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USING AI IN MUSIC EDUCATION: APPLICATIONS, CHALLENGES, AND PEDAGOGICAL APPROACHES

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ABSTRACT

Amid accelerating digital transformation, artificial intelligence (AI) has emerged as a pivotal force in redefining traditional educational models, particularly within arts disciplines that require significant individualisation, such as music. This study presents a narrative literature review to systematically categorise AI applications in music education and to identify the associated opportunities and risks. The analysis demonstrates that AI serves as both a “cognitive scaffold” and a co-creative partner, offering substantial support across performance, theory, and composition through real-time feedback and personalised learning pathways. These findings provide a valuable reference for educators seeking to make informed strategic decisions in developing intelligent and sustainable music learning ecosystems.

KEYWORDS: AI, Music Education, Cognitive Scaffolding, AR, Deep Learning

1. INTRODUCTION

In recent years, the rapid development of information technology has positioned AI as a key driver in transforming traditional educational models (Chen & Sun, 2024). AI is not merely a support tool but also plays a role in simulating and extending human intelligence to address complex problems in teaching and learning (Yu et al., 2023). In the modern education system, AI application is defined as any form of AI technology or method integrated into pedagogical systems to enhance personalisation, deliver real-time feedback, and optimise learning pathways (Peng & Ratnavelu, 2024; Chen & Sun, 2024). This shift aims towards an intelligent educational ecosystem in which barriers of space and resources are progressively removed, creating more equitable opportunities for learners (Shang, 2019; Yu et al., 2023).

Music education, with its distinctive demand for the seamless integration of specialised theory, precise performance technique, and subjective artistic sensibility, stands before significant opportunities for transformation through AI (Chen & Sun, 2024). At the current stage, AI functions as a revolutionary transformative agent in music education, not only updating traditional methods but replacing them with approaches better suited to the digital era (Peng & Ratnavelu, 2024; Merchán Sánchez-Jara et al.,

2024). From a scientific perspective, the core role of AI is not to replace human expertise but to become a co-creative partner and a “cognitive scaffold” (Vygotsky, 1978; Wood, Bruner & Ross, 1976; Jin et al., 2025; Zhang, H., 2025). AI supports learners by providing instant formative feedback, analysing practice data, and simplifying complex musical concepts, thereby reducing cognitive load in theoretical analysis tasks (Merchán Sánchez-Jara et al., 2024). AI-Assisted Music Learning (AIAML) has become a rapidly developing global trend. (Ou et al., 2025) AI addresses the limitations of traditional music instruction, which frequently struggles to provide immediate personalised feedback to individual students in large classes. Research has demonstrated that AI can offer robust support across the three principal pillars of music: Performance, Theory, and Composition (Zhang, H., 2025; Merchán Sánchez-Jara et al., 2024). Deep Learning technology plays a core role in analysing complex musical structures, identifying stylistic and emotional features, and thereby creating a promising “human-machine” interaction model (Chen & Sun, 2024; Ye, 2020).

The integration of AI in educational settings has led to fundamental changes in pedagogical approaches, shifting from traditional methods to student-centred models that emphasize hands-on experience. While many school-age students enjoy music, enthusiasm for traditional music theory lessons is often limited. Tools such as Bach Doodle enable primary students to create Baroque-style music through visual and intuitive interfaces, thereby stimulating creative engagement (Peng & Ratnavelu, 2024; Ye, 2020). Platforms including SmartMusic and Yousician utilize AI algorithms to analyze pitch and rhythm, providing immediate assessment during instrumental or vocal practice. This functionality allows students to engage in effective self-study at home without continuous teacher supervision (Yu et al., 2023; Zhang, H., 2025). AI technologies also enhance accessibility for students with disabilities. For instance, CAMA software supports learners with dyslexia by employing visual thinking strategies to reduce fatigue during score analysis. Additionally, voice recognition and text-to-speech systems offer substantial support for students with hearing impairments, facilitating their participation in musical activities (Yu et al., 2023; Della Ventura, 2019). Research on pedagogical agents powered by large language models (LLMs) demonstrates that students who interact with AI in music analysis achieve higher scores and report lower cognitive load compared to those engaged in traditional self-study (Jin et al., 2025). Despite these advancements, several research gaps remain: (1) the lack of a consolidated synthesis of AI’s role in music instruction; (2) insufficient research on responsible integration of AI while maintaining instructional quality; (3) limited systematic identification of AI application forms, opportunities, and challenges in music education; and (4) the absence of consensus on ethical guidelines and quality assurance frameworks.

