Música Hodie | ISSN: 2317-6776 DOI: 10.5216/mh.v25.80289

Using Internet of Things (IoT) Devices for an Interactive Learning Environment in Music Classes for Studying Bel Canto Technique

Usando dispositivos de Internet das Coisas (IoT) para um ambiente de aprendizagem interativo em aulas de música para estudo da técnica do Bel Canto

Jie Zheng
College of Music, Sichuan Normal University, ChengDu, China
jiezheng@gmx.com

Abstract: Regarding the context of creating an interactive learning environment, the impact of bel canto vocal pedagogy on the development of performance abilities among Chinese vocal students was studied. Based on the analysis method, the authors identified the advantages of using IoT devices for studying the Bel Canto technique by calculating the significance coefficient. The use of IoT devices for studying the Bel Canto technique contributes to training in breath control (2.557), standardization of musical sounds (2.518), development of vocal power (2.493), expansion of phonetic resonance (2.397), and vibrant expressiveness (2.009). The implementation of voice sensors facilitates detailed monitoring and analysis of students' vocal techniques. These technologies enable instructors to provide more precise and timely recommendations, enhance students' technical skills, and accelerate their progress. It is crucial to investigate the pedagogical and social aspects of IoT integration in music classes and the economic efficiency of these solutions. Standardized methods for assessing the effectiveness of IoT systems in music education need to be developed, and optimal approaches for their integration into traditional teaching methods must be determined.

Keywords: IoT-devices; phonetic differences; performance style; virtuosity of performance; workmanship.

Resumo: Em relação ao contexto de criação de um ambiente de aprendizagem interativo, foi estudado o impacto da pedagogia vocal do bel canto no desenvolvimento de habilidades de desempenho entre estudantes vocais chineses. Com base no método de análise, os autores identificaram as vantagens do uso de dispositivos IoT para estudar a técnica Bel Canto calculando o coeficiente de significância. O uso de dispositivos IoT para estudar a técnica Bel Canto contribui para o treinamento em controle da respiração (2,557), padronização de sons musicais (2,518), desenvolvimento de potência vocal (2,493), expansão da ressonância fonética (2,397) e expressividade vibrante (2,009). A implementação de sensores de voz facilita o monitoramento e a análise detalhados das técnicas vocais dos alunos. A utilização dessas tecnologias permite que os instrutores forneçam recomendações mais precisas e oportunas, aprimore as habilidades técnicas dos alunos e acelere seu progresso. É crucial investigar os aspectos pedagógicos e sociais da integração da IoT em aulas de música, bem como a eficiência econômica dessas soluções. É necessário desenvolver métodos padronizados para avaliar a eficácia dos sistemas de IoT na educação musical e determinar abordagens ótimas para sua integração em métodos de ensino tradicionais.

Palavras-chave: Dispositivos IoT; diferenças fonéticas; estilo de execução; virtuosismo da execução; acabamento.

Submitted on: August 26, 2024
Accepted on: October 1, 2024
Published on: January 2025

1. Introduction

The active interaction of musical cultures resulted in changes in the techniques of teaching vocal skills at the end of the 20th century and the beginning of the 21st century. Bel Canto is one such performance technique (Quin, 2021). The concept of "Bel Canto" implies a technique of virtuoso performance, which provides for the transition of smoothness of sounds, saturation of sound, and mobility of melodic patterns (Yu, Krom, 2018). In Chinese music, the Bel Canto technique directly relates to the Western style of performance, built with academism (Ho, 2018). The genesis of the bel canto technique is intricately linked to the manifestation of elevated standards in vocal performance, which are intertwined with technical precision and artistic mastery.

Furthermore, the canto technique is associated with the inherent nature of the human voice, specifically directed towards the rendition of high notes. Bel canto technique is characterized by exemplary singing, wherein substantial attention is accorded to the timbre of the voice and a high level of artistic finesse. Consequently, applying the bel canto technique can be extended to interpreting Chinese compositions, which are known for their brilliance, virtuosity in sound, and elevated levels of artistic expressiveness. The virtuosity of execution reflects adherence to the technical parameters of the composition, incorporating melodic embellishments to achieve harmonic resonance in the musical pieces. Based on this, Bel Canto's techniques for vocal training in China correlate with Western and national musical traditions (Zheng et al., 2017). The difference in sound stylistics, breathing techniques, and artistic elements reflects the juxtaposition of different cultures (Ho, 2018). A Chinese performer must master free breathing, artistic intonation, and resonator sound production, interrelated with phonetics and articulation through the Bel Canto technique (Hash, 2017). The Western manner of performance stems from sound mixing, which combines pure performance and falsetto as a result of smooth cross-fades (Chen, Lee, 2013).

Register cross-fades help Chinese performers comply with the requirements of the Bel Canto technique. Sound production should also be given special attention since it should aim at forming a free sound that affects the performance quality (Liu, Zhou, 2021). The difficulties of Chinese performers' mastering Bel Canto stem from the phonetic differences between Chinese and European languages (He, 2020). They manifest in a considerable distance between vowels and consonants in the Chinese language, which requires work on articulation (He, 2020). The challenges confronted by Chinese performers while utilizing the bel canto technique are also linked to the performance style, which manifests in sound stylistics and metro rhythmic aspects. The distinction between Western and Chinese performance styles may impact the reflection of sufficient artistic execution and expressiveness (Chen, 2023). Furthermore, challenges for Chinese vocalists are associated with the necessity of adopting diaphragmatic breathing and differences in the intonation of Chinese and European languages. Special attention should be directed towards intonation, as it significantly influences the artistic rendering of musical compositions.

