Research on the Application of AI in Music Education and Teaching in Primary and Secondary Schools

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Abstract

With the rapid development of Artificial Intelligence (AI) technology, its application in the field of education has become increasingly widespread. This study focuses on music education in primary and secondary schools, exploring how AI technology can facilitate the reform of music teaching. Currently, technical tools such as intelligent music software, automatic scoring systems, and virtual teachers are transforming traditional music classrooms, providing students with personalized learning experiences. Through the analysis of typical domestic application cases, it is found that AI technology can not only assist teachers in cultivating basic skills such as intonation training and rhythm teaching but also stimulate students' creativity through intelligent composition tools. However, the application of technology still faces many challenges, including insufficient investment in hardware equipment, teachers' lack of technical literacy, and poor human-computer interaction experience. To address these dilemmas, it is suggested to improve through strengthening teacher training, optimizing technical adaptability, and improving curriculum design. In the future, with the development of 5G and metaverse technologies, the application prospect of AI in music education will be broader, and it is expected to build an intelligent music learning environment integrating virtual and real elements. This study provides practical references for promoting the informatization of music education and has positive significance for realizing the aesthetic education goals in the new era.

Keywords

Artificial Intelligence, Music education in primary and secondary schools, Music teaching, Educational technology, Artificial Intelligence applications

Introduction

In recent years, the rapid advancement of Artificial Intelligence (AI) technology has brought profound transformations to the field of education. As a crucial carrier of aesthetic education, music education is undergoing a transition from traditional to intelligent teaching and learning modes. In 2023, the Ministry of Education's *Opinions on Strengthening School Aesthetic Education in the New Era* explicitly proposed promoting the in-depth integration of information technology with art courses, which provides policy support for the application of AI technology in music education. Currently, music teaching in primary and secondary schools generally faces problems such as unbalanced allocation of teachers and a single teaching method [1]. AI technology, through intelligent solutions, offers new possibilities for breaking through these bottlenecks.

From the perspective of teaching practice, traditional music classrooms are often constrained by hardware facilities and teachers' professional capabilities. In the training of basic skills such as intonation practice and sight-singing ear training, it is difficult for manual guidance to provide real-time and accurate feedback [2]. In music composition teaching, students often lose interest due to the high threshold of musical instrument proficiency. The intervention of AI technology can effectively make up for these shortcomings: Intelligent composition software can lower the threshold for creation. Automatic scoring systems can achieve instant feedback. And virtual teachers can break through the limitations of time and space to provide personalized tutoring. This technological empowerment not only improves teaching efficiency but also significantly enhances students' learning interest through gamified interactive design.

This study aims to systematically sort out the current application status of AI technology in music education in primary and secondary schools and analyze the implementation effects of typical cases [3]. It also intends to propose feasible suggestions for existing problems such as insufficient technical adaptability and teachers' lack of digital literacy. By exploring the development path of intelligent music education, this study provides a theoretical basis for constructing a music learning environment integrating virtual and real elements, and ultimately promotes the realization of aesthetic education goals in the new era. Accordingly, the research focuses on three core questions: How to optimize the music teaching process using AI technology? How to stimulate students' musical creativity through intelligent means? And how to establish a new human-machine collaborative teaching model? The discussion of these issues will provide important references for advancing the informatization of music education.

Current status of AI application in music education in primary and secondary schools

Development status of AI music education at home and abroad

Currently, the application of Artificial Intelligence (AI) technology in the global field of music education is showing a rapid development trend. From an international perspective, developed countries took the lead in AI music education and have established relatively mature application systems. Taking the United States as an example, intelligent music teaching platforms such as Artificial Intelligence Virtual Artist (AIVA) and Amper Music generate personalized practice pieces through algorithms, which have significantly improved students' musical creation capabilities. Many European countries have integrated AI technology with teaching methods such as Orff and Kodály to develop adaptive intelligent music games, making rhythm training and listening comprehension more engaging [4,5]. Since the curriculum reform in 2001, Hong Kong has continuously promoted the integration of music education and technology, and its AI-enabled constructivist teaching model has set an exemplary example internationally [6].

In China, although the development of AI music education started relatively late, it has achieved remarkable progress in recent years driven by policy support and market demand. The Guidelines on Strengthening School Aesthetic Education in the New Era issued by the Ministry of Education in 2023 have provided institutional guarantees for the application of AI technology in music classrooms of primary and secondary schools. Currently, typical domestic application scenarios mainly include three aspects:

(1) Intelligent music production software, such as the Yinkong AI composition platform, has been introduced into the classrooms of some universities and middle schools. It can help students break through the technical limitations of musical instrument performance and directly experience the joy of composition [7,8]. (2) Singing evaluation systems based on speech recognition technology. These systems can real-time analyze students' intonation and rhythm, and provide targeted improvement suggestions. (3) VR music scenario simulation systems. They can enhance students' musical expression through immersive environment simulation. The application of these technologies has shown positive effects in pilot schools in economically developed eastern regions, but their penetration rate in central and western regions still needs to be improved.