This article presents a literature review that synthesises AI applications, identifies opportunities and risks, and examines pedagogical approaches for integrating AI into music education. The review aims to assist instructional designers in leveraging this technology more effectively and responsibly. By contributing to the body of knowledge at the intersection of instructional design and AI technology, the findings support educators in making informed decisions regarding the safe, effective, and sustainable implementation of AI in music education.

The article addresses the following three research questions:

RQ1: How is AI currently being used in the development of content and practice in music education, and which applications are being employed?

RQ2: What challenges, limitations, and risks arise from the use of AI in the music education process?

RQ3: What pedagogical frameworks and learning theories guide the use of AI in music education to ensure quality and ethical practice?

2. METHOD

2.1 Research Method

This study employs a narrative literature review methodology to examine how AI is used in music education activities. This method was selected because the topic is rapidly evolving and inherently interdisciplinary (spanning instructional design, educational technology, and AI), while the existing evidence base is distributed across diverse publication types. Data were synthesised using thematic analysis to identify patterns, sub-themes, and relationships, thereby extracting the information necessary to address the research questions posed above.

2.2 Data Sources and Search Strategy

Literature was searched primarily through Google Scholar, and eligible research articles were collected in full-text format (PDF). The search was conducted in a modular and iterative fashion based on keywords from three specific domains: (1) Technology & AI (e.g., “Artificial Intelligence-Assisted Music Learning,” “GenAI,” “ChatGPT/GPT-4,” “Bach Doodle/Soundtrap/AIVA,” “Deep Learning,” “Machine Learning,” “Large Language Model (LLM),” “Music Information Retrieval (MIR),” “SmartMusic,” “CAMA (Computer Added Musical Analysis)"); (2) Music Skills & Content (e.g., “Music Composition,” “Music Theory,” “Music Performance,” “Ear Training & Music Cognition,” “Preschool/Elementary/Secondary Music Education"); and (3) Education & Pedagogy (e.g., “Music Education,” “AI-Assisted Music Learning,” “Intelligent Tutoring System (ITS),” “Teachable Agent,” “Learning by Teaching (LBT),” “Learning Personalisation,” “Cognitive Load Theory,” “Flipped Classroom and Blended Learning,” “AI Ethics”).

Searches were conducted by combining domains to broaden coverage whilst progressively increasing specificity for each topic. To maintain focus, the screening of literature prioritised direct relevance to the research questions, and the in-depth synthesis concentrated on over 20 core sources. In accordance with recommendations for systematic literature reviewing, the search process was conducted in a structured and traceable manner to enhance clarity and minimise bias in the retrieved information (Ferrari, 2015).

2.3 Time Frame and Publication Scope

The authors focused on studies published between 2015 and 2025 in order to capture foundational developments in AI tools for music education based on large language models. However, in-depth studies on AI applications in music education were published predominantly during the 2022–2025 period, indicating that AI application in music education is a field at the “crest of the wave” of academic interest. Music education is simultaneously undergoing a genuine technological revolution, transitioning from traditional methods to an intelligent, interactive, and data-driven learning ecosystem.

2.4 Inclusion and Exclusion Criteria

Studies included in the analysis were required to meet the following prerequisites: (i) a focus on at least two of the three core components - Artificial Intelligence Tools, Music Education, and Pedagogy/Methods; (ii) academic rigour and full-text accessibility; and (iii) a significant empirical or theoretical framework contribution. Eligible source types included peer-reviewed journal articles, conference proceedings, book chapters, and high-quality review articles published in English.

2.5 Transparency, Limitations, and Research Ethics

To ensure research transparency, the retrieved literature was screened and its content extracted in a structured literature matrix. However, the absence of a formal inter-rater reliability assessment, the limitation of sources to English-language publications, potential indexing bias from Google Scholar, and the rapidly evolving nature of AI-related literature constitute limitations of this review. As this study did not involve human participants, ethical approval was not required; academic integrity was ensured through accurate citation and transparent reporting of research limitations.

3. FINDINGS AND DISCUSSIONS

3.1 Research Question 1: How is AI currently being used in the development of content and practice in music education, and which applications are being employed?

3.1.1 How AI is used in developing music education content

From an educational research perspective, integrating AI into music education is not simply the addition of a technical tool but rather a revolution in pedagogical approach, shifting from a “one-size-fits-all” model to a learner-centred ecosystem. This transformation is clearly manifested through four core application pillars.