Contemporary technologies can ensure systematic training to address the presented challenges (Ho, 2018). The utilization of diverse repertoires facilitates the monitoring of precision in executing specific musical parameters, aiming at developing practical skills and their subsequent variations. This approach enables access to a musical library, fostering practical capabilities (Liu, Zhou, 2021). Digital technologies facilitate interaction between educators and students in a remote setting. Using Internet of Things (IoT) devices in interactive educational environments within music classrooms aims to enhance learning efficiency (Terzieva et al., 2022). However, traditional teaching methods often prove insufficiently flexible and adapted to individual student needs, potentially resulting in slowed learning processes and diminished motivation (Hofer et al., 2021). Modern IoT technologies offer innovative solutions to address these challenges by enabling the creation of interactive learning environments. Here, students can

receive instant feedback, utilize personalized learning programs, and interact in real-time with various musical instruments and devices (Li, Han, 2023; Nižetić et al., 2020; Sarker et al., 2023). Yet, implementing such technologies in educational settings is accompanied by several challenges, including the complexity of integrating diverse IoT devices, ensuring data security, and maintaining system stability under high load conditions (Liao et al., 2020; Sadeeq et al., 2021).

The motivation behind this article lies in the necessity to explore the capabilities and advantages of using IoT in music education, particularly for teaching bel canto technique, and to identify key technical and methodological approaches for developing effective interactive learning environments. The relevance of this topic is underscored by the increasing popularity of digital technologies in education and the need for individualized educational programs tailored to each student's abilities and requirements. This research contribution holds the potential to significantly refine methods for teaching musical techniques, foster a deeper understanding of vocal training processes, and enhance student outcomes through the application of modern technologies.

1.1 Literature Review

Multimedia training saves time and increases the effectiveness of acquiring musical knowledge and skills. In vocal training, multimedia technologies aim to display graphics, images, sound, and animation, establishing a logical relationship between students and learning tools. Computer technologies aim to facilitate and optimize the learning process, which contributes to transferring melodies and musical knowledge (Peng, 2021). Cross-vocal training contributes to the provision of modern training needs. Cross-training results from the study of several musical aspects that are applied during one lesson in turn. For example, the development of articulation and range of sound. During the development of vocal skills using the Bel Canto technique, the emphasis should also be placed on breathing, which is interrelated with performance

quality. The Bel Canto technique should rest on a combination of aesthetic, artistic, and technical indicators (Wilson, 2021). The Bel Canto technique should include resonance, sound formation, vocal phonetics, and articulation. For the distance-learning format, it is necessary to ensure high-quality transmission of acoustic processes, which can be achieved using online platforms.

Providing a vocal learning process in an online learning environment should be associated with listening to videos and audio materials that contribute to developing virtuoso vocal skills. Orientation on the singing of J. Puccini, who also used the Bel Canto technique, allows the development of academician vocal skills. During the training, the emphasis should be placed on vocal-technical and aesthetic indicators, which are interrelated with singing, breathing, and imaginative thinking. The expressiveness of the sound is achieved by improving the timbral tone, considering dynamic nuances (Semkin, Bushueva, 2020). Music education should rest on a high-quality sample of vocal art performed in the Bel Canto technique. Vocal training should develop vocalization skills, emphasizing passaggio and duration of notes (Zhang, Yu, 2021).

To develop vocal skills, performers should vary in genres and musical styles. Primary emphasis should be placed on breath control and resonance within the context of the Bel Canto technique and contemporary vocal music. The use of various musical styles influences a repertoire based on different vocal qualities (Winnie, 2017). The Bel Canto performance style should stem from analyzing sound recordings of famous performers (Fernando de Lucia, Alessandro Bonci, and Giacomo Lauri-Volpi). This makes it possible to study approaches to the interpretation of a musical text and to identify the characteristic attributes of a performance, which manifest themselves in the range of sound, the manner of performance, and the use of expressive elements. Listening to compositions also helps to determine a harmonious combination of virtuosity and ease of performance (Zaitov, 2016).

The development of Internet of Things (IoT) devices and their application in educational technologies is a topic actively researched within the academic community. General trends in published works indicate a growing interest in integrating IoT into various fields of education, including music education (Qiao, 2021). Researchers emphasize the potential of IoT to enhance learning effectiveness, provide interactivity and adaptability in educational environments, and explore its potential for creating more personalized educational programs (Cheung et al., 2021; Matthew et al., 2021).

Most studies focus on developing and testing individual IoT devices and systems that can assist in teaching musical techniques. For instance, a range of sensor devices has been developed to measure voice parameters and musical instrument data, providing instant feedback (Davanzo, Avanzini, 2020; Dickens, 2022; Turchet et al., 2020). However, in theory and practice, conflicts exist regarding the optimal methods for integrating these devices into the educational process. Some studies highlight the necessity of a comprehensive approach that combines IoT with traditional teaching methods, while others advocate for complete automation and digitalization of the process (Khanna, Kaur, 2020; Sadeeq et al., 2021).

Methodological issues also remain pertinent. Different approaches to designing IoT systems for music education often lead to discrepancies in research outcomes. The absence of standardized methods for assessing the effectiveness of such systems complicates comparisons across studies and limits the generalizability of conclusions.

Among the primary constraints in research, it is noteworthy to mention the insufficient amount of empirical data regarding the long-term impact of IoT usage in music education and the lack of studies analyzing the economic efficiency of implementing these technologies. Most existing works focus on the technical aspects of developing and testing IoT devices, neglecting the pedagogical and social aspects of their application. The relevance of this article is

driven by the necessity to overcome these limitations and develop a comprehensive approach to utilizing IoT in teaching the Bel Canto technique. The main novelty of the study lies in integrating IoT devices into the educational process while considering the specifics of music education and individual student needs, thereby enabling more effective and personalized learning. Thus, the article contributes to filling gaps in existing research and proposes new approaches to developing interactive learning environments for music classrooms.