From the perspective of technical implementation, the development of AI music education at home and abroad presents differentiated characteristics. Foreign countries focus more on fostering creativity, stimulating students' original capabilities through generative AI technology. In contrast, domestic development currently centers on skill training, with an emphasis on the intelligent evaluation of basic competencies such as intonation and rhythm. This difference not only reflects the impact of diverse educational concepts but also indicates that each is in a distinct stage of technological development. Notably, with the commercialization of 5G technology, some advanced domestic schools have begun to explore cloud-collaborative AI music teaching models, which provides a new possibility for narrowing the gap with the international advanced level.

The coordination between teachers and technology has attracted attention both domestically and internationally. Practice has proven that for AI technology to be truly integrated into music classrooms, it not only requires mature software and hardware support but also relies more on teachers' ability to understand and apply the

technology. Some foreign schools have established specialized technical training systems for music education, while domestic efforts in this regard are still in the exploratory stage. He pointed out in his research that university music teachers have a relatively high acceptance of AI composition platforms, but primary and secondary school teachers generally face obstacles in technical application [9]. This difference reminds us that in the process of promoting technology implementation, we must fully consider the actual needs and acceptance capabilities of teachers at different teaching stages.

Looking forward to the future, the development of AI music education will place greater emphasis on human-machine collaboration. Researchers at home and abroad have reached a consensus: Technology should not completely replace teachers, but rather serve as a tool to expand teaching possibilities. With the rise of the metaverse concept, building a music learning environment integrating virtual and real elements has become a new research direction. In this process, it is necessary to both absorb international advanced experience and base on local educational realities to ultimately promote the healthy and orderly development of AI music education.

Main application scenarios of AI technology in music education in primary and secondary schools

Currently, AI technology has been deeply integrated into multiple links of music education in primary and secondary schools, forming the following typical application scenarios:

(1) In terms of basic skill training, intelligent auxiliary systems have significantly improved teaching efficiency. Automatic scoring tools based on speech recognition and voiceprint analysis technology can conduct real-time detection of students' intonation and rhythm during singing and generate visualized feedback reports. Lv pointed out in her research that such systems "transform tedious vocal exercises into interesting challenges through gamified scoring mechanisms, effectively enhancing students' practice enthusiasm" [10]. Intelligent piano accompaniment software adopts optical recognition technology to correct detailed movements such as hand shape and fingerings, making up for the deficiency that teachers in traditional classrooms are difficult to take care of every student.

(2) Music composition teaching has undergone paradigm innovation due to AI technology. Composition platforms centered on generative AI allow students to complete orchestration by simply dragging and dropping note modules, greatly lowering the threshold for creation. Some advanced systems can also automatically generate harmony arrangements based on melody fragments input by students and simulate orchestration effects of different genres through style transfer technology. This model of "low technical threshold + high artistic expression" enables students without musical instrument foundation to experience the joy of music creation. Practices in Hong Kong have shown that combining such tools with constructivist teaching methods can significantly stimulate students' creative thinking [11].

(3) In music appreciation courses, intelligent recommendation systems play an important role. By analyzing students' listening records and emotional feedback, AI algorithms can accurately recommend repertoires that match their cognitive level and aesthetic preferences. Meanwhile, these algorithms are capable of automatically generating interactive courseware integrated with elements such as historical and cultural backgrounds and musical form analysis. The application of virtual reality technology goes further: Students can "enter" symphony performance venues or opera stages through VR equipment, and perceive the connection between music and space from multiple dimensions. This immersive experience makes abstract music theory knowledge intuitive and perceptible.

(4) Classroom teaching management has also been optimized with AI support. Intelligent attendance systems combine face recognition and voiceprint verification to quickly complete classroom check-in. Learning analysis platforms collect data such as practice duration and error frequency to provide teachers with personalized teaching suggestions. "AI teaching assistants" piloted in some schools can automatically generate classroom summary reports, mark lists of students requiring key attention, and reduce teachers' administrative burdens.

(5) After-class extended learning scenarios also benefit from AI technology. Cloud-based music libraries use natural language processing technology to realize intelligent retrieval and annotation of music scores. Mobile apps superimpose traditional musical instrument teaching videos onto real environments for

demonstration through augmented reality technology. These applications break through the limitations of time and space, extending music learning from classrooms to families and forming a coherent learning closed loop.

It is worth noting that the actual effect of these application scenarios is closely related to schools' hardware configurations and teachers' technical literacy. In demonstration schools in economically developed regions, the intelligent teaching model of multi-scenario collaboration has initially achieved results. However, in regions with limited resources, it is still necessary to gradually promote technology integration through lightweight applications. In the future, with the development of edge computing technology, locally deployed lightweight AI tools are expected to narrow this regional gap.