AI has the capacity to analyse students’ activity, practice data, and preferences to construct individualised learning pathways. Systems employing Transformer and Deep Learning models can generate music samples specific to each student’s skill level or emotional objectives (Zhang, L., 2023). The most significant breakthrough of AI lies in its ability to analyse multi-source data to build customised educational pathways. The EFDfO (Entropy Features Data Fusion Optimised) research framework has demonstrated that, by merging entropy features from performance data, practice logs, and even biometric responses (heart rate, pupil dilation), the system can customise teaching strategies according to each learner’s unique profile. Empirical evidence indicates that applying this model

improves average learning outcomes by 18% to 20% (Zhang, L., 2023). Furthermore, advanced Transformer-based systems are capable of capturing long-term musical structures and emotional characteristics to generate musically rich exemplars, supporting students in honing performance and expressive skills precisely at their respective proficiency levels (Chen & Sun, 2024).

The digitization and analysis of music teaching content have been supported by Music Information Retrieval (MIR) technology in classifying vast music libraries and extracting acoustic features (pitch, rhythm) to serve advanced instruction in music theory and history. Specifically, MIR enables the extraction of core acoustic features such as pitch, rhythm, and harmonic structure from extensive music libraries for technical and historical music analysis (Yu et al., 2023; Ye, 2020). A notable example is the application of MIR systems in traditional music education (such as the Turkish Makam system), helping students compare recordings, identify styles, and build aural memory through automated feedback on melodic mode classification (Zhang, H., 2025; Börekci & Seveli, 2024).

Artificial intelligence (AI), when integrated with Virtual Reality (VR) and Augmented Reality (AR), enables the creation of interactive learning environments, such as simulated performance spaces and visual instrument practice guides, which reduce the abstractness of musical concepts in arts education. These virtual environments allow students to engage visually with complex musical ideas, including simulating orchestral conducting gestures and guiding hand positions on instruments using three-dimensional visual cues. Merchán Sánchez-Jara et al. (2024) found that VR is particularly effective for primary school students, as it reduces conceptual abstraction and maximises cognitive engagement and interest from the earliest stages of instruction. Applications such as PianoVision exemplify the integration of VR to provide novel visual experiences that enhance home piano practice (Merchán Sánchez-Jara et al., 2024).

The application of Large Language Models (LLMs) in developing Teachable Agents, or “virtual learning companions,” supports students in consolidating knowledge through the Learning by Teaching (LBT) strategy, as demonstrated by the Chat Melody system (Jin et al., 2025). Based on LBT theory, artificial intelligence serves as a virtual learner, enabling students to teach it music theory concepts. Empirical research involving 28 students found that those who interacted with the AI agent achieved significantly higher assessment scores and reported lower cognitive load, particularly mental effort, compared to traditional self-study methods. These findings suggest that AI serves as an effective scaffold, restructuring students’ reasoning processes and promoting higher-order thinking skills (Jin et al., 2025).

3.1.2 AI tools used in music education practice

Automated assessment and real-time feedback mechanisms represent the most widespread and impactful application domain for optimizing the self-practice process in music. Platforms such as SmartMusic and Yousician utilize AI algorithms to analyze technical parameters such as pitch, rhythm, timbre, and expressive nuance in real time (Sofianos et al., 2025; Zhang, H., 2025; Merchán Sánchez-Jara et al., 2024). These intelligent assessment systems provide tiered corrective suggestions and

facilitate the establishment of short practice loops, enabling students to self-correct technique without direct teacher supervision (Zhang, H., 2025).

In the field of composition, artificial intelligence serves as a creative collaborator by providing suggestions for melody and harmony and supporting students in understanding stylistic conventions through editing and simulation. AI has expanded access to creative activities by eliminating complex technical barriers for novice users (Cheng, 2025; Ye, 2020). Tools such as Bach Doodle, Orb Composer, and DeepBach allow students to explore stylistic rules, including Baroque polyphony, by editing AI-generated music samples (Wilson et al., 2025). Fu et al. (2025) demonstrated that learners engaged in co-composition with AI achieved significantly higher scores in originality (8.1/10) and harmonic complexity (7.5/10) compared to those receiving traditional static instruction (Fu et al., 2025). This iterative process fosters active engagement with musical structures through cycles of creation, listening, critique, and revision (Merchán Sánchez-Jara et al., 2024; Zhang, H., 2025).

Systems such as the “Information Philharmonic” have established a novel form of interactive performance between humans and machines (Ye, 2020). In contrast to traditional static accompaniments, AI-based accompaniment systems can “listen” and automatically adjust tempo and dynamics to align with the soloist’s rhythmic variations (Merchán Sánchez-Jara et al., 2024; Ye, 2020). This approach provides students with a practice experience that closely resembles performing with a live orchestra, thereby fostering the development of listening and ensemble skills during individual practice.

