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Preparing Music Teachers for Artificial Intelligence: An Integrative Review of AI Literacy, Pedagogical Readiness, and Responsible Educational Practice

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ABSTRACT: Artificial intelligence is transforming music education across lesson planning, performance assessment, personalized learning, creative music-making, and learning analytics, yet successful implementation depends critically on teachers' preparedness to integrate AI responsibly. This integrative literature review examines AI in music teacher education through research published primarily between 2020–2025, identifying adopted technologies, required competencies, pedagogical and ethical challenges, and proposing a conceptual framework for responsible integration. Synthesizing heterogeneous evidence — empirical studies, conceptual papers, systematic reviews, and policy documents — via PRISMA-guided screening and Whittemore and Knafl's integrative approach with theory-oriented narrative synthesis, findings reveal that generative AI, LLMs, intelligent tutoring systems, learning analytics, computer vision, and automated assessment increasingly support instructional planning and creative composition. Effectiveness, however, depends on teachers critically evaluating outputs while preserving musical creativity. AI literacy, music-specific TPACK, ethical awareness, and institutional readiness emerge as interdependent success factors, amid persistent challenges of algorithmic bias, privacy, and limited empirical evidence. The review proposes the Responsible AI Readiness Framework for Music Teacher Education, positioning AI as a pedagogical and creative partner to guide curriculum design, policy development, and future research.

Keywords: Artificial Intelligence, Music Education, Music Teacher Education, AI literacy, TPACK, Responsible Artificial Intelligence, Integrative Literature Review

INTRODUCTION

Artificial intelligence has become an increasingly influential component of educational transformation, particularly through its capacity to automate routine tasks, personalize learning processes, generate instructional content, and provide immediate feedback. Between 2020 and 2025, these functions became progressively visible in music education, where artificial intelligence-supported systems have been used to evaluate student work, monitor progress, recommend

individualized practice activities, and assist teachers in making pedagogical decisions. Automated evaluation and instant feedback are frequently presented as mechanisms for reducing the time teachers spend on repetitive instructional tasks while enabling more targeted support for individual learners (Patrick & Bakar, 2024; Pham & Sampson, 2022). Artificial intelligence-driven analytics have similarly been used to identify patterns in student development, adapt task difficulty, and align practice trajectories with students' abilities and goals (Ng et al., 2023). In creative domains, artificial intelligence-supported music creation systems have expanded opportunities for composition, arrangement, and experimentation, allowing learners to generate alternatives, explore polyphonic structures, and engage with new forms of musical expression (Marievych et al., 2022; Yuan, 2024). These developments indicate that artificial intelligence is no longer limited to technical or administrative support but is increasingly involved in pedagogical, evaluative, and creative dimensions of music teaching.

The significance of these developments is heightened by the distinctive characteristics of music education. Unlike subjects in which learning outcomes can often be represented primarily through factual knowledge or standardized written responses, music learning combines conceptual understanding, auditory discrimination, embodied technique, interpretive judgment, emotional communication, creativity, and collaborative performance. Instrumental and vocal learning require sustained attention to pitch, rhythm, intonation, articulation, posture, breathing, tone quality, phrasing, and stylistic awareness. Ensemble learning also depends on listening, coordination, responsiveness, and collective interpretation. Consequently, artificial intelligence systems designed for music education must account for both measurable performance features and less easily quantifiable artistic qualities (Goncharova & Gorbunova, 2020; Yuan, 2024). Although algorithmic systems may identify note-level errors or inconsistencies in tempo, they may be less capable of judging expression, cultural appropriateness, stylistic intention, and communicative meaning. The creative character of music education further distinguishes it from other disciplines because artificial intelligence may contribute ideas or compositional materials without being able to determine the artistic significance of those materials. Teacher guidance therefore remains essential to ensure that technological support strengthens, rather than narrows, students' musical understanding and creative agency (Marievych et al., 2022; Yuan, 2024).