Analysis of practical cases of AI in music education in primary and secondary schools

Case analysis of AI-assisted music composition teaching

In music education in primary and secondary schools, AI-assisted music composition teaching has emerged as a typical practice of technology-empowered aesthetic education. Through the analysis of cases from multiple pilot schools in China, it is found that such applications reconstruct the traditional music composition teaching model mainly through three dimensions: lowering technical thresholds, stimulating creative interest, and providing real-time feedback. The Yinkong AI composition platform "enables students with no foundation to complete full music compositions in class through modular note dragging and intelligent harmony generation functions". This feature is particularly prominent in the application of a middle school in Beijing. After the school introduced the platform into the 8th-grade music classes, the number of melody fragments created by students increased significantly compared with the traditional teaching period, and the works showed diverse stylistic characteristics.

In the specific implementation process, the application of AI composition tools is usually divided into three stages: (1) The stage of introductory guidance, where students learn basic musical form structures through preset templates. (2) The stage of free creation, where intelligent recommendation algorithms are used to obtain harmony and orchestration suggestions. (3) The stage of achievement sharing, where the system automatically generates visualized spectrum analysis reports. A lesson case from an experimental primary school in Shanghai shows that teachers combine AI-generated accompaniments with students' main melodies to form a teacher-student collaborative creation model. This interaction not only retains teachers' leading role but also gives full play to the auxiliary value of technology. Notably, some schools in Hong Kong have also combined such tools with constructivist teaching methods to complete AI musical creation through group collaboration, which effectively cultivates students' teamwork ability.

At the technical implementation level, mainstream AI composition teaching platforms currently rely primarily on algorithms such as Generative Adversarial Networks (GANs) and Variational Autoencoders (VAEs). These technologies can automatically complete musical phrases that comply with music theory rules based on note sequences input by students, and simulate the characteristics of different genres such as classical and pop through style transfer. Practice at a key primary school in Nanjing has shown that when the system provides real-time audio-visual feedback, students' cognitive accuracy of musical elements (e.g., tonality, meter) is significantly improved. However, some teachers have reported that the accompaniments generated by certain algorithms are overly formulaic, which may limit students' innovative thinking. This suggests that technology developers need to enhance the diversity and flexibility of algorithms.

From the perspective of teaching effect evaluation, the changes brought by AI-assisted composition are mainly reflected in three aspects: First, this approach breaks the constraints imposed by musical instrument performance proficiency. Thereby more students can engage in music creation [12]. Second, it visualizes abstract music theory knowledge by means of visualized pitch curves and rhythm grids. Third, its cloud-based work-sharing function fosters an inter-class music creation community. A comparative experiment conducted in a district of Guangzhou showed that students in the experimental group using AI tools outperformed those in the control group in the indicators of "musical expression" and "creative uniqueness". However, problems have also

emerged, such as some students' over-reliance on system recommendations, leading to a tendency of homogenization in works.

To address the current challenges, excellent cases generally adopt the following optimization strategies: First, a "human intervention" link is established to require students to conduct secondary revisions based on AI-generated suggestions. Second, a hierarchical task system is built to provide creative requirements with varying complexity according to students' differences in ability. Third, side-by-side analyses of AI-generated works and traditional creations are performed to cultivate students' critical thinking. These experiences provide important references for other schools to carry out similar practices and also confirm the unique value of AI technology in stimulating students' musical creativity. In the future, with the development of multimodal interaction technology, new creation methods such as voice command composition and somatosensory control orchestration are expected to further enrich the form of music teaching.

Case application of AI in music appreciation and evaluation

The application of AI technology in music appreciation and evaluation has brought innovative transformations to music teaching in primary and secondary schools. Through the analysis of typical domestic cases, it is found that intelligent music appreciation tools optimize the traditional teaching model mainly through three dimensions: personalized recommendation, emotional analysis, and immersive experience. The research pointed out in her research that the AI-enabled online merge offline (OMO) teaching model can "dynamically adjust music appreciation content according to students' cognitive levels and aesthetic preferences, realizing the seamless connection of online and offline resources". This feature is particularly prominent in the application of a middle school in Zhejiang Province. After the school introduced an intelligent music recommendation system, the proportion of students actively participating in extracurricular music appreciation increased significantly.

In specific application scenarios, the AI system first analyzes students' musical foundation through pre-tests to construct personalized auditory feature profiles. In a practical case of an experimental primary school in Shanghai, the system converts classical music works into animated story segments based on students' age characteristics, which are displayed synchronously with AI-generated dynamic music scores. This audio-visual integration approach has significantly improved third-grade students' ability to understand "The Carnival of the Animals" suite. Additionally, the system can real-time capture students' facial expressions and body movements, evaluating their concentration and empathy through emotion computing technology to provide references for teachers in adjusting teaching strategies. Peters 's research indicates that such technologies "help teachers accurately identify teaching difficulties through the visualization of learning situation data" [13].