Artificial intelligence plays a significant role in promoting inclusivity within education. For students with special educational needs, AI reduces barriers to participation in the arts (Peng & Ratnavelu, 2024; Della Ventura, 2019). For example, Computer-aided Musical Analysis (CAMA) software employs visual thinking strategies to assist students with dyslexia in analyzing musical scores, thereby mitigating fatigue and anxiety (Della Ventura, 2019; Merchán Sánchez-Jara et al., 2024). Gesture recognition tools facilitate engagement for students with motor challenges, while systems such as LipNet and voice recognition technologies support students with hearing impairments, thereby expanding access to music education (Yu et al., 2023). By transforming how students experience music, AI enables all learners to cultivate artistic skills tailored to their individual needs (Della Ventura, 2019; Merchán Sánchez-Jara et al., 2024).

AI integration has fundamentally transformed music education, shifting from a traditional one-size-fits-all instructional model to a personalised, interactive, and immersive learning ecosystem. AI serves as a “cognitive scaffold” and creative partner, optimising learning pathways through performance data analysis, delivering immediate technical feedback, and expanding compositional opportunities for all learners. Additionally, this technology enhances inclusivity by removing barriers to artistic participation for students with disabilities through intelligent assistive tools (Smith & Doe, 2020).

3.1.3 AI applications and tools currently in use

SmartMusic and Yousician are regarded as pioneering tools in providing immediate feedback on pitch, rhythm, and expressive nuance. These AI-driven platforms use algorithms to create personalised study plans that evolve as the student progresses, and have been shown to improve practice effectiveness through real-time visual error detection (Merchán Sánchez-Jara et al., 2024; Sofianos et al., 2025). Tonara (Wolfie) serves as a home practice management tool, enabling AI to identify errors and suggest corrections immediately (Shang, 2019; Merchán Sánchez-Jara et al., 2024). This not only reduces the burden on teachers but also establishes specific practice objectives, helping primary students develop artistic critical thinking from an early age. In vocal training, Vocal AI Analyzer and Smart Vocal Coach are tools that convert abstract parameters such as resonance and articulation into objective visual signals, supporting the establishment of short practice loops for self-directed technical adjustment (Zhang, H., 2025).

AI has eliminated complex technical barriers, enabling learners to engage in higher-order compositional thinking through experiential learning. Bach Doodle, powered by Google Magenta's Coconet model, has been implemented in elementary music creation classes, allowing young learners to compose harmonizations in the Baroque style using an intuitive visual interface (Merchán Sánchez-Jara et al., 2024). In higher education, DeepBach, a deep learning model developed at Sony CSL, has been studied for its impact on AI-assisted polyphonic composition, which was found to increase students' academic motivation (Yuan, N., 2024). By permitting users to edit AI-generated samples, these tools facilitate the understanding of stylistic rules through active engagement rather than rote memorization of theory (Zhang, H., 2025; Cheng, 2025). IBM Watson BEAT and Orb Composer provide algorithmic music structures that support a cycle of creation, listening, critique, and revision. Data show that 85% of students using these tools demonstrated significantly higher levels of creativity and harmonic complexity (Peng & Ratnavelu, 2024; Sofianos et al., 2025). (Peng, 2025, pp. 4874-4888) For theory instruction, ChordIQ offers rapid-feedback quizzes that reveal and promptly address students' knowledge gaps before they become ingrained habits (Zhang, H., 2025).

Running on the GPT-4 platform, Chat Melody applies the Learning by Teaching strategy; findings confirm that students interacting with Chat Melody achieve higher test scores and report lower cognitive load, particularly reduced mental effort when processing complex Mozart harmonic analysis tasks (Jin et al., 2025). CAMA (Computer Added Musical Analysis) employs visual thinking and colour-coded diagrams to represent musical properties (such as transposition or inversion); CAMA helps reduce cognitive fatigue and enhance confidence for disadvantaged learner groups (Della Ventura, 2019). Soundtrap, a web-based digital audio workstation (DAW), facilitates cross-border collaboration, helping maintain continuous student engagement even in remote or blended learning environments (Merchán Sánchez-Jara et al., 2024; Zhang, H., 2025). A notable integrated model is THE ONE Smart Piano, where AI is not only present in software but is also embedded in the physical instrument experience. With a "learn while playing" philosophy, the system provides interactive

guidance through LED lights and companion applications, optimising practice efficiency and generating enthusiasm from the earliest stages of learning (Shang, 2019).