The central problem is that the growing availability of artificial intelligence tools has not been matched by equivalent development in music teacher preparation. Many pre-service and in-service music teachers encounter artificial intelligence-supported platforms without sufficient knowledge of how these systems operate, how their outputs should be evaluated, or how they can be aligned with music-specific pedagogical aims. Existing evidence points to gaps in artificial intelligence literacy, digital competence, technological pedagogical content knowledge, and confidence among teachers expected to integrate these technologies into practice (Jusoh & Nasri, 2023; Sain et al., 2024). These gaps create a discrepancy between technological potential and educational implementation. A system may be technically sophisticated, but its contribution remains limited when teachers lack the capacity to select appropriate applications, interpret automated feedback, identify inaccuracies, or determine whether an artificial intelligence-supported activity contributes meaningfully to musical learning. Differences in infrastructure, access to professional

development, institutional support, and local policy further produce uneven levels of readiness across educational contexts (Vodiana et al., 2020; Ng et al., 2023; Sain et al., 2024).

Addressing this problem requires a shift from technology-centered adoption to teacher-centered and pedagogically grounded preparation. Artificial intelligence should be understood simultaneously as an educational tool and as a domain of professional knowledge. This dual framing distinguishes learning with artificial intelligence from learning about artificial intelligence and emphasizes that teachers require both practical competence and conceptual understanding(Mamaeva et al., 2022). Music teachers must be able to use artificial intelligence for tasks such as planning, feedback, assessment, and content development, while also understanding uncertainty, bias, data practices, hallucination, and the limitations of automated judgment. Their role is therefore not merely to operate available interfaces but to configure, contextualize, verify, and, when necessary, reject artificial intelligence-generated outputs. Research concerning teacher identity in artificial intelligence-supported education reinforces this position by arguing that educators must understand the mechanisms and assumptions embedded in digital systems rather than depending passively on default functions (Gentile et al., 2023; Пістунова et al., 2021; 최, 2023). A general solution must consequently integrate artificial intelligence literacy, pedagogical competence, disciplinary expertise, and professional autonomy within music teacher education.

One specific response identified in the literature is the development of artificial intelligence literacy as a foundational component of teacher preparation. Artificial intelligence literacy includes knowledge of basic concepts, awareness of system capabilities and limitations, understanding of ethical and social implications, and the ability to make informed decisions about classroom use(Tatnall, 2023). In music education, this competence must extend beyond general digital literacy because teachers are required to evaluate outputs involving notation, harmony, style, performance, repertoire, and creative authorship. They must also recognize that generative systems may provide inaccurate theoretical explanations, fabricate references, produce stylistically inappropriate materials, or simplify complex musical judgments. Artificial intelligence literacy should therefore include critical verification, prompt formulation, data awareness, and the ability to explain to students how and why particular tools are being used. It should also prepare teachers to distinguish between artificial intelligence as scaffolding and artificial intelligence as a substitute for listening, reflection, creative decision-making, or independent problem solving. Such literacy can support more informed adoption while reducing the risks of overreliance, superficial integration, and uncritical acceptance.

A second response is to extend technological pedagogical content knowledge to incorporate artificial intelligence-specific and music-specific competencies. The TPACK framework emphasizes that technology cannot be integrated effectively in isolation from pedagogy and disciplinary content. In music teacher education, artificial intelligence-enabled TPACK requires teachers to understand how particular technologies interact with musical knowledge, instructional methods, assessment practices, and learner characteristics (Ng et al., 2023). For example, an automated pitch-analysis system may be pedagogically useful in early technical training but insufficient for evaluating interpretation or stylistic nuance. A generative composition platform may support divergent thinking but should be accompanied by activities requiring students to

compare, revise, justify, and take responsibility for artistic decisions. Similarly, large language models may assist with lesson planning or theory explanation, but teachers must verify disciplinary accuracy and adapt generated content to learner level and cultural context. Professional development should therefore be designed around authentic music-teaching tasks, including performance assessment, composition instruction, repertoire selection, reflective practice, and ethical decision-making, rather than focusing only on tool operation.