In terms of music evaluation, intelligent systems demonstrate unique advantages. Traditional music appreciation assignments primarily adopt the form of written comments, and students often struggle to accurately describe their listening experiences due to limited expressive abilities. After an experimental school in Jiangsu Province introduced an AI multimodal evaluation system, students can provide feedback on their listening experiences through multiple methods such as voice description, emotional label selection, and melody doodling. The system uses natural language processing technology to analyze semantic and emotional tendencies, and combines it with painting element recognition technology to generate comprehensive multidimensional reports on students' aesthetic competence. Cheng found in her research that this evaluation method "not only lowers the threshold for expression but also more comprehensively reflects the process of students' aesthetic perception" [14]. Notably, some schools have further combined AI evaluation results with traditional teacher comments, forming a hybrid evaluation model of "technical diagnosis + human guidance".

From the perspective of technical implementation, mainstream intelligent music appreciation systems currently mainly adopt collaborative filtering algorithms and deep learning models. By analyzing massive amounts of users' listening data, the systems establish a feature vector space for musical works to achieve intelligent recommendation of similar works. A case study of a key middle school in Beijing shows that when the system incorporates regional cultural factors (e.g.,

automatically associating dialect explanations when recommending local opera excerpts), students' depth of cultural understanding is significantly enhanced. However, algorithmic bias has also emerged in practice - for instance, systems tend to over-recommend pop music while neglecting folk music. This reminds developers of the need to strengthen the construction of diverse datasets.

Evaluation of teaching effects indicates that the application of AI technology exerts positive impacts mainly in three aspects: First, it meets the learning needs of students at different levels through the design of hierarchical listening tasks. Second, it recreates historical performance scenes using VR technology to enhance the understanding of musical cultural backgrounds. Third, the intelligent feedback system helps teachers quickly grasp the overall appreciation level of the class. A comparative experiment conducted in a district of Shenzhen shows that after using AI-assisted teaching, students' test scores in two dimensions - "musical element identification" and "style discrimination" - have both improved. Notably, this AI-enabled music teaching model essentially belongs to a typical blended learning paradigm, where the integration of online intelligent tools and offline classroom interaction contributes to the cultivation of students' deep learning abilities. Li et al. systematically explored the evaluation methods and improvement paths of deep learning abilities in blended learning environments, confirming that personalized feedback, scenario-based interaction, and multi-dimensional evaluation are key factors in promoting deep learning [15]. Some schools have also innovatively applied AI-generated music visualization graphics to interdisciplinary teaching, such as explaining the relationship between waveforms and frequencies in mathematics classes.

To address the current technical limitations, excellent cases have provided actionable solutions: First, a manual review mechanism is established to conduct educational screening of AI-recommended content. Second, a dual-track review system of "AI + teacher" is designed to balance technical efficiency and humanistic care. Third, education on algorithm transparency is implemented to help students understand technical principles and cultivate critical thinking. These practical experiences offer clear directions for the optimization of intelligent music appreciation systems and confirm the unique value of AI technology in improving students' aesthetic literacy. With the maturity of emotion computing technology, future systems are expected to more accurately capture students' aesthetic responses, further realizing the teaching goal of "promoting learning through listening".

Practical cases of AI in music skill training

In the field of music skill training, AI technology has significantly improved the accuracy and interestingness of music teaching in primary and secondary schools through intelligent means. An analysis of practical cases from multiple domestic schools reveals that AI tools mainly focus on three core skill modules - intonation correction, rhythm training, and musical instrument technique - bringing innovative breakthroughs to traditional training methods. Çelenk emphasized in her research on music literacy cultivation that AI systems "transform tedious skill practice into an active learning process for students through real-time feedback and gamified design" [16]. This feature is particularly prominent in the intelligent sight-singing training at a junior high school in Guangdong Province. After the school adopted an AI evaluation system based on voiceprint analysis, the pass rate of students' intonation significantly increased compared with the traditional teaching stage.

In terms of vocal skill training, the application of intelligent systems demonstrates unique advantages. Taking an experimental primary school in Jiangsu Province as an example, the AI singing evaluation platform it adopted can real-time capture the waveform characteristics of students' singing and intuitively display intonation deviations through color changes. The system decomposes textbook pieces such as "The Cowherd's Flute" (by He Lvting) into segmental exercises, and students receive immediate star ratings and revision suggestions after completing each musical phrase. This "micro-teaching training" model effectively addresses the problem that teachers in traditional large-class teaching struggle to attend to every student. More notably, some schools have introduced somatosensory interaction technology, allowing students to control the trajectory of virtual intonation lines through physical movements, transforming abstract interval relationships into spatial movement experiences. Practice at an elementary school in Hangzhou shows that this multi-

sensory collaborative training method is particularly suitable for younger students to establish correct intonation concepts.