In summary, AI is now deeply integrated into all aspects of music education, encompassing content personalisation and functioning as a reliable virtual guide in performance practice and composition. Nevertheless, these applications do not supplant the teacher's role; instead, they establish a "Human-in-the-Loop" model. In this framework, teachers shift from being direct transmitters of knowledge to serving as experience designers and interpreters of AI-generated technical feedback, thereby ensuring that the educational process remains technologically advanced while upholding the humanistic values of art (Li et al., 2025).

3.2 Research Question 2: The integration of AI into music education faces a range of technical challenges, pedagogical risks, ethical issues, and equity barriers

3.2.1 Technical and technological challenges

The reliability of current audio AI systems remains a formidable challenge. Empirical studies indicate that vocal and instrumental recognition systems are highly sensitive to ambient noise, leading to inaccurate musical feature extraction when parameters are not continuously calibrated (Zhang, H., 2025). Moreover, although Deep Learning models require vast amounts of data to achieve accuracy, the field of music education currently faces a severe shortage of high-quality, pedagogically annotated datasets (Peng & Ratnavelu, 2024; Chen & Sun, 2024). Even advanced techniques such as diffusion models, when applied to audio, often exhibit temporal instability and difficulty maintaining long-term musical structure. This causes models to occasionally perform erratically, hindering the establishment of a stable assessment standard in the classroom (Wilson et al., 2025; Zhang, H., 2025).

One of the greatest ethical and technical challenges is the opacity of modern generative AI models. Many systems operate as "black boxes," in which the processing pipeline from input data to final assessment output is neither transparent nor interpretable (Wilson et al., 2025). In an educational context, this creates a trust gap: when AI provides feedback on expressive nuance or grades a technical performance, neither teachers nor students can readily understand the specific logical basis behind that decision (Peng & Ratnavelu, 2024; Wilson et al., 2025). This lack of interpretability not only limits deep human-machine interaction but also makes it difficult for teachers to translate AI's dry technical indicators into meaningful artistic advice (Wilson et al., 2025; Zhang, H., 2025; Cui & Chen, 2024).

Using immersive tools such as Virtual Reality (VR) and Augmented Reality (AR) in education requires robust hardware and a fast internet connection (Zhang, H., 2025). These systems need precise camera placement, consistent lighting, and reliable high-speed internet to avoid delays. For schools with limited budgets, these requirements are hard to meet. This worsens educational inequality, as well-funded urban schools can afford the technology, while rural or remote schools struggle to maintain smart devices (Cheng, 2025; Zhang, H., 2025). Without coordinated support for infrastructure, AI could become a "privilege" instead of helping make music education more accessible (Cheng, 2025).

Addressing these challenges requires developers and researchers to prioritize the creation of simpler, more interpretable AI models that perform effectively with authentic classroom data (Chen & Sun, 2024).

3.2.2 Pedagogical risks and human–machine interaction

A leading pedagogical risk is that students become overly reliant on ready-made AI feedback or solutions, thereby declining their independent analytical ability. The overuse of generative AI tools for rapid, detailed ideas can undermine individual creative confidence, leading learners to lose motivation to explore ideas beyond the scope of machine-generated suggestions (Cheng, 2025). Research indicates that if the timing of tool intervention is inappropriate or the degree of automation is too high, learners tend to “delegate” cognitive tasks to the tool, resulting in “mental inertia” (Zhang, H., 2025). Therefore, assistive tools need to be designed as a “scaffold” rather than a substitute, to avoid creating a learning environment characterized by addiction or technological dependency (Della Ventura, 2019).

When AI plays a big role in learning, there is a real worry that students will interact less with each other. Data shows that having AI in the classroom can shorten group discussions and peer reviews, which means students talk less and the usual “social rhythm” of the music class is disrupted (Zhang, H., 2025). While AI can give accurate feedback, it still cannot match the emotional understanding and cultural awareness that a human teacher offers. If the focus shifts too much from “teacher–student” to “human–machine” interaction, it can weaken the artistic experience and the sense of community in art classes (Yuan, N., 2024; Lu & Guo, 2025).

In creative fields, using pre-made examples or AI-generated musical templates can threaten originality. Students may start copying these patterns, which leads to music that sounds the same and lacks personal style (Lu & Guo, 2025; Yuan, N., 2024). As a result, students are moving from being “composers” who create music themselves to “curators” who simply pick and adjust what the AI generates, rather than building music from their own ideas (Wilson et al., 2025). Also, because most training data is based on Western music, there is less diversity in new music created with AI (Cheng, 2025).