2. Materials and Methods

2.1 Study Design

The first stage of the study included determining the advantages of the Bel Canto technique for vocal training. We chose the Bel Canto technique as the basis of the survey since it contributed to improving vocal skills based on the traditions of different nationalities. This study emphasized the combination of Western European and Chinese vocals. Bel Canto promotes the development of virtuoso vocal singing, contributing to sound's free reproduction. Using the analysis method, the authors revealed the following advantages of the Bel Canto technique:

- respiratory training;
- combining musical sounds;
- development of sound power;
- expansion of sound phonetics;
- colorful expressiveness.

The chosen analysis method for this study involved the exploration of theoretical materials and existing musical compositions utilized in the practice of the Bel Canto technique. Within the scope of the study, vertical analysis was employed, enabling the examination of the nuances of musical composition

performance in the bel canto style. Additionally, vertical analysis facilitated the identification of specific indicators influencing the development of the bel canto technique. The analysis of musical works within the Bel Canto technique and Chinese national compositions facilitated the identification of distinctive features of Bel Canto. Identifying specific elements presupposed their presence in more than 50% of the 580 analyzed compositions. The authors of the article directly determined the findings.

Additionally, among the identified features of the bel canto technique, their significance was further determined by the potential enhancement of the quality of vocal performance in Chinese compositions. This impacted the development of teaching approaches in the context of distance learning. They calculated the significance coefficient by determining the most effective impact of the identified advantages. The formulation development was undertaken by the authors based on the assumption of the potential effectiveness of a specific characteristic indicator of the bel canto technique. This endeavor was directed towards achieving high-quality vocal performance in the future.

$$k_{sign} = \frac{\sum \left(N_a T_{a(i)} \right)}{N_p}, \quad (1)$$

where N_a is the number of significant indicators; $T_{a(i)}$ is the conditional effect of the advantages of the Bel Canto technique; N_p is the total number of advantages.

The advantages of the Bel Canto technique made it possible to determine the need to introduce it into the educational process. The progression of Bel Canto vocal skills was aligned with established methodologies, prioritizing aspects such as breath control, pitch development, sound clarity, and expressive aptitude (Wilson, 2021; Yoo, 2017; Zaitov, 2016). The uniqueness of this study lies in the formation of approaches to vocal training based on the Bel Canto technique because of its adaptation to the distance-learning format. We identified the following methods to learning to ensure the educational process is effective for one semester (September 2023 – February 2024):

- communication during training;
- work on vocals;
- work on diction;
- emphasis on conducting movements;
- group singing.

The training took place gradually, evolving through the development of communication skills among the participants in the educational process, which subsequently influenced work on vocal techniques, diction, emphasis on conducting gestures, and group singing. The training was centered on the practical development of vocal skills by applying the Bel Canto technique. The selection of a musical composition for the study involved initial vocal work that required developing technical skills.

The third stage of the study involved determining the effectiveness of the developed approaches to learning. Initially, we determined the three most compelling aspects of training (technical skills, expressive performance, and learning processes) for students and teachers. They also determined the indicators for calculating the significance coefficient using formula (1). Determining instructional aspects involved using the same formula as employed in the initial stage of the research. This approach aimed to affirm the interconnection between different phases of the study.

Using the Cohen coefficient, they calculated the statistical relationship between the indicators within one study group (students or teachers).

$$d=\frac{(M_1-M_2)}{\sqrt{\frac{S_1^2+S_2^2}{2}}}, \quad (2)$$

where M_1 and M_2 are the average values of the indicators between students and teachers; S_1 and S_2 are the quadratic mean deviations of the data obtained between students and teachers.

The calculation of the Cohen coefficient shows the relationship between the values when the calculated values approach 0.

We determined the quality of the student's knowledge at the third stage of the study. The musical compositions were selected for performance based on the authors' preferences and the specified songs. In this process, students were required to possess technical knowledge, which contributed to their understanding of the Bel Canto technique. Accurate and clean performance of musical compositions resulted in high students' knowledge. Up to 3 mistakes marked average knowledge; failure to complete the tasks indicated low knowledge. The assessment of student's knowledge was conducted by 20 educators who instructed over 700 students in vocal performance using the bel canto technique.

$$y_m = \frac{\sum O_T + \sum O_{ae}}{\sum O} \times d, \quad (3)$$

where ΣO_T – points for the technique of execution; ΣO_{ae} – points for the aesthetics of performance; ΣO – the number of acceptable points; d – the performance quality coefficient.

The calculated indicator from 0.79 to 1.0 showed a high quality of knowledge. The average level of knowledge was 0.51 to 0.78. The calculated indicator from 0.1 to 0.5 characterized a low quality of expertise.

A multimodal system was employed that detects the student's vocal pitch and respiratory state, providing real-time visual feedback. The system displays musical scores with the tonic sol-fa and breathing cues in the background mode. Based on singing mechanics, the wearable device utilizes pressure sensors to detect movements of the ribs, lower abdomen, and waist to measure respiratory state. Subsequently, the detected data on respiratory movements and pitch frequency are processed and visualized to help students understand their breathing patterns and pitch characteristics. The device comprises five thin-film pressure

sensors on an RP bend length of 110 mm and five resistance-to-force conversion modules connected sequentially to the sensors. The pressure sensors are separately located on the front lower abdomen, two segments of the waist at the back, and two sides of the ribs. Each pressure sensor consists of two parts: a thin film and a pressure-sensitive layer on the upper part of the sensor and a thin film and a conductive circuit on the lower part. When external force is applied to the active area, the disconnected chain of the lower layer will connect through the upper layer's pressure-sensitive layer, converting force into resistance. We affixed elastic Velcro straps on the sides of the belt, overlapping to adjust the length and ensure a snug fit to the student's body. To better accommodate the positioning of each sensor for various body shapes, we placed a large area of loops on the inner layer of the belt so that sensors with hooks could be adjusted to the desired location.

