



A New Approach to the Cultivation of Bel canto Skills in Vocal Music Education in the Digital Era

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SUMMARY: *Digital music education is in line with the trend of educational innovation and the combination of art and science, and music education must catch up with the requirements of the information age. This paper proposes to extract students' voice waveforms based on digital technology, and then implement the guidance of singing state, rhythm, melody, pronunciation and biting to realize the cultivation of their Bel canto skills. By using melodic feature extraction, similarity comparison, and pitch data analysis to sing automatically, the research-designed Bel canto comparison system finds the problem position, estimates the error's reason, and provides the student with thorough feedback and recommendations. Students' singing status, pronunciation, rhythmic pitch, and classroom happiness all dramatically altered in four areas following the application of this paper's teaching methodology. Additionally, the average score on the Bel canto professional skills test increased by 4.12 points. Consequently, the use of digital technology in the development of Bel canto abilities can facilitate the process of teaching vocal music and make it simpler to observe outcomes.*

KEYWORDS: *digitalization; singing comparison system; sound waveform; Bel canto skill cultivation*

1 Introduction

Singing skills training generally contains several aspects such as gas, vocalization, spitting and listening training, which are closely linked and mutually reinforcing in the actual training process, forming an organic dynamic singing skills training as a whole [1]. In the singing skills training, singers should consciously take into account each training content, and combined with different training conditions and practice to develop a reasonable training plan, to maximize the avoidance of one-sided training, the training of their own singing skills have a negative impact [2]. At the same time, singing skills training can not be simply understood as the exercise of muscle movement, which is more important to train the brain's ability to command the body and the coordination of all parts of the body. The training content of breath, voice, spitting and hearing are all affected by the dominant ability of the brain. Therefore, singers in the actual training process must be good at discovering the problems that exist in the singing training process, and actively explore the corresponding measures to solve the problem [3]. In addition, singers in the singing training also generally have certain problems, such as breathing, vocal organs are too tense, etc., which seriously affects the training effect. Based on this, singers should pay attention to cultivating their own singing consciousness, overcoming problems in

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the singing process, coordinating the movement of various body organs, and improving their singing skills [4, 5].

Digital technology is drastically altering every facet of higher education in the context of the period of fast information technology growth. As a crucial area of professional art education, music education in higher education has created a significant potential for digital change. For instance, research [6] found that body coordination, diaphragmatic breathing training, inhalation and exhalation training, mixed breathing training, and coordination of vocal organs are significant markers of singing training when using contemporary digital technology to create a breathing setup mechanism that can encourage singing. Literature [7] utilized digital technology and digital music to develop and enhance singers' good singing skills through the use of psychological methods such as sensation, perception, imagination, emotion, and temperament, through which physiological skills in singing are controlled and adjusted. Literature [8] argues that the combination of digital processing technology and traditional voice training forms a complementary training system, where traditional training focuses on basic vocal skills and body regulation, while digital technology provides scientific analysis and auxiliary tools to make the training process more efficient and personalized, and the two are complementary to each other. Literature [9] proposes a way to integrate mobile apps into singing skills training, which provides students with the opportunity to master aural skills and allows singers to receive personalized feedback, and combines technology with teaching methods that can enable digital music education. Literature [10] argues that in the field of modern digital vocal training, the integration of computer data-aware technology has become an important means of enhancing the training effect, which enables the training model to more accurately capture and analyze the student's vocal performance through the introduction of advanced data-aware technology to achieve personalized guidance and optimization. Literature [11] found that digital singing training tools effectively improved users' pitch accuracy by 94.81% through real-time interaction and visual feedback, highlighting the important role of digital tools in music education, especially in improving learning efficiency and enhancing learning experience.

Bel canto is one of the common techniques in vocal singing, which emphasizes the completion of the main process of spitting and breath exchange in the laryngeal area, where the airflow is exhaled, vibrating the vocal cords, producing sound, and realizing the cavity resonance [12]. Literature [13] incorporates the Bel canto method in singing skill training, which begs singers to use half-volume when singing, avoiding the use of strong breath to produce impact, especially in the process of soprano singing, which should be sung with natural and soft intonation in order to make the voice become more fluent. According to literature [14], Bel canto is characterized by the larynx blowing the vocal cords with the aid of the exhaled airflow while maintaining the inhalation posture so that the open resonance chamber can resonate fully and evenly. This technique encompasses three aspects of musical performance: intuition, interest, and style. According to literature [15], Bel canto is an essential musical expression that is indispensable in music education. Research has demonstrated that Bel canto helps students develop their artistic literacy and self-confidence in addition to improving their vocal abilities and expressiveness.