Related literature also identifies technology acceptance and policy support as important conditions for sustainable implementation. Teachers' willingness to use artificial intelligence is influenced by perceived usefulness, perceived ease of use, confidence, cognitive load, access to resources, institutional expectations, and alignment with pedagogical goals (Tatnall, 2023; Ng et al., 2023). Acceptance should not, however, be treated as equivalent to readiness. Teachers may hold positive attitudes toward artificial intelligence while lacking the competence to evaluate its outputs responsibly, or they may resist useful technologies because of insufficient training and institutional guidance. Human-centered policy frameworks therefore emphasize transparency, fairness, data governance, accessibility, professional responsibility, and the protection of teacher and student rights (Sain et al., 2024; Vodiana et al., 2020). Policy instruments such as digital education plans and national or regional guidelines provide an important governance foundation, but their application remains uneven. In music education, additional concerns arise from the collection of audio, video, movement, and performance data, as well as from questions of copyright, authorship, cultural representation, and artistic validity. These issues demonstrate that teacher readiness is simultaneously technological, pedagogical, ethical, professional, and institutional.

Despite increasing interest in artificial intelligence-supported music education, the literature remains fragmented across technology development, creativity, assessment, teacher education, and policy. Existing studies document automated feedback, personalized learning, intelligent tutoring, music generation, and learning analytics, yet fewer syntheses explain how teacher literacy, TPACK, technology acceptance, ethical awareness, professional autonomy, and institutional readiness interact. Claims that artificial intelligence improves motivation, creativity, efficiency, or learning outcomes also require careful interpretation because results vary according to context, infrastructure, research design, teacher preparation, and the duration of implementation (Кравцова et al., 2022; Yuan, 2024). Readiness gaps differ across regions and institutions, while professional development models remain inconsistent in scope and delivery (Ng et al., 2023; Sain et al., 2024). Policy frameworks offer direction but do not guarantee classroom-level implementation, especially in music programs with distinctive resource, scheduling, performance, and assessment demands (Vodiana et al., 2020; Sain et al., 2024). This fragmentation reveals the need for an integrative review that places the music teacher, rather than the technology, at the center of analysis.

Accordingly, this study aims to synthesize literature published primarily between 2020 and 2025 on music teachers' preparation for artificial intelligence, with particular attention to artificial intelligence literacy, pedagogical readiness, TPACK, technology acceptance, ethical competence, institutional support, and professional autonomy. The review is guided by the proposition that successful integration depends less on technological sophistication than on the capacity of teachers

and institutions to use artificial intelligence critically, contextually, and responsibly. Its novelty lies in connecting previously dispersed strands of research within a unified Responsible Artificial Intelligence Readiness Framework for Music Teacher Education. The framework positions artificial intelligence literacy and music-specific TPACK as foundational competencies, while calibrated trust, ethical awareness, human oversight, institutional readiness, and professional autonomy mediate the transition from technological access to responsible educational practice. The scope includes pre-service and in-service music teacher education, classroom and higher-education settings, artificial intelligence-supported planning, assessment, feedback, creativity, and professional learning, as well as the ethical and policy conditions that shape implementation. Through this synthesis, the study seeks to provide a conceptual basis for future empirical research, curriculum development, professional development, and governance in human-centered artificial intelligence-supported music education.

METHOD

Review Design

This study adopted an integrative literature review design to synthesize heterogeneous evidence concerning artificial intelligence in music teacher education. An integrative review was selected because the relevant literature comprises multiple forms of evidence, including quantitative studies, qualitative inquiries, mixed-method research, conceptual papers, policy documents, design reports, systematic reviews, and pedagogical analyses. Such heterogeneity makes a narrowly defined systematic review insufficient for addressing the broader conceptual, pedagogical, ethical, and institutional questions examined in this study. Integrative review methods are specifically intended to combine diverse evidence streams in order to generate new conceptual insights, identify relationships across fields, and develop frameworks that are applicable to complex educational problems (Deroncele-Acosta et al., 2024; Weil & Ceryes, 2024).