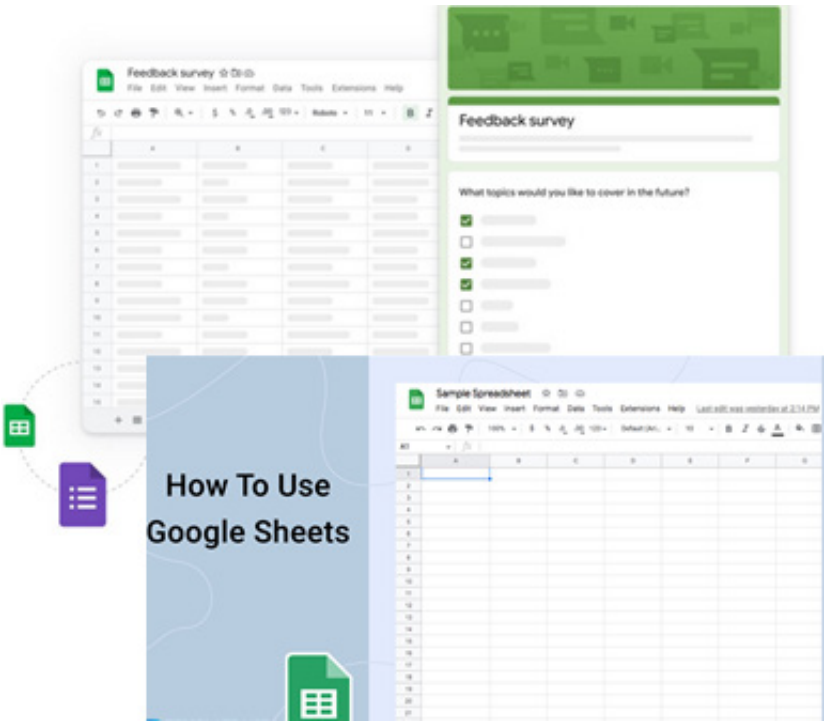
2.2 Sampling

The study involved 182 students (79 males and 103 females) and 20 teachers from Minxi Vocal & Technical (Longyan, China). Gender distribution did not impact the study or the attainment of final results. The sampling condition included vocal specialties to perform Chinese national musical compositions. First-year students were selected for the study as they did not possess the established Bel Canto technique, which ensures the preservation of the national vocal style. The limitations within the scope of the study allowed for monitoring the level of development in technical skills and expressive performance after undergoing the training. The sample of students consisted of 200 people. However, 18 students did not meet the criteria because they studied modern musical creativity. As the study aimed to examine the comprehensive application of Bel Canto techniques for vocal development in a distance learning setting, it was not obligatory to gather information regarding the distribution of students by gender and age.

2.3 Statistical Processing

We selected the Spreadsheet application to calculate the results (Figure 1). It allowed formatting and creating tables with the necessary data for calculations. The program's functionality is analogous to Microsoft Excel, enabling the input of formulas for calculations and the creation of distinct figures. They used Spreadsheets to calculate the effectiveness of the influence of Bel Canto's advantages on the learning process, the quality of training, and the Cohen coefficient.

Figure 1 - The functionality of the Spreadsheet application utilized for conducting calculations



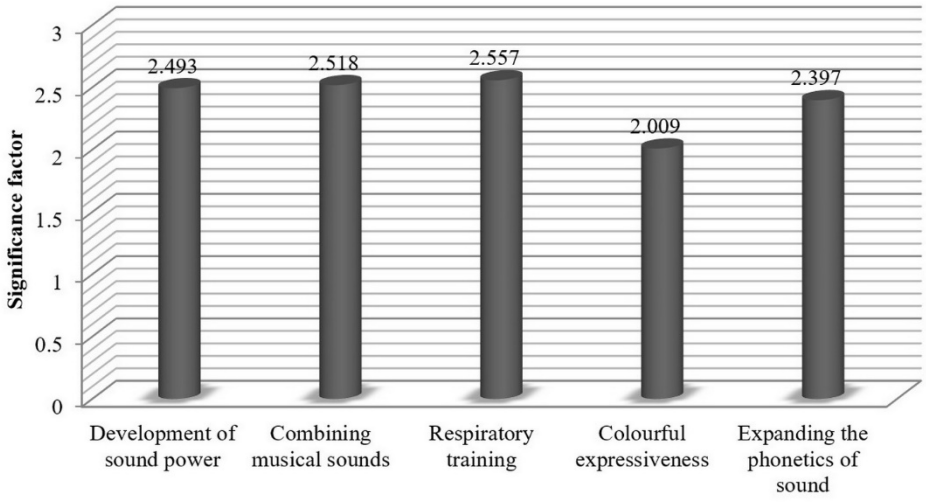
2.4 Ethical Issues

Ethical issues contribute to conducting research within the framework of regulated norms (ESOMAR, 2016). The confidentiality of data from the students and teachers ensured high-quality research results. The authors exclude falsification and borrowing of the proposed research results.

3. Results

The development of vocal performance skills can result from effective methods and techniques, which can be represented by an emphasis on the development of practical skills, the study of theoretical material, the development of creative skills, and the application of the Orff or Suzuki techniques. The conducted research emphasized vocal training using the Bel Canto technique. We employed the significance coefficient (Figure 2) to demonstrate the advantages of using IoT devices for studying the Bel Canto technique. The establishment of significance parameters was achieved based on the utilization of the vertical analysis method.