Rhythm training is another important application scenario of AI technology. Traditional rhythm teaching relies on teachers' beat demonstration, and students tend to lose interest due to monotonous repetition. A key middle school in Beijing introduced an intelligent rhythm coach system, which captures students' beating movements through cameras and generates interactive rhythm games in conjunction with an AI drum machine. The system can automatically identify and correct common problems such as "rushing the beat" and "dragging the beat", and dynamically adjust the tempo according to students' proficiency levels. Tabuena found in her research on the Orff teaching method that when AI tools are integrated with rhythmic movement teaching, "students' rhythm stability and physical coordination are simultaneously improved" [17]. The innovative practice of a rural school in Hunan Province is even more distinctive: teachers and students use waste materials to make simple percussion instruments and conduct ensemble training through the AI recognition function of a mobile APP. This low-cost solution provides a feasible model for resource-constrained areas.

In the training of musical instrument techniques, AI technology also demonstrates transformative potential. Intelligent piano accompaniment systems capture finger movements through optical sensors, display correct hand postures via 3D animations, and provide vibration alerts for common mistakes (such as curved fingers and collapsed wrists). A case study of a key primary school in Shanghai shows that the built-in "level-up mode" of the system gamifies the content of Ferdinand Beyer's *Elementary Method for the Piano*, significantly extending students' average daily practice time. For the teaching of ethnic musical instruments, the erhu bowing assistance system developed by a middle school in Fujian Province is quite representative. By analyzing parameters such as bow speed and pressure, AI generates training curves to help students understand the performance aesthetic principle of "interplay between emptiness and solidity". Collectively, these cases indicate that AI technology not only improves the efficiency of skill training but also transforms traditionally oral and experiential knowledge into quantifiable learning paths through visualization.

Currently, AI music training systems mainly adopt three types of technical solutions: (1) The intonation analysis module based on voiceprint recognition uses the Mel Frequency Cepstral Coefficient (MFCC) feature extraction method, which can effectively distinguish the characteristics of children's voices. (2) Motion capture systems mostly use open-source frameworks such as OpenPose to achieve key point detection. (3) Intelligent feedback algorithms generally incorporate reinforcement learning mechanisms, enabling them to adjust prompt strategies according to students' error patterns. The combined application of these technologies in practice has created a variety of rich training scenarios. However, some systems have the problem of "excessive reliance on standard answers", which may restrict students' personalized expression.

From the perspective of teaching effects, the advantages of AI technology are mainly reflected in three aspects: first, enhancing learning motivation through real-time positive feedback; second, achieving precise tutoring by analyzing error patterns; third, tracking the trajectory of skill development with the help of cloud-based data. A comparative experiment conducted in a district of Chengdu showed that the classes using the AI training system made significant progress in two indicators: "intonation stability" and "rhythm complexity". Meanwhile, technical limitations have also been exposed, such as the low accuracy of the system in evaluating national vocal music and insufficient support for improvisation training. To address these issues, exemplary case schools generally adopt a technology complementarity strategy: On-site teachers are assigned to provide artistic guidance after AI-assisted training, and peer evaluation activities are organized among students to foster their critical listening skills. These experiences provide important references for balancing technical efficiency and the essential requirements of art education.

Challenges and countermeasures of AI in music education in primary and secondary schools

Technical challenges and solutions in AI application

Although AI technology has achieved remarkable results in its application to music education in primary and secondary schools, it still faces numerous technical challenges. These challenges are mainly reflected in

three aspects: hardware adaptability, algorithmic limitations, and human-computer interaction experience. Targeted solutions need to be proposed.

In terms of hardware adaptability, the uneven equipment configuration caused by urban-rural differences is prominent. Schools in economically developed regions can be equipped with high-performance AI music teaching terminals, while resource-constrained areas often have to rely on ordinary electronic devices to run lightweight applications. This hardware gap prevents some AI functions from being fully utilized. For example, applications requiring strong computing power such as VR music scenario experience and high-precision motion capture are difficult to popularize. To address this situation, solutions can be implemented from three perspectives: First, cross-platform compatible lightweight applications are developed, and local hardware requirements are reduced via edge computing technology. Second, a cloud-collaborative computing model is constructed to offload complex computational tasks to cloud servers. Third, enterprises are encouraged to develop low-cost dedicated devices. For example, music teaching modules are built on open-source hardware platforms such as the Raspberry Pi. Fitria pointed out that "teachers and students should make good use of the intelligence and convenience of AI tools to adapt to the teaching reform brought by AI" [18].