The review design was structured around a multi-stage process comprising problem identification, literature searching, screening, data extraction, quality appraisal, data reduction, thematic comparison, and synthesis. This approach is consistent with recent integrative and scoping-informed reviews in artificial intelligence in education, which emphasize the need for flexible but transparent procedures when synthesizing evidence across disciplines and methodologies (Deroncele-Acosta et al., 2024; Ng et al., 2023). The review also incorporated theoretical mapping to connect the evidence with three central analytical perspectives: artificial intelligence literacy, technological pedagogical content knowledge, and technology acceptance. These lenses were selected because they provide complementary explanations of teachers' knowledge, pedagogical competence, willingness to adopt technology, and capacity to use artificial intelligence responsibly in music education (Tatnall, 2023; Ng et al., 2023).

The methodological framework combined three complementary traditions. First, PRISMA principles were used to strengthen transparency in searching, screening, and documenting study selection. Second, the integrative review procedures associated with Whittemore and Knafl

informed the organization, comparison, and synthesis of heterogeneous evidence. Third, a Torraco-inspired narrative approach was used to connect empirical findings with theory and to construct a new conceptual interpretation of artificial intelligence readiness in music teacher education. This combination is appropriate for educational technology research because it balances reporting transparency, methodological flexibility, and theoretical synthesis (Martínez-Heredia, 2025).

Review Scope and Research Period

The principal review period covered literature published between 2020 and 2025. This period was selected because it captures the rapid expansion of artificial intelligence applications in education, including generative artificial intelligence, large language models, intelligent tutoring systems, learning analytics, automated assessment, and artificial intelligence-supported creativity. Publications from 2026 may be considered as emerging evidence but should be interpreted separately because the publication year remains incomplete.

Earlier studies were included selectively when they provided foundational theoretical or methodological concepts relevant to the analysis. These included literature on technological pedagogical content knowledge, artificial intelligence literacy, teacher readiness, technology acceptance, professional autonomy, human-centered artificial intelligence, and responsible educational technology. The review was therefore temporally focused but conceptually inclusive.

The scope covered pre-service and in-service music teachers, music teacher educators, higher-education music programs, school music contexts, professional development, and policy or institutional frameworks relevant to music teacher preparation. Studies focusing on student learning were also considered when they contained direct implications for teacher competence, pedagogical decision-making, or institutional readiness.

Information Sources

The search was designed to identify literature across education, music education, educational technology, computer science, and teacher preparation. The principal databases included Scopus, Web of Science, ERIC, ScienceDirect, SpringerLink, IEEE Xplore, ACM Digital Library, and ProQuest. Google Scholar was used only for supplementary searching, citation chaining, and locating potentially relevant works that may not have been indexed consistently in the principal databases.

This broad database selection was necessary because artificial intelligence in music education is distributed across several disciplinary traditions. Educational databases capture teacher education, pedagogy, and policy research, whereas technical databases contain studies on intelligent tutoring, signal analysis, machine learning, and multimodal systems. Music education literature may also appear in journals that are not consistently indexed within computer science databases. Previous

reviews in artificial intelligence in education have similarly used broad database coverage and combined systematic searching with bibliometric or thematic mapping to identify trends across disciplinary boundaries (Sang, 2024; Yeter et al., 2024).

Search Strategy

The search strategy combined terms from three concept groups: artificial intelligence, music education, and teacher preparation. Artificial intelligence terms included "artificial intelligence," "generative AI," "large language model," "machine learning," "intelligent tutoring system," "learning analytics," "automatic assessment," "computer vision," "automatic music transcription," and "multimodal AI." Music education terms included "music education," "music teaching," "music pedagogy," "instrumental education," "vocal education," "composition education," and "music teacher education." Teacher-related terms included "music teacher," "pre-service music teacher," "in-service music teacher," "teacher readiness," "AI literacy," "TPACK," "technology acceptance," "professional development," "ethical competence," and "professional autonomy."