Figure 2 - Advantages of the Bel Canto technique for vocal training



Respiratory training is essential to the Bel Canto technique (2.557), which affects the sound that is aligned and clear during performance. The Bel Canto technique during the performance of Chinese songs contributes to the breathing amplitude because of the development of mixed breathing. The Bel Canto technique involves using a large amount of air, which is not typical of the Chinese manner of performance. Therefore, Bel Canto contributes to a subtle flow of air, affecting the performance depth.

Combining musical sounds (2.518) is also an advantage of the Bel Canto technique since it promotes a combination of natural sound and falsetto, which is displayed harmoniously and affects the pitch of sounds. Bel Canto contributes to the sounding range, which can result from a smooth sound rather than using a single register, which was previously characteristic of Chinese folk compositions. Combining musical sounds contributes to the clarity and precision of sounds. Shallow breathing contributes to less force of sounds, which affects the variety of breathing.

The development of sound power (2.493) is also possible using the Bel Canto technique, while vowel sounds are formed in the forepart of the mouth. A half-breath helps to create long sounds supported by breathing in the Bel Canto technique. To maintain the purity of sounds and the development of Chinese national vocals, the resonator center should be directed forward, while the throat should be used minimally. Using the Bel Canto technique allows for sound reinforcement in Chinese vocals, manifesting itself in high notes' purity. Using mixed resonance contributes to combining Chinese national vocals and Western singing.

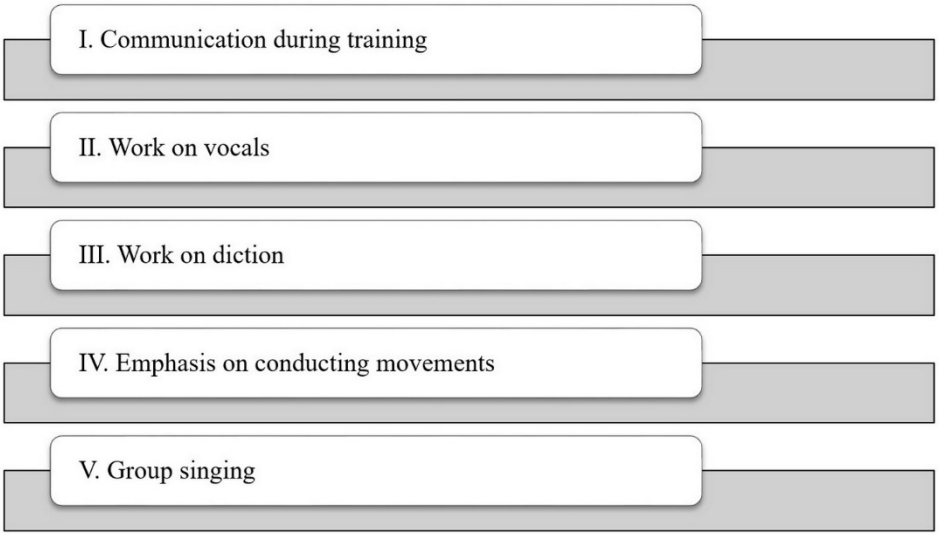
The expansion of sound phonetics (2.397) affects the preservation of national color, which results from a rigorous approach to word pronunciation and articulation. Hard consonants are formed because of airflow, and the emphasis is primarily on consonant sounds. Combining syllables and lengthening the middle part of words achieves a harmonious combination of words and music. The middle part also affects the change in timbre and resonance, while the first part affects the naturalness of performance.

Colorful expressiveness (2.009) stems from using register and intonation ratio and ease of sound formation in the Bel Canto technique—the principles of Bel Canto rest on maximum naturalness, which is also characteristic of Chinese singing. When training the Bel Canto technique, the emphasis should be on smooth register transitions, which contribute to the evenness of sounds in different ranges. The expressiveness of sounds is achieved

because of reducing the load on the vocal cords and affecting the performance quality when using the Bel Canto technique.

Based on the advantages of the Bel Canto technique, this research identified approaches that contributed to acquiring national vocal performance skills in a distance-learning format using online platforms. The development of teaching approaches also involved the application of the vertical analysis method aimed at facilitating the education of 182 students (Figure 3).

Figure 3 - Approaches for acquiring vocal skills in a remote format



We identified the expectations of students (182 students) and instructors (20 instructors) regarding the presented teaching process over 6 months (Table 1).

Table 1 - The influence of the learning process on the development of technical, expressive skills and training

Group of respondents	Development of technical skills	Development of performance expressiveness	Organization of learning processes
Students	2.731	2.018	1.964
Teachers	2.615	1.872	2.597
Comparison of data based on the Cohen coefficient	0.027	0.052	0.047

The results indicated that students (2731) and teachers (2615) perceive that the presented teaching approach predominantly enhances technical skills development. This is attributed to the adherence to Bel Canto technique requirements during instruction, facilitated by IoT devices. This has impacted the quality of sessions and the fidelity of sound reproduction, which is crucial for developing vocal skills. Students believe that these teaching approaches contribute to expressive performance development (2.018), as they could perceive melodies played by the instructor accurately.

The culmination of the research process involved assessing the quality of knowledge acquired by students (Table 2).

Table 2 - The quality of knowledge acquired by the students during the distance learning process

Quality of training	Percentage distribution of the students	Training quality indicator
High	73%	0.92
Average	26%	0.67
Low	1%	0.21

The results indicated that 73% of students achieved high-quality knowledge, as evidenced by their ability to correctly interpret musical compositions using the Bel Canto technique. However, 1% of students acquired weak knowledge due to incomplete attendance at all sessions, which affected the quality of information assimilation.