Literature [16] believes that Bel canto can express the profound artistic connotation contained in songs through the structure of sound, timbre and emotion, so they analyze the influence of Bel canto on the level of students' aesthetic consciousness and personality psychological characteristics from the students' perception of beauty. Literature [17] explored the effect of aesthetic singing training on the acoustic and aerodynamic characteristics of the singing voice, and it was found that aesthetic singing training could lead to a significant increase in both the pitch range and the sound pressure level of the students, in which the increase in the

sound pressure level was usually caused by an increase in the amount of inhalation, an increase in the airflow, and a decrease in the laryngeal resistance, with individual differences.

About how digital technology affects the development of artistic voice skills, literature [18] constructed an interactive learning environment with the synergy of IoT devices, and found that aesthetic voice technology training with the help of IoT devices could monitor and analyze students' vocal skills more accurately, and that the application of these technologies enabled teachers to provide more accurate and timely instructional advice, which could further enhance the level and accelerate the progress of students' aesthetic voice skills. Literature [19] constructed an acoustic parameter modeling system based on deep learning algorithms in Artificial Intelligence (AI), which aims to achieve accurate diagnosis and real-time intervention of deficiencies in the process of Bel canto training through Mel spectral analysis, resonance tracking, and respiratory dynamics modeling. A hybrid model linked to the Long Short-Term Memory Network (LSTM) from the field of deep learning is constructed in literature [20] with the goal of using this tool to help teach Bel canto and enhance students' capacity to recognize emotions and enjoy music. Literature [21] proposes an innovative Bel canto color anomaly detection system based on timbre perception, which aims to accurately capture the acoustic features in Bel canto so as to achieve effective identification of voice anomalies, and to use Short Time Fourier Transform (STFT) for spectral analysis of acoustic signals with the aim of optimizing the representation of the frequency domain data through the reduction of redundant information in the spectrum.

The improvement of Bel canto skills can be realized by guiding students' state, rhythm, melody, pronunciation and biting when singing Bel canto through the sound waveform diagram. In this regard, this paper designs an Bel canto comparison system that contains a feature extraction module, a similarity comparison module and a feedback module. The system is not only able to accurately extract the sound waveforms of students' Bel canto but also significantly improves the students' vocal performance, as well as their singing status, pronunciation, rhythmic intonation, and classroom satisfaction after the system is used in teaching practice. The application of digital technology provides a reliable way for the cultivation of Bel canto skills.

2 The way of cultivating aesthetic voice skills based on digital technology

The cultivation of vocal skills is mainly realized through the instruction of its state, rhythm, melody, pronunciation and biting. After the intervention of digital music education tools, vocal music teaching can be visualized through computer music technology.

2.1 Adjustment and Modification of Singing State

In the vocal music classroom, teachers will conduct vocal exercises for students. In order to promote the correct singing state through the basic vowel training, at this time, the students can selectively record the voice before they have not entered the state and the voice after they have entered the state, and carry out comparative analysis of waveforms, so that the students can recognize and perceive the state of the organism and the collaboration of the functions of the various parts of the body under the singing state, so as to strengthen the memory of the singing state. After finding the correct singing state, students are then taught the sound characteristics of different registers and sound areas to help them find a good sound position. For example, through the Cake Walk software recording function to assist the teaching of Bel canto skills, students can hear their own "objective voice", but also can see the waveform of the voice and

synchronized score, etc., the use of multi-track recording, the students will be practicing each time the process of practicing and singing are recorded, compared with the correct or incorrect state of the voice, and Explain and analyze, point out the problem, and then teach the correct way to correct it, in order to help students find the scientific state of voice.