An illustrative search string was:

("artificial intelligence" OR "generative AI" OR "large language model" OR "machine learning" OR "intelligent tutoring system") AND ("music education" OR "music teaching" OR "music pedagogy") AND ("music teacher" OR "pre-service teacher" OR "teacher education" OR "AI literacy" OR "TPACK" OR "teacher readiness")

The search terms were adapted to each database according to its indexing structure, Boolean syntax, and subject headings. Searches were conducted iteratively because the terminology used in the literature varies across fields. For example, relevant studies may describe artificial intelligence-supported instruction through terms such as adaptive learning, intelligent feedback, automated evaluation, digital music pedagogy, or learning analytics without using the phrase "artificial intelligence" prominently in the title. Prior reviews of artificial intelligence in education and music education have similarly used broad combinations of technology, educational context, and application terms to ensure adequate coverage (Yeter et al., 2024; Yuan, 2024).

Inclusion and Exclusion Criteria

Studies were eligible for inclusion when they met the following criteria: publication in English; primary publication between 2020 and 2025; direct relevance to artificial intelligence in education, music education, music teacher preparation, or transferable teacher-related implications; sufficient methodological or conceptual detail; and explicit attention to pedagogy, teacher competence, assessment, ethics, policy, technology acceptance, or institutional implementation.

Because the review was integrative, eligible evidence included experiments, quasi-experiments, surveys, case studies, qualitative research, mixed-method studies, design-based research, systematic reviews, conceptual papers, and policy documents. This broad inclusion was necessary to support

cross-method synthesis and reflects common practice in integrative reviews of artificial intelligence in education (Deroncele-Acosta et al., 2024; Yeter et al., 2024).

Studies were excluded when they focused solely on technical music generation, signal processing, or algorithmic performance without meaningful educational implications. Purely engineering-oriented papers, conference abstracts without full text, promotional materials, unsupported opinion pieces, duplicate reports, and studies lacking sufficient analytical detail were also excluded. Music-related artificial intelligence studies were retained only when they addressed pedagogy, assessment, creativity, teacher preparation, or educational implementation. This distinction was necessary because the broader field of artificial intelligence and music contains substantial technical research that does not directly inform teaching practice (Sang, 2024; Willett et al., 2024).

Screening and Study Selection

All retrieved records were compiled and duplicates were removed. Screening then proceeded in two stages. First, titles and abstracts were reviewed against the inclusion and exclusion criteria. Second, potentially relevant papers were assessed in full text. Reasons for exclusion at the full-text stage were documented to support transparency.

The selection process was reported using a PRISMA-style flow diagram. Although this review was integrative rather than a conventional systematic review or meta-analysis, PRISMA was used because it provides a clear structure for documenting record identification, duplicate removal, screening, eligibility assessment, and final inclusion. Previous integrative and artificial intelligence-related reviews have similarly adopted PRISMA procedures to improve reproducibility and reader confidence (Baidoo-Baiden, 2022; Yeter et al., 2024).

Backward and forward citation searching were used to identify additional relevant sources. Reference lists of included reviews and highly relevant empirical studies were screened, and citation tracing was used to locate newer studies addressing similar concepts. This supplementary process was especially important for literature on emerging technologies and music-specific applications, where indexing may be inconsistent.

Data Extraction

A structured extraction form was developed to ensure consistency across heterogeneous sources. The form included bibliographic information, research design, educational setting, participants, sample size, artificial intelligence technology, music domain, pedagogical function, teacher-related variables, institutional conditions, ethical concerns, and reported outcomes.

Teacher-related variables included artificial intelligence literacy, perceived usefulness, perceived ease of use, trust, cognitive load, behavioral intention, pedagogical confidence, technological pedagogical content knowledge, ethical awareness, and professional autonomy. Institutional

variables included infrastructure, leadership, policy, funding, professional development, technical support, curriculum integration, and equity.

The extraction process also recorded whether artificial intelligence functioned as a tool, assistant, tutor, evaluator, creative partner, or administrative support system. This classification enabled comparison between technologies that differ substantially in pedagogical authority and risk. Data extraction was guided by recurring themes identified in previous reviews, including feedback and assessment, personalization, learning analytics, teacher preparedness, artificial intelligence literacy, TPACK, policy, and ethics ((Patrick & Bakar, 2024; Tatnall, 2023).