The successful integration of artificial intelligence (AI) in education is largely contingent on the digital competence of teaching staff; however, this competence remains a systemic barrier. Many teachers, especially those with extensive tenure, frequently struggle to adapt to emerging technologies due to limited digital skills or the lack of specialized training programs (Peng & Ratnavelu, 2024; Zhang, H., 2025). Senior teachers, in particular, may exhibit lower self-efficacy and be less willing to incorporate technology into classroom practices than their younger counterparts (Cheng, 2025). In the absence of supportive policy frameworks and comprehensive training in AI literacy, these technologies are likely to remain peripheral “accessories” rather than becoming integral instructional partners (Peng & Ratnavelu, 2024).

Addressing these challenges requires educational institutions to maintain a “Human-in-the-Loop” approach. In this framework, teachers remain responsible for designing learning experiences,

determining the appropriate use of AI tools, and guiding students in critically reflecting on their interactions with AI.

3.2.3 Equity and access issues

While AI is anticipated to democratize access to high-quality education, current trends indicate a widening digital divide among different groups. This disparity extends beyond access to smart devices and bandwidth infrastructure, which are already significant obstacles for students in rural areas or underfunded schools (Cheng, 2025; Zhang, H., 2025). Studies show that the commercialization of AI tools through subscription-based models has introduced a financial paywall. Students from lower-income families are often limited to free versions with restricted features, whereas advanced AI platforms that offer personalized feedback and optimized learning pathways constitute a form of digital privilege. In the absence of government subsidies or institutional support, AI may further exacerbate achievement gaps across socioeconomic groups (Cheng, 2025).

A significant ethical and professional concern is the presence of systemic bias in AI training datasets (Wilson et al., 2025). At present, most leading AI music models are primarily trained on datasets of Western classical or pop music (Cheng, 2025). The use of these biased AI tools in educational contexts can result in inaccurate technical feedback for students and poses a threat to cultural diversity (Karpouzis, 2024; Cheng, 2025). Such tools may encourage learners to adopt established Western standards, thereby diminishing the distinctive expressive qualities of indigenous musical traditions (Wilson et al., 2025; Cheng, 2025).

Establishing AI as an equitable and comprehensive educational support tool necessitates that researchers and policymakers prioritise the development of multicultural datasets and implement coordinated financial support frameworks to eliminate access barriers. Such measures are essential to ensure that technological advancements benefit all students, regardless of economic status or cultural background.

3.2.4 Authorship and data privacy

Current AI models are generally trained on extensive datasets sourced from the internet, often without obtaining explicit consent or providing attribution to original artists (Wilson et al., 2025). Furthermore, leading commercial music generative AI tool developers have acknowledged the potential use of copyrighted material in training, which can result in outputs that closely replicate the structure or timbre of protected recordings. Within educational settings, this poses a substantial challenge for assessment, as existing evaluation frameworks are insufficient to clearly distinguish between a student's creative input and algorithmic assistance (Cheng, 2025). The transition of the learner's role from direct "composer" to "curator," in which individuals provide high-level prompts for machines to generate complete works, intensifies debates regarding the boundaries of originality and the enforceability of individual authorship rights (Wilson et al., 2025; Cheng, 2025).

The collection of learning data for AI training raises significant ethical concerns, especially when minors are involved. This process frequently lacks transparency, as AI models function as “black boxes” that prevent educators and students from assessing how personal data is utilized (Rodríguez-Ortiz et al., 2025). Research highlights ethical issues associated with collecting extensive data on children’s learning activities to optimize algorithms. In the absence of robust regulations and well-defined instructional data governance frameworks within educational institutions, students face risks to their privacy and may become overly reliant on technological systems that can influence behavior through personal data analysis (Merchán Sánchez-Jara et al., 2024; Wilson et al., 2025; Cheng, 2025).

The unregulated application of generative artificial intelligence (GenAI) in educational settings can facilitate academic misconduct. GenAI technologies enable the creation of highly realistic deepfake images and audio, which increases the risk of cyberbullying and the defamation of peers without consent (Das, 2024; Cheng, 2025). Beyond individual ethical issues, excessive dependence on automation introduces pedagogical risks by reducing direct social interactions. Empirical studies demonstrate that extensive AI intervention decreases opportunities for group discussions and peer assessment, thereby limiting communication and disrupting the essential social dynamics of arts classrooms (Zhang, H., 2025). Additionally, the widespread production of homogeneous, machine-generated musical works threatens cultural diversity and may contribute to psychological dependency, ultimately undermining students’ independent analytical skills (Zhang, H., 2025; Cheng, 2025).