Algorithmic limitations constitute the core constraint on teaching effectiveness. Existing AI music systems generally exhibit two shortcomings: First, it doesn't have enough understanding of ethnic music culture, such as low accuracy in recognizing the timbre of traditional Chinese musical instruments and inadequate modeling of traditional music theories. Second, the capacity for providing creative support is insufficient, as algorithm-generated accompaniments or harmonies tend to fall into rigid patterns. For instance, in erhu teaching, AI systems struggle to accurately evaluate the artistic expression of unique techniques of ethnic musical instruments, such as "glissando" and "vibrato". Notably, neural network algorithms - such as the BP neural network - have been proven effective in optimizing the adaptability and accuracy of educational intelligent systems in previous studies. Deng et al. developed a BP neural network-enhanced support system for college students' employment and mental health, which significantly improved the system's ability to capture user needs and provide personalized feedback through algorithm optimization [19]. This provides a valuable reference for addressing the current algorithmic limitations in AI music education, such as enhancing the recognition accuracy of ethnic musical instrument timbres or optimizing creative recommendation logic through BP neural network tuning. Addressing these issues requires enhanced algorithm optimization: (1) Enhancing the capacity to capture ethnic music features by incorporating attention mechanisms. (2) Adapting Western music theory models to traditional Chinese music teaching scenarios via transfer learning techniques. (3) Establishing multi-style music datasets to mitigate algorithmic bias. Savaş emphasized in his research that "we should jointly explore the innovation of AI in teaching applications", which reminds technology developers to strengthen collaboration with music educators [20].

Inadequate human-computer interaction experience directly affects students' learning engagement. Currently, some AI music tools suffer from problems such as complex interface design and single feedback methods, making them difficult for younger students to operate. In a school that adopted an intelligent composition software, over 30% of students reported that the functional menu hierarchy was excessively deep. Other rhythm training apps have reduced students' interest due to overly mechanical voice prompts. Improving interaction experience can be achieved through breakthroughs in three dimensions: First, adopting an age-appropriate design principle to customize differentiated interfaces for students of different academic stages. Second, introducing multimodal interaction, such as natural operation methods like gesture control and voice commands. Third, enhancing the emotional expression of feedback to increase interest through animated characters and gamified scenarios. Practice has proven that when the interaction design of AI systems aligns with children's cognitive characteristics, students' willingness to use them continuously is significantly improved.

Addressing the aforementioned challenges requires collaborative efforts from multiple stakeholders. Education authorities can take the lead in formulating standards for AI music teaching equipment to ensure the

compatibility of basic functions. Schools should establish a collaborative mechanism between technical teachers and music teachers, involving both parties in tool selection. Enterprises, on the other hand, need to strengthen user research and continuously iterate their products. It is worth noting that the resolution of these technical issues cannot be separated from the essence of education - all improvements should serve to enhance students' musical literacy and aesthetic ability. In the future, with the popularization of 5G networks and the maturity of AR/VR technologies, a more natural and intelligent music teaching environment is expected to be gradually realized. However, balancing technical adaptability and educational applicability remains a key consideration that must be firmly grasped.

Ethical and privacy issues in AI education and corresponding strategies

The application of AI technology in music education in primary and secondary schools has brought remarkable transformations, while also triggering a series of ethical and privacy issues. These issues require joint attention from educators and technology developers, who must formulate targeted response strategies. Focused primarily on data security, algorithmic bias, and technology dependence, these problems directly affect the sustainable development of technological applications.

Data security stands as the most prominent privacy risk in AI music teaching. Intelligent music systems often need to collect students' biometric information, such as voice characteristics, performance videos, and even facial expressions. The storage and transmission of these sensitive data carry inherent leakage risks. For instance, an intelligent scoring system used by a school once suffered from the leakage of students' singing recordings due to insufficient cloud encryption, sparking parents' concerns about privacy protection. More alarmingly, some free music apps engage in excessive data collection, such as accessing irrelevant permissions like device address books. First, an education-specific data center should be established, with local data storage implemented in strict compliance with the provisions of the *Law of the People's Republic of China on the Protection of Minors*. Second, the "privacy-first" principle should be embedded in technical design, and privacy-preserving technologies such as federated learning should be adopted to achieve the goal of "data available but not visible". Third, data literacy training programs should be organized for teachers and students, with explicit notification of the scope and purpose of data collection provided to all participants. Researchers pointed out that "education in the age of AI should continuously update its concepts", which includes attaching great importance to data ethics [21,22].

Algorithmic bias undermines the fairness of music education. Most current AI music systems are primarily trained on Western classical music data, leading to biases in the recognition and understanding of ethnic music cultures. For instance, an intelligent composition software often incorrectly adds Western harmonic progressions when generating accompaniments in folk song styles. Such implicit cultural bias may shape students' aesthetic perceptions. Additionally, recommendation algorithms trained on historical data tend to reinforce gender stereotypes - for example, more frequently recommending gentle-style practice pieces to female students. Addressing these issues requires a multi-pronged approach: Technically, datasets should be expanded to incorporate diverse musical cultures, and fairness detection mechanisms should be introduced. Pedagogically, teachers and students should be encouraged to jointly scrutinize AI-generated outputs to foster their critical thinking. Managerially, algorithmic transparency standards should be established, which mandate developers to disclose the design logic of core parameters.