4. Discussion

Improving the quality of vocal training following the Bel Canto technique can result from using computer applications based on semantic recognition of Bel Canto elements. The clustering method would help to appraise sound quality (Ke, 2022). The development of vocal skills should begin in childhood, contributing to the accuracy of vocal performance. Education using IoT devices

contributes to forming a new educational system that enhances accessibility to learning regardless of location and time constraints. The development of singing should stem from improving vocal fold vibrations and the degree of voice interruption. Voice production should emphasize rhythmic intonation. The results showed that the performance accuracy of familiar songs was higher than that of unfamiliar compositions (Kim, 2022). Skills in using melodic patterns result from imitative processes, which are based on modeling sounds in one tone and during the transition to another. In our article, the determination of the optimal perception of music education based on the age of students was not explored. However, we indicated that the quality of acquiring vocal knowledge depends on the approaches employed. Based on this, researchers have elucidated the advantages of using IoT devices for studying the Bel Canto technique, which results in improved breath control, standardized musical sounds, development of vocal strength, expansion of phonetic range, and vibrant expressiveness.

When learning vocals, attention should be paid to the accuracy of pronunciation. The motor skills of speech have a direct impact on pitch and intonation. The pitch of sounds stems from studying new associations of speech and sound and receiving auditory feedback using online technologies. Vocal training should be a systematic and disciplined process which affects the quality of sound production and emission (Chen et al., 2015). The precision and excellence of performance are interconnected with the act of breathing, as it significantly influences the fluidity of sound production (Wang, 2022). The study of national musical compositions should rest on the use of rich sounds that reflect the history and culture of China. At the same time, preserving acoustic parameters is an essential aspect of a harmonious combination with texts of compositions. When using the Bel Canto technique, they must repeat melodic models to comply with the national musical style. Therefore, the same melodies should be played in different keys during training (Chan, 2022). Unlike the analyzed studies, our research

demonstrated that teaching methods and expressiveness can be enhanced through the application of IoT devices.

Intercultural communication allows for extending the potential of the learning process. The improvement of vocal skills stems from playing melodies aurally and recording and listening to songs, chords, and intervals. The interaction of technologies and training programs allows for effective feedback and individual training (Shi, 2021).

Integrating devices in music classrooms presents new opportunities for enhancing the quality of education and achieving outcomes. In particular, using sensors, smart devices, and Internet of Things (IoT)-based applications enables the real-time collection of detailed data on students' vocal performance metrics. Consequently, instructors can analyze student performances with greater precision and provide personalized recommendations. This approach has the potential to significantly transform the dynamics of teaching, making it more interactive and flexible. Rather than adhering to traditional "passive" learning methods, where students merely absorb knowledge, IoT devices can facilitate active student engagement in self-analysis of their performance. However, it is crucial to acknowledge that implementing such technologies necessitates changes in lesson planning and assessment approaches, as educators will need to familiarize themselves with new methods for working with IoT technologies. The social implications of integrating IoT into music education are equally significant, as introducing these devices alters not only teaching methodologies but also the social dynamics within the classroom. Students can receive immediate feedback not only from their instructors but also from IoT systems. Conversely, it is essential to consider the potential social challenges; for instance, using IoT devices may exacerbate the digital divide between students with access to these technologies and those without, potentially impacting learning outcomes and developmental opportunities. Moreover, some students may experience feelings of isolation if their interaction with technology supplants interpersonal communication with instructors or peers.

To evaluate the effectiveness of IoT systems in vocal education, it is advisable to develop preliminary frameworks or criteria that encompass both the pedagogical and technical aspects of these technologies' impacts. It is essential to focus on student learning outcomes. The primary criterion for assessing the effectiveness of IoT technologies should be the enhancement of students' technical proficiency in performing vocal exercises and techniques. This proficiency can be measured using objective data collected by IoT devices, such as pitch accuracy, duration of tone retention, and breath control.

Additionally, the level of student engagement in the learning process should be taken into account; assessment criteria may include the quantity and quality of interactions with IoT devices during lessons, the frequency of independent practice utilizing these technologies, and student participation in feedback and discussions with instructors. Another component is the effectiveness of the pedagogical process: educators must be able to adapt their teaching methods based on the data obtained through IoT. Criteria could be developed to assess how the integration of IoT assists instructors in providing individualized feedback and adjusting curricula according to each student's needs. This assessment may involve evaluating the extent to which analytical data are utilized in teaching materials and strategies and the overall impact of this data on teaching effectiveness.

Furthermore, an essential component is the technical performance metrics of IoT systems, which encompass device stability, the accuracy and timeliness of data collection and processing, and the user-friendliness of technologies for both students and educators. It is also vital to assess the integration of IoT with other educational resources and platforms; criteria could include user feedback regarding the convenience and ease of use of these systems, along with technical reports on device uptime and error rates.

Finally, the extent to which IoT usage fosters interaction between students and educators should be evaluated, along with any issues of social inequality or digital divide that may arise. Ethical considerations related to student data privacy and the confidentiality of collected information should also be addressed. Therefore, these criteria can be a foundation for further research and enhancement of IoT systems in music education.

While discussing literary sources, researchers identified that most studies focus on exploring the benefits of a single program, which has led to the emergence of new approaches to creating interactive learning environments. In our study, the research process was centered on enhancing Bel Canto's vocal skills through the application of IoT devices. The research also identified the overall effectiveness of the proposed teaching approaches and assessed the quality of student learning outcomes.