2.2 Bite, Speech and Pronunciation

Pronunciation and articulation are also very important parts of the Bel canto process, directly affecting vocal performance and play. Teachers can improve students' subjective and objective perception by modifying the waveform timing or modifying the head of the tone, making a rhyme mark, and then comparing the waveforms. Problems in the student's singing can be quickly corrected by comparison.

2.3 Rhythm and Intonation Development

Rhythm and pitch are essential for the development of Bel canto skills. How to make students better grasp the rhythm and pitch to promote the expression of the connotation of Bel canto works is also an important part of teaching. The rhythm and pitch problems expressed in this paper refer to the problems caused by improper singing condition and control. Vocal singing often encounters pitch problems caused by the position of the voice, breath and other reasons, especially for the singing skills are not yet skillful, the singer's inner pitch is accurate, in the absence of reference, the performer is difficult to detect. At this time, the teacher can point out the problem according to the waveform of the inaccurate part of the pitch, and correct the pitch, and then tell the students to adjust the singing state, such as the mouth is not open enough, the voice position is low, the breath support is unstable, etc., which will be very easy to make the students in a good state of singing to find the right pitch and grasp the rhythm. At the same time, the digital music accompaniment can avoid the artificial fast and slow rhythm caused by the inaccuracy, so that students can grasp the rhythm of the music, so as to achieve the accuracy of expression.

3 Bel canto Comparison System

In the previous section, it was proposed that the cultivation of Bel canto skills can be realized by comparing, correcting and analyzing the sound waveforms with the help of digital technology. In this regard, this chapter constructs an Bel canto singing comparison system to provide a basic guarantee for the path of Bel canto skill development.

3.1 System architecture

Fig. 1 illustrates the Bel canto comparing approach. The audio feature extraction module will first receive the digitalized vocal signal from the user input module. Pitch features will be taken from the input audio stream in this module, and the singing-pitch sequence will be extracted for additional comparison. The program will get the pitch sequences from the Bel canto Music Feature Library after the pupils have selected the recordings. The pitch files for every song in the template music library produced by the feature extraction module are included in this collection. Following the singing session, the similarity comparison module will be used to examine the pitch sequences' short-time and overall scores. Next, using pitch data, the feedback module will identify the five things with the lowest scores and provide users with suggestions on how to become better.

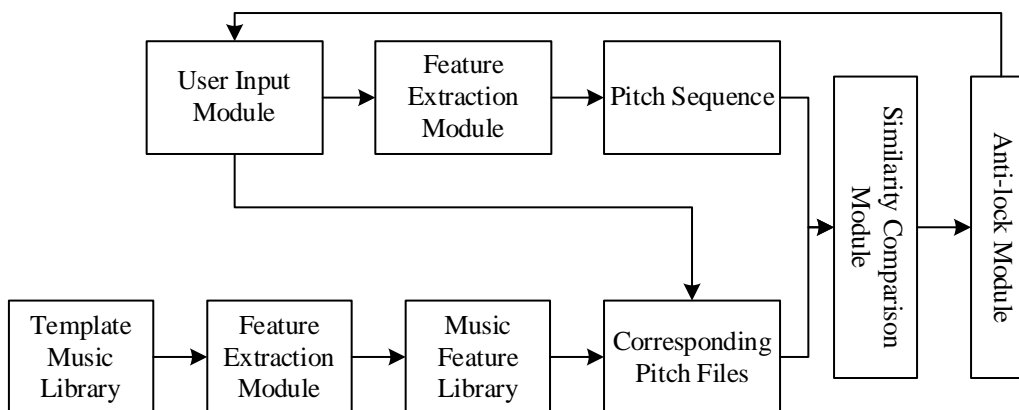


Figure 1: Sound singing comparison system framework

3.2 Algorithm Implementation of the Bel canto Comparison System

3.2.1 Soprano extraction

The feature extraction module's job is to extract the students' voice signals' pitch sequences for Bel canto, as well as the MIDI pitch sequences from the template music library. Due to the different file formats, the methods of extracting the pitches are different. We present the two extraction methods used in the system respectively:

(1) wave file pitch extraction

This extraction method is required to extract the pitch of the sound signals sung by the students' voices.