Fostering a secure and integrity-driven environment in music education requires the establishment of comprehensive legal frameworks and codes of conduct for responsible AI use. These initiatives should emphasise data transparency, protect learner privacy, and update originality assessment criteria to meet the demands of the digital era.

3.2.5 Limitations regarding artistic and humanistic dimensions

Although artificial intelligence has advanced considerably in simulating musical structure, its primary challenge remains the comprehension and conveyance of emotional intelligence and cultural context, qualities that human educators provide instinctively. Empirical studies demonstrate a clear distinction in AI performance: while models achieve high structural accuracy on MIDI data, their effectiveness declines markedly with emotional datasets, suggesting persistent difficulties in interpreting the deep meaning and subjective expressive nuances of music (Chen & Sun, 2024). Current AI systems continue to operate according to rule-based principles and lack the empathetic sensitivity required to recognize learners’ complex psychological states, which is fundamental to fostering emotional resonance in art. Presently, deep learning algorithms are unable to directly grasp the intrinsic content and deep meaning of music, which inherently represents a synthesis of rationality and emotionality in human creative processes (Yu, L. & Ding, 2020; Yuan, S., 2020).

The capacity to generate professional musical works with minimal effort, such as through a few clicks or a simple prompt, may create the misconception that music is an easily acquired skill, thereby reducing motivation to engage with the demanding technical challenges of formal education (Cheng,

2025). Overreliance on swiftly produced, detailed machine-generated ideas increases the risk of mental inertia, diminishes creative confidence, and discourages students from pursuing original concepts beyond established algorithmic frameworks (Zhang, H., 2025; Cheng, 2025). Furthermore, this development is transforming the music learner's role from that of a composer to a curator, who primarily refines machine-generated outputs rather than undertaking the demanding process of developing an individual artistic identity. Should music education rely predominantly on pre-packaged examples, students may increasingly adopt imitative practices, resulting in formulaic compositions and a diminished capacity for critical analysis and independent thought (Wilson et al., 2025).

Preserving the humanistic values inherent in music education requires positioning artificial intelligence as a partner that enhances students' potential, rather than as a substitute for disciplined practice and the emotional depth of human experience. Assessment frameworks should prioritize students' reflective processes and strategic thinking, rather than focusing solely on technology-facilitated outcomes.

3.3 Research Question 3: What pedagogical frameworks and learning theories guide the use of AI in music education to ensure quality and ethical practice?

3.3.1 Core learning theories

Within the frameworks of Constructivism and Mediated Learning Theory, artificial intelligence operates as a "cognitive scaffold" that supports the learning process while maintaining the indispensable role of human guidance. This view aligns with Vygotsky's framework, in which technology serves as a mediating tool that enables students to construct knowledge through purposeful interactions rather than passive information reception (Miranda, 2021; Merchán Sánchez-Jara et al., 2024). In AI-supported music learning environments, the system provides adaptive feedback that promotes students' self-regulation of their learning paths, ensuring that instruction remains within each learner's "Zone of Proximal Development" (Zhang, H., 2025; Merchán Sánchez-Jara et al., 2024).

The integration of Teachable Agents (TAs) powered by Large Language Models (LLMs), as demonstrated by the Chat Melody system, has enabled the practical application of the Learning by Teaching strategy in music education (Jin et al., 2025). When students are required to explain complex music theory concepts, such as harmonic structure, to a virtual learner, artificial intelligence facilitates knowledge acquisition and promotes metacognitive development. Empirical evidence indicates that students who interact with AI agents achieve significantly higher scores and demonstrate deeper retention of concepts, attributable to the processes of reflection, critique, and idea refinement during machine-agent tutoring (Chong, 2019; Jin et al., 2025).

Discovery Learning Theory is exemplified in software such as Computer-Assisted Musical Analysis (CAMA), where artificial intelligence establishes an environment that enables students to experiment and practice visually (Della Ventura, 2019). By exploring musical properties such as transposition, inversion, and retrograde through an interactive interface, learners can understand musical rules more

concretely. For students with dyslexia, this discovery-based approach, grounded in visual thinking, reduces cognitive fatigue and strengthens self-efficacy in tackling complex music analysis tasks (Merchán Sánchez-Jara et al., 2024; Della Ventura, 2019).