5. Conclusions

The study enabled researchers to identify the advantages of using IoT devices to study the Bel Canto technique. It was found that these advantages include breath training, standardization of musical sounds, development of vocal strength, expansion of phonetic range, and vibrant expressiveness. After a semester of training, we found that the students (2.731) and the teachers (2.615) believed that training influenced the development of technical skills due to the selection of high-quality auxiliary elements that affected the effectiveness of training. This allowed for the development of vocal singing skills in the bel canto technique, which manifested in the performance of musical compositions of varying levels of complexity. The practical significance of this paper includes improving online vocal training using the presented technologies, the effectiveness of which the researchers determined by calculations. The research prospects should be associated with combining vocal development techniques to ensure greater expressiveness of sounds. Additionally, there are plans to explore the advantages of contemporary technologies and the difficulties that arise from

their integration into music instruction. In the future, the authors plan to expand the age category of respondents for teaching vocal skills based on the advantages of the Bel Canto technique (school-age children (9-12 years old) and students (17-21 years old).

References

CHAN, Stephen C. K. Resistance, activism and ordinary life: An editorial introduction. **Cultural Studies**, v. 36, n. 2, p. 171–184, 2022. https://doi.org/10.1080/09502386.2021.1912799.

CHEN, Jason Chi Wai; LEE, Han Wai. A pilot study of using jazz warm-up exercises in primary school choir in Hong Kong. **Music Education Research**, v. 15, n. 4, p. 435–454, 2013. https://doi.org/10.1080/14613808.2013.788142.

CHEN, Meng. Investigation of the Understanding and Application of Musical Imagery in China University Music Students. **Applied & Educational Psychology**, v. 4, n. 3, p. 54–58, 2023. https://doi.org/10.23977/appep.2023.040308.

CHEN, Zhaocong; WONG, Francis C. K.; JONES, Jeffery A.; LI, Weifeng; LIU, Peng; CHEN, Xi; LIU, Hanjun. Transfer effect of speech-sound learning on auditory-motor processing of perceived vocal pitch errors. **Scientific Reports**, v. 5, p. 13134, 2015. https://doi.org/10.1038/srep13134.

CHEUNG, Simon K. S.; KWOK, Lam For; PHUSAVAT, Kongkiti; YANG, Harrison Hao. Shaping the future learning environments with smart elements: challenges and opportunities. **International Journal of Educational Technology in Higher Education**, v. 18, p. 1–9, 2021. https://doi.org/10.1186/s41239-021-00254-1.

DAVANZO, Nicola; AVANZINI, Federico. Hands-free accessible digital musical instruments: conceptual framework, challenges, and perspectives. **IEEE Access**, v. 8, p. 163975–163995, 2020. https://doi.org/10.1109/ACCESS.2020.3019978.

DICKENS, Amy. **Digital Musical Instruments, Accessibility, and Facilitated Performance**. Doctoral dissertation. University of Nottingham, 2022.

ESOMAR. **International ICC/ESOMAR Code**. 2016. Available at: https://www.esomar.org/uploads/public/knowledge-and-standards/codes-and-guidelines/ICCESOMAR_Code_Russian_.pdf. Accessed on 26 August 2024.

HASH, Phillip M. Development and validation of a music self-concept inventory for college students. **Journal of Research in Music Education**, v. 65, n. 2, p. 203–218, 2017. https://doi.org/10.1177/0022429417695750.

HE, Chengzhou. 'The most traditional and the most pioneering': New concept Kun opera. **New Theatre Quarterly**, v. 36, n. 3, p. 223–236, 2020. https://doi.org/10.1017/S0266464X20000469.

HO, Wai-Chung. The Confucian value of harmony in music education in relation to songs. **Cultural Studies and Transdisciplinarity in Education**, v. 7, p. 119–154, 2018. https://doi.org/10.1007/978-981-10-7533-9_5.

HOFER, Sarah I.; NISTOR, Nicolae; SCHEIBENZUBER, Christian. Online teaching and learning in higher education: Lessons learned in crisis situations. **Computers in Human Behavior**, v. 121, p. 106789, 2021. https://doi.org/10.1016/j.chb.2021.106789.

KE, Feng. Research on machine semantic recognition in different Bel Canto music backgrounds. **Advances in Multimedia**, v. 2022, p. 9509672, 2022. https://doi.org/10.1155/2022/9509672.

KHANNA, Abhishek; KAUR, Sanmeet. Internet of things (IoT), applications and challenges: a comprehensive review. **Wireless Personal Communications**, v. 114, p. 1687–1762, 2020. https://doi.org/10.1007/s11277-020-07446-4

KIM, Bong-Hyun. Analysis of learning effect through voice signal analysis in online education environment. **Journal of Curriculum and Teaching**, v. 11, n. 5, p. 95–104, 2022. https://doi.org/10.5430/JCT.V11N5P95.

LI, Lintao; HAN, Zhongling. Design and innovation of audio IoT technology using music teaching intelligent mode. **Neural Computing and Applications**, v. 35, n. 6, p. 4383–4396, 2023. https://doi.org/10.1007/s00521-022-07025-7.

LIAO, Bin; ALI, Yasir; NAZIR, Shah; HE, Long; KHAN, Habib Ullah. Security analysis of IoT devices by using mobile computing: a systematic literature review. **IEEE Access**, v. 8, p. 120331–120350, 2020. https://doi.org/10.1109/ACCESS.2020.3006358.

LIU, Jinyi; ZHOU, Min. The role of innovative approaches in aesthetic vocal performance. **Musica Hodie**, v. 21, p. e69132, 2021. https://doi.org/10.5216/MH.V21.69132.

MATTHEW, Ugochukwu; KAZAURE, Jazuli; OKAFOR, Nwamaka. Contemporary development in E-Learning education, cloud computing technology & internet of things. **EAI Endorsed Transactions on Cloud Systems**, v. 7, n. 20, p. e3, 2021. https://doi.org/10.4108/eai.31-3-2021.169173.