Sound is a series of vibrations of different frequencies and amplitudes emitted by the articulator. One of these vibrations has the lowest frequency, and the tone emitted from it is the fundamental tone, while the rest are overtones. The fundamental tone determines the pitch, so you need to extract the fundamental tone of the audio.

However, the composite sound signal cannot be evaluated or processed as a whole using traditional methods since its features are constantly changing. Nonetheless, the characteristics of the composite signal remain constant for a relatively little amount of time; in other words, they might be regarded as stable. This suggests that there is short-time smoothness in the voice signal. The rectangular or Hamming window approach is used to divide the voice stream into frames based on this idea.

This method uses a rectangle window with a step of 0 and a frame length of 22 ms. The time domain estimate method and the transform domain estimation method are the two primary categories of basic period extraction techniques. The system employs the autocorrelation function approach (ACF), which is a time domain estimation technique.

Another method for determining the fundamental frequency is the autocorrelation function approach. This method's essential principle is that the autocorrelation function of the speech signal will have peaks in integer multiples of the fundamental period, which may be used to determine the fundamental period. The algorithm for the autocorrelation function is shown below:

$$acf(\tau) = \sum_{i=0}^{n-1-\tau} s(i)s(i+\tau) \quad (1)$$

Since the peaks are affected by the resonance peaks in the fundamental detection, after the

autocorrelation calculation, a bandpass filter with a bandwidth of 45 to 1020 HZ is used to remove the resonance peaks by removing the values that are too high or too low. Ensure that the accurate fundamental cycle is extracted.

After the base tone sequence is successfully extracted, it is converted into a pitch sequence in semitones according to equation (2):

$$\text{semitone} = 12 * \log_2(\text{frequency} / 440) + 69 \quad (2)$$

After the pitch sequence is obtained, post-processing is performed to make the obtained sequence more consistent with the actual pitch value. In the process of real-time recording, the breath change and environmental noise of students singing will inevitably be recorded, due to the weak energy of these signals, we can find those frames whose volume value is lower than 1/10 of the maximum volume value, and eliminate the interference by assigning their pitch data to the method of nan.

(2) MIDI Music Pitch Extraction

MIDI file is a descriptive music file, so it is easier to extract the pitch sequence. We used a program written in MATLAB about reading MIDI files to read out the pitch of each note directly from the MIDI file to get the pitch sequence based on the notes. We also referred to TOOLBOX about MIDI file processing to convert the note-based pitch sequences into frame-based pitch sequences so that they are equal in length to the pitch sequences of the speech sung or played by the students, which is convenient for the similarity comparison in the next step.

3.2.2 Similarity comparison

Before doing the similarity comparison, the pitch sequences need to be regularized so that the audio pitch sequences practiced by the students are roughly at the same level as the template pitch sequences. The method we used was to take the template pitch sequence as a reference and regularize the arithmetic mean of the self-sung pitch sequence to the same level as the arithmetic mean of the template pitch sequence.

For the similarity comparison algorithm, considering the absolute nature of time and audio signals, we do not use the dynamic time normalization algorithm (DTW) with audio length warping, but use the shorter time-consuming cosine similarity formula as shown in equation (3). The cosine similarity calculates the trend of two sets of data in a two-dimensional space vector, which meets our requirement of comparing the trend of two sets of pitch data:

$$\text{sim}_{ij} = \cos \theta = \frac{\sum_{k=1}^n R_{ik} R_{jk}}{\sqrt{\sum_{k=1}^n (R_{ik})^2 \sum_{k=1}^n (R_{jk})^2}} \quad (3)$$

3.2.3 Feedback processing

(1) Instant feedback

During the student's singing or playing, the pitch features are extracted from the recording data per second and the pitch curve is displayed in real time.

(2) Delayed feedback

1) Total Scoring

After regularizing the pitch data, first do the similarity comparison in terms of bars and normalize the scores so that they are between 0 and 100 to get the short-time scores. Then the arithmetic mean of all the short-time scores is calculated to get the total score of the song, which

is displayed to the students.

2) Locate the error position and provide suggestions for correction

First, the system displays a pitch comparison chart to give students a clear visualization of the error. Secondly, in addition to displaying the pitch comparison chart, before the student sings, the system pulls out the MIDI file information of the corresponding track from the template music library, which makes it easy for the student to grasp the overall singing rhythm.