Technology dependence may erode the humanistic essence of music education. Some schools over-rely on intelligent scoring systems, replacing teachers' comprehensive evaluation of students' artistic expression with machine standards. A case study showed that when AI systems gave low scores to creative composition assignments, students were more inclined to revise their work to align with algorithmic preferences, suppressing personalized expression. Martínez-Bravo et al. also noted in his research the need to cultivate talents "with both technological literacy and humanistic feelings", reminding us to guard against the tendency of technical instrumentalization [23]. Response strategies include: (1) Retaining teachers' final discretion over AI evaluation results and establishing a "human review" process. (2) Balancing technical applications with traditional

teaching in curriculum design, such as alternating AI sight-singing training with in-person chorus rehearsals. (3) Conducting technical ethics education to help students understand the limitations of AI.

A systematic solution to these issues requires the construction of a multi-stakeholder collaborative governance framework. Education authorities should formulate specialized ethical guidelines for AI education applications, clarifying red lines for data collection and requirements for algorithmic audits. Schools need to establish technical ethics review committees to conduct compliance assessments of introduced intelligent systems. Enterprises must set up user feedback mechanisms to promptly rectify ethical flaws in their products. It is particularly important that all solutions take promoting students' artistic development as the fundamental goal, avoiding hindering technological innovation due to excessive risk prevention. In the future, with the improvement of regulations such as the *Interim Measures for the Administration of Generative Artificial Intelligence Services*, the ethical norms for AI music education will become clearer, providing institutional guarantees for the healthy development of technology.

Conclusion

This study systematically examines the current application of AI technology in music education in primary and secondary schools, revealing both the positive impacts of AI on music teaching reform and the existing challenges. The research finds that technical tools such as intelligent music software, automatic scoring systems, and virtual teachers have effectively improved classroom teaching efficiency, particularly in fostering basic skills like intonation training and rhythm teaching. Analysis of typical cases shows that AI tools have significantly enhanced students' engagement and learning outcomes through personalized learning and real-time feedback mechanisms. Meanwhile, the application of technology still faces practical issues, including insufficient hardware investment, teachers' lack of technical literacy, and algorithmic bias, which need to be addressed through strategies such as strengthening teacher training and optimizing technical adaptability.

Looking forward, the application of AI technology in music education in primary and secondary schools will present three development trends. Technological progress will drive music teaching tools toward greater intelligence and humanization. With the popularization of 5G networks and the maturity of emotion computing technology, virtual music teachers will possess more natural interaction capabilities, enabling them to accurately identify students' emotional states and adjust teaching strategies accordingly. The application of augmented reality (AR) technology will visualize abstract music theories - for example, displaying sound wave propagation laws through holographic projections to help students intuitively understand music theory knowledge. The rise of metaverse platforms will break the limitations of time and space, constructing a music learning environment integrating virtual and real elements, where students can collaborate with global peers in virtual concert halls.

Innovation in educational models will promote the in-depth integration of AI technology with music curricula. The design of personalized learning paths will become the norm. Intelligent systems can dynamically adjust teaching content and difficulty according to students' cognitive characteristics and artistic preferences. Interdisciplinary integrated teaching is expected to achieve pivotal breakthroughs in educational practice. Typical applications include explaining mathematical wave functions through AI-generated music visualization graphics, as well as recreating the evolution of ancient musical instruments via virtual scenarios in history classes. Project-based learning will become more prevalent, allowing students to use intelligent composition tools to complete the entire process from creation and arrangement to performance, fostering comprehensive artistic literacy. These innovative models will transform music education from mere single-skill instruction to the cultivation of holistic artistic capabilities.

The improvement of social collaboration mechanisms will provide institutional guarantees for AI applications. Education authorities need to accelerate the formulation of standards for intelligent music teaching equipment and data security regulations to ensure the compliance of technical applications. Schools should establish university-enterprise cooperation platforms to encourage technology enterprises to participate in curriculum development and teacher training. Parents and social organizations can enhance their understanding of

technology through activities such as “AI Music Open Days” to form a joint educational force. Particularly importantly, a multi-stakeholder evaluation mechanism involving educators, technical experts, and ethicists should be established to ensure that the development of AI always serves the goal of aesthetic education and avoids technological alienation.