NIŽETIĆ, Sandro; ŠOLIĆ, Petar; GONZÁLEZ-DE-ARTAZA, Diego López-de-Ipiña; PATRONO, Luigi. Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future. **Journal of Cleaner Production**, v. 274, p. 122877, 2020. https://doi.org/10.1016/j.jclepro.2020.122877.

PENG, Fang. Optimization of music teaching in colleges and universities based on multimedia technology. **Advances in Educational Technology and Psychology**, v. 5, n. 5, p. 47–57, 2021. https://doi.org/10.23977/aetp.2021.55009.

QIAO, Xinjie. Integration model for multimedia education resource based on internet of things. **International Journal of Continuing Engineering Education and Life Long Learning**, v. 31, n. 1, p. 17–35, 2021. https://doi.org/10.1504/IJCEELL.2021.111849.

QUIN, Rhythy. East meets west: Investigating the state of DJing culture and turntablism pedagogy in China. **International Journal of Music Education**, v. 39, n. 3, p. 327–339, 2021. https://doi.org/10.1177/0255761421990813.

SADEEQ, Mohammed Mohammed; ABDULKAREEM, Nasiba M.; ZEEBAREE, Subhi R. M.; AHMED, Dindar Mikaeel; SAMI, Ahmed Saifullah; ZEBARI, Rizgar R. IoT and Cloud computing issues, challenges and opportunities: A review. **Qubahan Academic Journal**, v. 1, n. 2, p. 1–7, 2021. https://doi.org/10.48161/qaj.v1n2a36.

SARKER, Iqbal H.; KHAN, Asif Irshad; ABUSHARK, Yoosef B.; ALSOLAMI, Fawaz. Internet of things (IoT) security intelligence: a comprehensive overview, machine learning solutions and research directions. **Mobile Networks and Applications**, v. 28, n. 1, p. 296–312, 2023. https://doi.org/10.1007/s11036-022-01937-3.

SEMKIN, Dmitry; BUSHUEVA, Lyubov. Giacomo Puccini's operatic legacy and its study in the practice of vocalists. **Wisdom**, v. 15, n. 2, p. 199–209, 2020. https://doi.org/10.24234/WISDOM.V15I2.355.

SHI, Yaoyao. The use of mobile internet platforms and applications in vocal training: Synergy of technological and pedagogical solutions. **Interactive Learning Environments**, v. 31, n. 6, p. 3780–3791, 2021. https://doi.org/10.1080/10494820.2021.1943456.

TERZIEVA, Valentina; ILCHEV, Svetozar; TODOROVA, Katia. The Role of Internet of Things in Smart Education. **IFAC-PapersOnLine**, v. 55, n. 11, p. 108–113, 2022. https://doi.org/10.1016/j.ifacol.2022.08.057.

TURCHET, Luca; PAUWELS, Johan; FISCHIONE, Carlo; FAZEKAS, György. Cloud-smart musical instrument interactions: Querying a large music

collection with a smart guitar. **ACM Transactions on Internet of Things**, v. 1, n. 3, p. 1–29, 2020. https://doi.org/10.1145/3377881.

WANG, Yueli. Music education: Which is more effective – traditional learning or the introduction of modern technologies to increase student motivation?. **Learning and Motivation**, v. 77, p. 101783, 2022. https://doi.org/10.1016/j.lmot.2022.101783.

WILSON, Lara C. Bel canto to punk and back: Lessons for the vocal cross-training singer and teacher. **Voice and Speech Review**, v. 15, n. 3, p. 330–341, 2021. https://doi.org/10.1080/23268263.2021.1889245.

WINNIE, Brian J. Bridging the gap between classical and contemporary vocal technique: Implications for the choral rehearsal. **Voice and Speech Review**, v. 11, n. 1, p. 55–71, 2017. https://doi.org/10.1080/23268263.2017.1370803.

YOO, Hyesoo. Multicultural choral music pedagogy based on the facets model. **Music Educators Journal**, v. 104, n. 1, p. 34–39, 2017. https://doi.org/10.1177/0027432117708602.

YU, Fan; KROM, Anna E. The study and practice of applying the serial technique in China. **Music Scholarship**, v. 2, p. 66–73, 2018. https://doi.org/10.17674/1997-0854.2018.2.066-073.

ZAITOV, G. S. The particularities of the performing art of the masters of the Bel Canto school. **Music Scholarship**, v. 1, p. 107–113, 2016. https://doi.org/10.17674/1997-0854.2016.1.107-113.

ZHANG, Hao-Lan; YU, Peng-Jiang. Design of multimedia vocal music education data integration system based on adaptive genetic algorithm. **Security and Communication Networks**, v. 2021, p. 3897696, 2021. https://doi.org/10.1155/2021/3897696.

ZHENG, Xiaomei; LI, Dongyang; WANG, Lei; SHEN, Lin; GAO, Yanyuan; ZHU, Yuanyuan. "An automatic composition model of Chinese folk music." In: Liu, L. (Ed.). **Advances in Materials, Machinery, Electronics I: Proceedings of the International Conference on Advances in**

Materials, Machinery, Electronics (AMME 2017). Melville, NY: AIP Publishing LLC, 2017. p. 080003. https://doi.org/10.1063/1.4977359.

Authorship contribution

Jie Zheng: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Research ethics committee approval

The study protocol was approved by the Ethics Committee of Sichuan Normal University (Protocol No. 359 of 20 Apr 2023). The study was conducted in accordance with the rules of the Declaration of Helsinki. All subjects gave written informed consent prior to participation.

Publisher

Federal University of Goiás. School of Music and Performing Arts. Graduate Program in Music. Publication in the Portal of Periodicals UFG.