(3) By saving pitch curves and audio samples for student study, the tool for comparing audio and pitch curve interaction enables mistake analysis. It may offer the wave forms for a visual depiction of the pitch information and read external pitch curves. Through visual analysis, the students will be able to recognize the distinctions between their voice and the original content. The loaded pitch curves' maximum and minimum values will cause the wave shapes to vary, revealing the altered areas.

4 Simulation test

4.1 Experimental design

Firstly, a clip of Bel canto was recorded using a computer, and the sound signal was captured by the American singing comparison system, after which the waveform diagram was simulated. Then the noise signal is artificially added to the sound signal. The noisy signal is coded and decoded by the Bel canto Comparison System, and its waveform is analyzed and compared with the previous sound signal. The acquired initial waveform and the waveform after adding noise are shown in Fig. 2, (a) and (b) represent the initial waveform graph and the waveform graph after adding noise, respectively. The waveform and frequency of the initial sound signal are relatively smooth, the sound is smoother, the fluctuation is not very large, and the frequency is concentrated. After adding noise, the original sound signal is completely covered by the newly generated noise signal, the sound is very noisy, and it can be seen that the waveform is very chaotic.

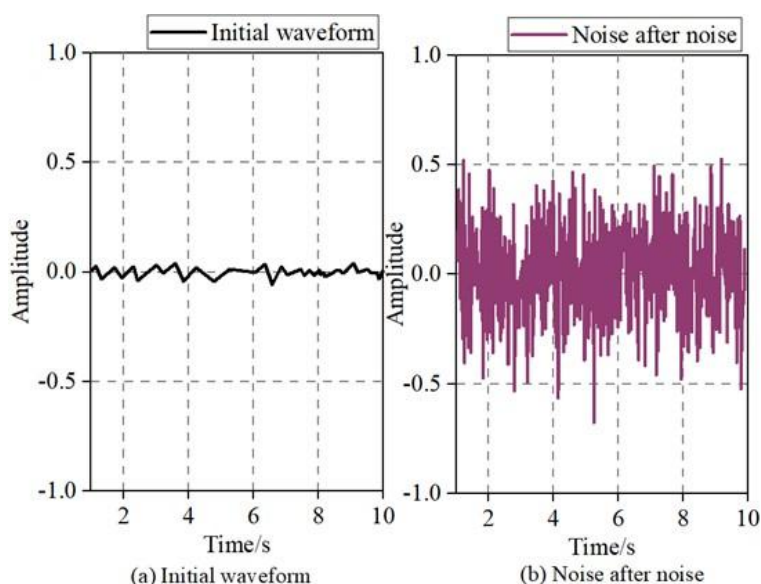


Figure 2: Initial sound signal waveform

4.2 Analysis of simulation results

After processing the sound signal by the Bel canto Comparison System, the simulation results of the signal waveforms before and after the addition of noise are shown in Fig. 3, (a) and (b) represent the sound signal waveforms before the addition of noise and after the addition of noise, respectively. The processed waveform has an obvious fluctuation trend, and the original fluctuation trend can still be maintained after noise addition. Playing back the simulated sound signal, the simulation results show that the processed sound signal of the Bel canto comparison system is very close to the original sound signal. The results show that the Bel canto Comparison System can effectively present the sound waveforms of Bel canto works, which can be used in vocal music teaching to help students to guide the state, rhythm, melody, pronunciation and diction.

