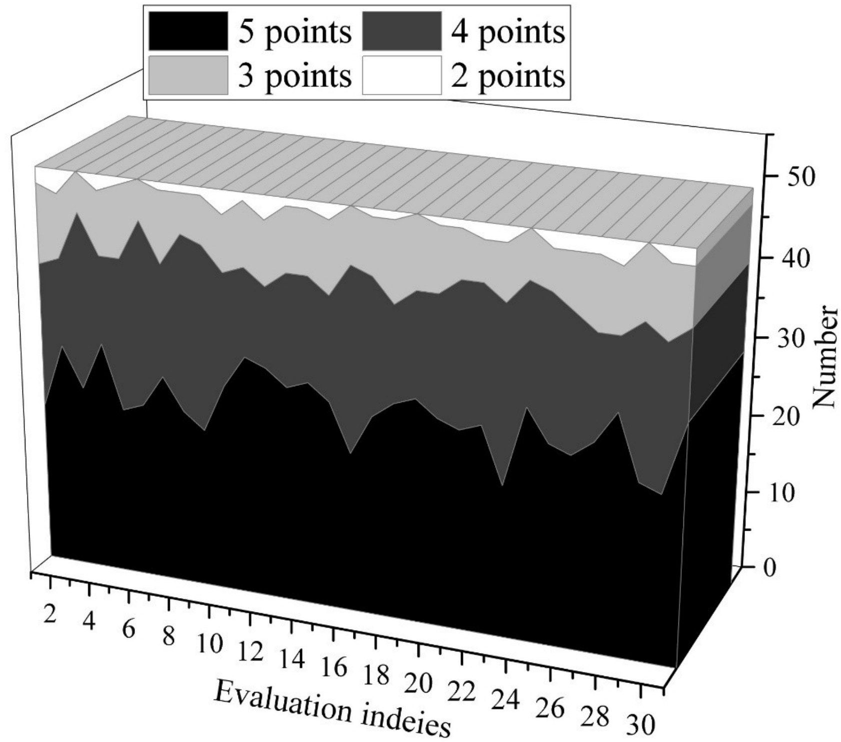

Fig. 9. Multimedia technology promotes the suitability of teaching

As can be seen from the results of the expert evaluation suitability survey in Figure 9, the values of the suitability survey results for the three levels of expert evaluation indicators were integrated and calculated by the fuzzy evaluation algorithm for the first level of expert indicators Classroom preparation, Classroom teaching, Classroom teaching effect, Classroom teaching reflection of the total expert rating. The results of expert ratings and appropriateness classifications of the system-level evaluation indicators in this paper are shown in Table 4. As can be seen from the table, according to the fuzzy evaluation algorithm finally get the rating of each level of indicators are more than 90 points, and the overall weighted average value is 93.437. It shows that the experts on the effectiveness of this multimedia vocal teaching is appropriate, which means that it is satisfactory, thus obtaining a quantitative result. 93.437 this number between 90 to 100, that is, the expert evaluation rating is between appropriate and very appropriate, that is, the the expert evaluation rated the teaching effectiveness of this class as satisfactory.

Table 4. The expert score and appropriate level of the first level evaluation index

Primary indicator	Expert score	Grade
Classroom preparation	91.153	Very appropriate
Classroom teaching	95.461	Very appropriate
Classroom teaching effect	93.244	Very appropriate
Classroom teaching reflection	90.653	Very appropriate
Weighted mean	93.437	Very appropriate

5. Conclusion

This study is based on the optimization of vocal music teaching strategies and the evaluation of their effectiveness. Based on the application of multimedia technology in vocal music teaching, a multimedia technology-driven vocal music teaching system architecture is designed. The system realizes the diversified teaching in the vocal classroom through the functions of voice interaction, vocal course design, and online vocal practice. Meanwhile, the study quantitatively assesses the teaching effectiveness through experiments as well as fuzzy comprehensive evaluation method.

1) Experimental findings: Driven by multimedia technology, the vocal ability of students in the experimental class increased by 5.98% to 10.48% compared with the control class, and the theoretical score increased by 6.56 points, which is a significant difference. And the quantitative mean value of students' positive interest in vocal music learning increased under this system, while the mean value of negative interest decreased by 0.96. In addition, this paper's system gained the highest recognition from students in terms of learning interactive experience, which is 4.608, i.e., this paper's system can be used for interactive teaching to improve students' vocal music learning effect. The overall evaluation of the effectiveness of this paper's system in teaching vocal music is very suitable, with a weighted score of 93.437. The above conclusions show that this paper utilizes multimedia technology in the teaching of vocal music with excellent results, but there are also some shortcomings.

2) Shortcomings and Prospects: In the design and development of the multimedia system, the main effort is put on the interactive function setting of the language, and the combination of the virtual experiment and the specific experimental teaching process is not detailed and professional enough, and many details of the experimental process need to be further optimized and improved. Multimedia technology, as an emerging technology applied to vocal music teaching, provides a brand new learning channel for students' learning and shows its great potential in the development of teaching resources. It is hoped that the development of the system in this paper can inspire more attention to the application in vocal music teaching and enhance the level of vocal music teaching informatization.

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