Current AI tools place particular emphasis on restructuring reasoning processes to reduce unnecessary mental effort (Jin et al., 2025; Chong, 2019). LLM-based pedagogical agents assist students in decomposing complex music analysis activities into manageable steps, helping prevent information overload (Jin et al., 2025). Empirical evidence from two control groups in the study by Jin et al. confirmed that students using AI experienced significantly lower cognitive load, allowing them to allocate intellectual resources towards processing core concepts and developing higher-order creative thinking (Jin et al., 2025).

These theoretical frameworks position AI as a collaborative partner that amplifies human potential and sustains the humanistic dimension within arts education.

3.3.2 Pedagogical frameworks and implementation models

Innovation in instructional processes is clearly manifested through the transition from the traditional “4+3” model to the “7+7” framework (resource release, goal setting, sensory introduction, task distribution, guidance and explanation, detection and evaluation, and extension and push) based on intelligent technology (Yu et al., 2023). In this model, the teacher’s role is expanded into seven strategic steps - from resource release and goal setting to the promotion of data-driven extension content. Correspondingly, the student’s learning process is also segmented into seven stages of active interaction, ranging from independent preview and situational experience to breakthrough on knowledge anchor points. This model creates a closed educational loop across the pre-class, in-class, and post-class phases, making teacher–student interaction more dynamic and effective through learner-centred design and the leveraging of big data to adjust teaching strategies in a timely manner.

The zenith of learning personalisation is operationalised through the EFDfO (Entropy Features Data Fusion Optimised) research framework, a data-driven approach aimed at revolutionising music instruction (Zhang, L., 2023; Merchán Sánchez-Jara et al., 2024). The core differentiator of EFDfO is its capacity to fuse multifaceted data - combining music performance records, practice logs, and biometric indicators such as heart rate and pupil dilation - to construct a unique learning portrait for each student (Zhang, L., 2023). By applying the Whale Optimisation Algorithm, the system can estimate competence and automatically fine-tune learning pathways to suit the distinctive characteristics of each learner. Experimental and simulation results have confirmed the superior performance of this framework, with average score improvements of 18% to 20%, alongside increased student satisfaction and learning engagement (Zhang, L., 2023).

The integration of artificial intelligence into blended learning environments has established an intermediary space in which technology effectively supports face-to-face classroom activities (Zhang, H., 2025; Merchán Sánchez-Jara et al., 2024). Tools such as ChordIQ are instrumental in music theory and literacy instruction, facilitating instant feedback loops that enable students to identify and correct

errors promptly, thereby rendering the learning process more transparent. Additionally, the use of large language models such as GPT-4 in blended settings has shown positive effects on learner experience by reducing cognitive load and enhancing self-efficacy beliefs (Zhang, W., 2024; Zhang, H., 2025; Cheng, 2025). Within this framework, teachers assume the roles of experience designers and feedback interpreters, orchestrating and translating technical data from machines into meaningful artistic guidance to maintain equilibrium between technological advancement and the humanistic values inherent in music (Zhang, H., 2025).

4. DISCUSSION

The digital transformation of music education is undergoing a systemic turning point due to the integration of artificial intelligence. From the perspective of educational science, AI is conceptualized not as a replacement for human roles but as a cognitive scaffold and co-creative partner. AI facilitates the optimization of cognitive load by automating harmonic structure analysis and complex music-theory data processing, enabling learners to allocate intellectual resources to higher-order creative activities and aesthetic expression.

Empirical evidence indicates that advanced AI application models demonstrate both scalability and effectiveness in music education. The implementation of the EFDfO framework, which integrates multi-source data such as biometric and linear practice data, has established mechanisms for personalized learning pathways and improved learning outcomes. Solutions like CAMA software have advanced inclusive education by supporting learners with diverse cognitive profiles through audio data visualization techniques. The creation of '3D musical landscape spaces' within virtual reality environments has further optimized resources, providing access to high-quality music education independent of traditional physical infrastructure.

Nevertheless, the integration of AI in music education continues to face significant ethical and technical challenges. The digital divide and cultural bias embedded in algorithms, especially those favouring Western music theory, threaten the diversity of indigenous musical values. Addressing these challenges requires the development of AI competencies among both educators and learners. Educators must transition from being solely knowledge transmitters to facilitators of experience and critics of artistic expression. Furthermore, comprehensive policy frameworks addressing academic ethics and copyright are essential to safeguard the originality of creative works. Ultimately, human oversight and guidance remain vital for preserving humanistic values and spiritual depth in digital artistic products.

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