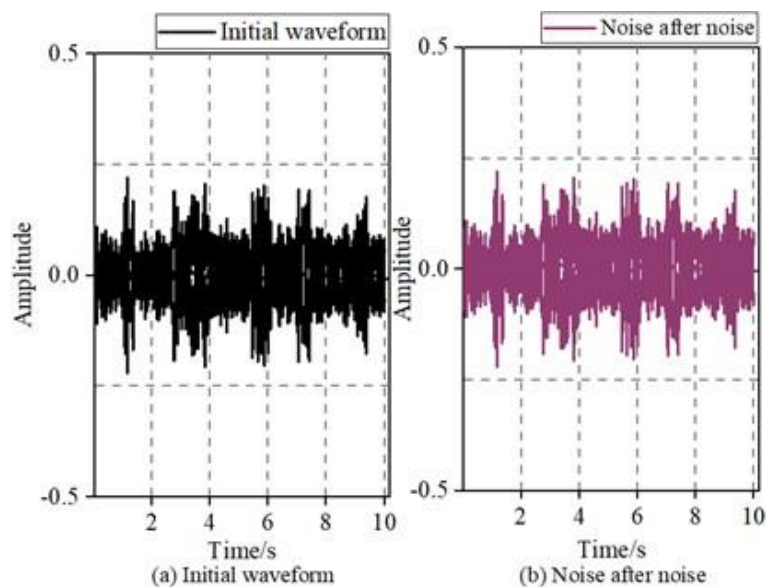


Figure 3: Sound signal waveform simulation results

5 Analysis of the effect of cultivating Bel canto skills based on digital technology

In this chapter, based on the previously proposed pathway for the development of Bel canto skills on the sophomore class B (experimental class) of the School of Music at S University, class A (control class) was taught in a traditional way, and the implementation classes were two undifferentiated classes. The purpose of the implementation was to explore whether the application of the Bel canto comparison system could effectively improve Bel canto skills. The practical effect of this teaching application was concluded using skill assessment and questionnaire.

5.1 Comparative Analysis of Student Achievement

Following instruction, a teaching-test separation method including 50 points for fundamental knowledge and 50 points for Bel canto professional abilities was used to evaluate the students in both groups. After that, post-test data was collected for each of the two classes independently. The post-test data was then processed in the same manner as the pre-test data, and sample pairing was employed to get matching survey data pairs from the two surveys. Table 1 below

lists the two subjects' independent samples t-test findings as well as the two classes' total scores. According to the test findings, the experimental class's average score was 81.58 with a standard deviation of 4.05, whereas the control class's average score was 71.68 with a standard deviation of 2.45, yielding a probability value of 0.001. The experimental class's performance differs significantly from the control class's at the significance level of 0.05. Additionally, the experimental group outperforms the control group in terms of total scores, Bel canto professional skills, and basic knowledge. In summary, the results show that the students in the experimental group, by applying the Bel canto Comparison System, made significant progress in music theory scores and Bel canto skills, indicating that voice training based on sound waveform chart has a positive impact on Bel canto skill improvement.

Table 1: Independent sample t test of the posttest results

Index	Class(M±SD)		T	P
	A(N=45)	B(N=45)		
Basic knowledge	35.44±2.55	41.32±3.01	3.204	0.001**
Professional skill	36.24±2.56	40.36±3.52	2.554	0.006**
Total	71.68±2.45	81.58±4.05	5.412	0.001***

Note: Significance levels *p<0.05, **p<0.01, ***p<0.001 (below)

5.2 Comparative analysis of questionnaires

The questionnaire was created using the four dimensions of singing status (D1), pronunciation (D2), rhythmic intonation (D3), and classroom satisfaction (D4) to assess the impact of developing Bel canto skills. The higher the score, the more the impact of developing Bel canto skills is acknowledged. There were a total of twenty questions on the questionnaire, which was disseminated and recovered using Questionnaire Star online. Ninety questionnaires were sent out, ninety of them were found, and their information was counted and examined.

5.2.1 Reliability analysis

The reliability of the 20 multiple-choice items was assessed using the Cronbach's Alpha reliability test. High dependability is indicated by values larger than 0.8. High dependability is demonstrated by those between 0.7 and 0.8, while adequate reliability is demonstrated by those between 0.6 and 0.7. Low dependability is indicated by values less than 0.6.

Table 2 displays the findings from the questionnaire's reliability test. The reliability index of 0.922 is more than 0.8, according to the SPSSAU analysis. This suggests that both the questionnaire and the data gathered for the study are trustworthy.

Table 2: Reliability analysis

Cronbach's Alpha	Cronbach`s Alpha Based on Standardized Items	N of Items
0.922	0.863	20

Evaluation of the questionnaire. The data is very suitable for information extraction and validity if the Kaiser-Meyer-Olkin (KMO) metric is higher than 0.8. High validity and appropriateness are indicated by KMO values between 0.7 and 0.8. Information extraction becomes moderately appropriate with average validity when the KMO score falls between 0.6 and 0.7. A value less than 0.6 indicates poor validity and appropriateness for information extraction. As shown in Table 3, validity was determined using KMO measures and Bartlett's Test. The data is very suitable for information extraction, as evidenced by the derived KMO value of 0.854, which exceeds the 0.8 measure.