It is emphasized that while promoting technological applications, we must uphold the humanistic essence of music education. AI tools should serve as a means to expand artistic expression rather than replace human emotional expression. The intelligent music education of the future should be a human-machine collaborative and complementary ecological system. It should not only give full play to technological advantages to improve teaching efficiency but also cultivate students’ aesthetic taste and creativity through teachers’ artistic guidance. With the continuous development of relevant technologies and the innovation of educational concepts, AI is expected to bring more profound impacts on music education in primary and secondary schools, providing strong support for the realization of aesthetic education goals in the new era.

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References

[1] Bulathwela, S., Pérez-Ortiz, M., Holloway, C., Cukurova, M., Shawe-Taylor, J. (2024) Artificial intelligence alone will not democratise education: on educational inequality, techno-solutionism and inclusive tools. *Sustainability*, 16(2), 781.

[2] Lou, F., Wang, H. (2025) Exploring the role of digital technologies in solfeggio and ear training pedagogy and memory. *Interactive Learning Environments*, 1-15.

[3] Yu, X., Ma, N., Zheng, L., Wang, L., Wang, K. (2023) Developments and applications of artificial intelligence in music education. *Technologies*, 11(2), 42.

[4] Ma, Y., Wang, C. (2025) Empowering music education with technology: a bibliometric perspective. *Humanities and Social Sciences Communications*, 12(1), 1-14.

[5] Jiang, Q. (2025) The impact of Kodály, Orff Schulwerk, and Suzuki music teaching methods on the development of students’ musical abilities: a systematic review. *Teaching and Teacher Education*, 159, 104991.

[6] Yin, L. W. (2024) Using five music instructional methods to illustrate the social constructive music teaching framework in Hong Kong Primary level music education. *Sino-US English Teaching*, 21(6), 247-269.

[7] Wei, J., Karuppiah, M., Prathik, A. (2022) College music education and teaching based on AI techniques. *Computers and Electrical Engineering*, 100, 107851.

[8] Zulić, H. (2019) How AI can change/improve/influence music composition, performance and education: three case studies. *INSAM Journal of Contemporary Music, Art and Technology*, (2), 100-114.

[9] He, S., Ren, Y. (2025) Exploring pre-service music teachers’ acceptance of generative Artificial Intelligence: a PLS-SEM-ANN approach. *Frontiers in Psychology*, 16, 1571279.

[10] Lv, H. Z. (2023) Innovative music education: Using an AI-based flipped classroom. *Education and Information Technologies*, 28(11), 15301-15316.

[11] Ng, D. T., Ng, E. H., Chu, S. K. (2022) Engaging students in creative music making with musical instrument application in an online flipped classroom. *Education and information Technologies*, 27(1), 45-64.

[12] Fang, P. E. N. G. (2021) Optimization of music teaching in colleges and universities based on multimedia technology. *Advances in Educational Technology and Psychology*, 5(5), 47-57.

[13] Peters, M. A., Green, B. J. (2024) Wisdom in the age of AI education. *Postdigital Science and Education*, 6(4), 1173-1195.

[14] Cheng, L. (2024) The use of digital technology in school music education: Artificial Intelligence and emerging practices. *The Sage Handbook of School Music Education*, 381-390.

[15] Li, Y., Cheng, H., Qin, Q. (2025) Evaluations and improvement methods of deep learning ability in blended learning. *International Journal of e-Collaboration (IJeC)*, 21(1), 1-17.

[16] Çelenk, K., Lehimler, E. (2019) A Study on learning styles of individuals receiving vocational music education. *Online Submission*, 7(10), 108-122.

[17] Tabuena, A. C. (2021) Carabo-Cone, Dalcroze, Kodály, and Orff Schulwerk Methods: an explanatory synthesis of teaching strategies in music education. *Online Submission*, 2(1), 9-16.

[18] Fitria, T. N. (2023) The use of Artificial Intelligence in education (AIED): Can AI replace the teacher's role? *Epigram*, 20(2), 165-187.

[19] Deng, Z., Xiang, H., Tang, W., Cheng, H., Qin, Q. (2024) BP neural network-enhanced system for employment and mental health support for college students. *International Journal of Information and Communication Technology Education (IJICTE)*, 20(1), 1-19.

[20] Savaş, S. (2021) Artificial intelligence and innovative applications in education: the case of Turkey. *Journal of Information Systems and Management Research*, 3(1), 14-26.

[21] Tan, S. (2023) Harnessing Artificial Intelligence for innovation in education. *Learning Intelligence: Innovative and Digital Transformative Learning Strategies: Cultural and Social Engineering Perspectives*, 335-363.

[22] Ramkissoon, L. (2024) AI: powering sustainable innovation in higher ed. *The Evolution of Artificial Intelligence in Higher Education*, 203-229.

[23] Martínez-Bravo, M. C., Sádaba Chalezquer, C., Serrano-Puche, J. (2022) Dimensions of digital literacy in the 21st century competency frameworks. *Sustainability*, 14(3), 1867.