Table 3: Validity analysis

Kaiser -Meyer-Olkin Measure of Sampling Adequacy		0.854
Bartlett's Test of Sphericity	Approx.Chi-Square	425.524
	Df	123
	Sig	0.000

5.2.2 Comparative Analysis of Students' Bel canto Skill Development Before the Experiment

Results of Independent Samples t-test on four aspects of pre-test data in the experimental and control groups are shown in Figure 4 below. Results from the analysis of the questionnaire data show that the p-values for the four aspects – singing condition, pronunciation, rhythmic intonation, and classroom satisfaction, are greater than 0.05 for both the experimental and control groups. An Independent Samples t-test showing that the pre-test scores of the two groups have no significant difference in supporting the null hypothesis, i.e., the pre-test scores of the experimental and control groups are not significantly different.

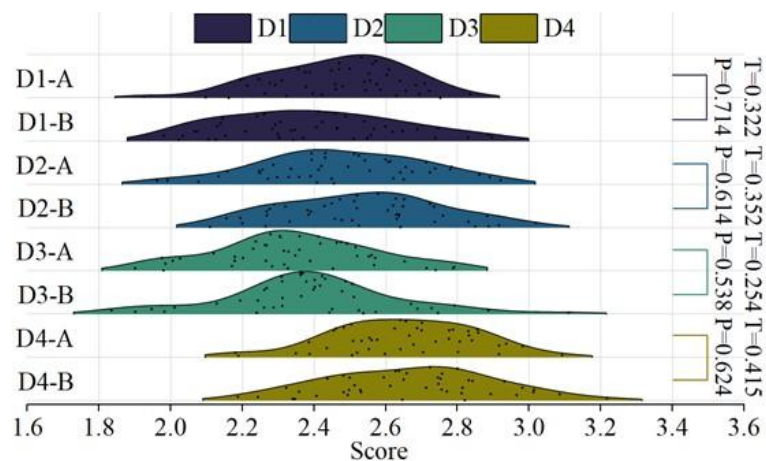


Figure 4: Comparison of pretest skill cultivation

5.2.3 Comparative Analysis of Students' Bel canto Skill Development after the Experiment

Comparison Analysis of Students' Music Learning in the Two Classes after Experimenting can be seen in Figure 5 below. The analysis showed that the p-values of the two groups in all four dimensions of learning were 0.000. This indicates that the value was less than 0.05; hence, there was a significant difference. Scores from the experiment class in all four dimensions were significantly higher than those from the control class. Both the control and the experimental classes recorded improvement in all four dimensions of singing status, pronunciation, rhythm, and classroom satisfaction. The experimental class, which used digital teaching approach, showed better improvement.

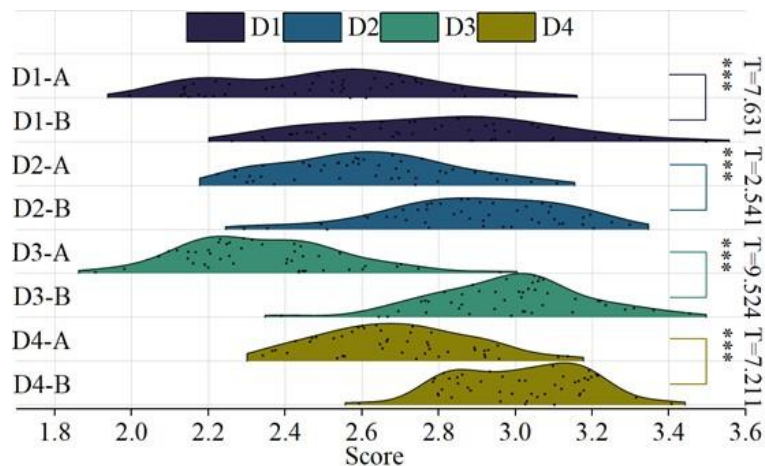


Figure 5: Comparison of posttest skill cultivation

5.2.4 Comparative Analysis of Students' Bel canto Skill Development Before and After the Experiment

(1) Comparison of Bel canto skill development before and after the experiment in the control class

The result of the paired sample t-test from the four dimensions of the pre-test and the post-test of the control class at the time before the experiment to the time after the experiment completion is presented in Table 4. The findings indicate that the control group had variations in the values in all four dimensions related to the singing status, pronunciation, rhythmic intonation and classroom satisfaction; however, these differences were not statistically significant. The p-values of the students in the control class for each of the four dimensions of singing, pronunciation, rhythmic intonation and classroom satisfaction are 0.852, 0.522, 0.036 and 0.441, respectively, compared to the significance level of 0.05. The post-test score of the control class is higher than the pre-test score only in one dimension, namely the rhythmic intonation, while there is no statistical difference in other three dimensions.

Table 4: Comparison of results before and after experiment of Cross-reference class

	Pretest	Posttest	Posttest-Pretest	T	P
D1	2.44±0.225	2.46±0.251	0.02	0.235	0.852
D2	2.52±0.214	2.54±0.228	0.02	2.514	0.522
D3	2.33±0.214	2.38±0.206	0.05	5.214	0.036*
D4	2.65±0.219	2.66±0.206	0.01	0.854	0.441

(2) Comparison of the development of Bel canto skills before and after the experiment in the experimental class

Paired Sample Test from the four dimensions in the pre-test data before the implementation of the experimental class, and the post-test data after the completion of the experiment, is provided in Table 5. The analysis results indicated that the figures for the experimental class students in terms of the four dimensions mentioned above have changed. Moreover, the change is significant, while the p-value of the experimental class students in the four dimensions is 0.001, 0.000, 0.000, 0.000, and 0.000. The value of 0.05 will be considered as the significance level reference point. Thus, the post-test level in the experimental class was significantly better compared to the pre-test level, which means that, after the teaching experiment, the four dimensions of the experimental class were significantly improved. This means that the Bel canto comparative system improved the musical rhythmic intonation in the students, helped the

formation of the good pronunciation in the students, and also increased the singing status and classroom satisfaction of the students to some extent.

Table 5: Comparison of results before and after experiment of Laboratory class

	Pretest	Posttest	Posttest-Pretest	T	P
D1	2.43±0.252	2.85±0.252	0.42	8.554	0.001***
D2	2.52±0.225	2.93±0.252	0.41	3.541	0.000***
D3	2.34±0.225	2.96±0.211	0.62	10.234	0.000***
D4	2.66±0.224	3.01±0.192	0.35	5.248	0.000***

In summary, the traditional Bel canto classroom teaching method is single, mainly with the teacher explaining and demonstrating, and students imitating and practicing, which is not able to mobilize the students' interest in learning in the whole classroom, and the students can't really participate in and integrate into the music classroom, which results in the students' low satisfaction of the music classroom, and it is difficult to improve the effect of the cultivation of the Bel canto skills. The use of Bel canto comparison system to visualize and analyze students' American vocalizations can quickly and accurately provide guidance for students to improve their Bel canto skills.

6 Conclusion

In this paper, we designed the Bel canto comparison system to extract the Bel canto sound waveforms and realize the guidance for students in the cultivation of Bel canto skills. Through simulation tests, the sound waveforms extracted by the Bel canto comparison system can clearly show the fluctuation of the sound, and teachers can provide timely and accurate guidance for students based on the extracted waveforms. After the music teaching practice based on the Bel canto Comparison System, the students' music scores improved by 9.9 points, and the students' changes in the four dimensions of singing status, pronunciation, rhythmic intonation, and classroom satisfaction were large ($p < 0.001$). The application of digital technology makes vocal music teaching more intuitive, and can bring great space for exploration and development of traditional vocal music education and teaching system in terms of concept, content, means and methods.

About the Author

Xinna Li was born in Zhengzhou, Henan, P.R. China, in 1986. She obtained a doctor's degree from Keimyung University in South Korea. I am currently serving as a vocal music lecturer at the Music and Dance College of Zhengzhou Normal University. My main research direction is Vocal music education.

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