Quality Appraisal

A flexible quality appraisal strategy was used because the evidence base included diverse study designs. Rather than excluding studies solely because of methodological variation, each source was assessed according to its credibility, transparency, pedagogical relevance, and contribution to the review questions. This approach is consistent with integrative review methodology, which seeks to preserve useful conceptual and contextual evidence while identifying methodological strengths and limitations (Deroncele-Acosta et al., 2024; Sang, 2024).

The appraisal considered clarity of purpose, appropriateness of design, participant description, validity of instruments, transparency of data analysis, credibility of conclusions, and ethical reporting. For technology-focused studies, additional attention was given to the transparency of the artificial intelligence system, the quality of the dataset, and the alignment between technical evaluation and educational objectives. For music education studies, ecological validity, pedagogical authenticity, and relevance to real teaching practice were emphasized because small samples and context-specific designs are common in this field (Yuan, 2024; Willet & Na, 2024).

Thematic Synthesis

The synthesis followed an iterative process of data reduction, coding, comparison, and conceptual integration. Initial codes were generated from the review questions and theoretical framework, while additional codes were developed inductively from the included studies. Related codes were grouped into broader themes.

The final thematic structure comprised: artificial intelligence technologies in music teacher education; teacher artificial intelligence literacy and competencies; teacher readiness and technology acceptance; artificial intelligence-enabled TPACK; pedagogical applications; institutional readiness; ethical and professional challenges; and future research priorities.

Cross-domain comparison was used to identify both convergence and divergence between general artificial intelligence in education and music-specific literature. This was particularly important because music education requires attention to performative, expressive, ensemble, creative, and

culturally situated learning that may not be adequately represented in broader educational technology research (Goncharova & Gorbunova, 2020; Mamaeva et al., 2022; Yuan, 2024). The synthesis therefore examined not only what artificial intelligence technologies can do, but also how their pedagogical value is mediated by teacher knowledge, disciplinary context, institutional conditions, and ethical governance.

Methodological Rigor and Transparency

Methodological rigor was strengthened through transparent documentation of the search process, explicit inclusion criteria, structured data extraction, design-sensitive quality appraisal, and systematic thematic comparison. PRISMA supported reporting clarity, Whittemore and Knafl informed the integration of heterogeneous evidence, and Torraco's approach supported theory-driven narrative synthesis.

The combination of these methods was intended to produce a review that is both methodologically transparent and conceptually generative. Rather than merely cataloguing artificial intelligence tools, the review sought to explain how teacher literacy, TPACK, technology acceptance, ethical awareness, institutional readiness, and professional autonomy interact in responsible music teacher preparation. This methodological triangulation therefore provided the foundation for developing the Responsible Artificial Intelligence Readiness Framework proposed in the later sections of the article.

RESULT AND DISCUSSION

Overview of the Evidence Base

The reviewed literature presents a rapidly expanding but methodologically diverse body of research on artificial intelligence in music education and music teacher preparation. The evidence covers generative music systems, large language models, intelligent tutoring systems, learning analytics, computer vision, multimodal artificial intelligence, automated assessment, and artificial intelligence-supported creative tools. Across these areas, the strongest concentration of research concerns automated feedback, composition support, personalization, learning analytics, and the professional competencies required for responsible adoption. However, the literature remains uneven in terms of empirical maturity. Many studies describe technological possibilities or short-term educational outcomes, whereas longitudinal evidence concerning sustained learning, professional practice, and teacher autonomy remains limited (Goncharova & Gorbunova, 2020; Yuan, 2024).

The findings were organized into two major thematic domains. The first concerned the technologies used in music teacher education and the educational tasks they support. The second concerned the professional competencies required for successful and responsible implementation.

Across both domains, the literature consistently positioned teachers as interpreters, designers, and ethical decision-makers rather than as passive users of automated systems.

Artificial Intelligence Technologies in Music Teacher Education

Generative Artificial Intelligence and Music-Creation Platforms

Generative artificial intelligence and artificial intelligence-assisted music-creation platforms were among the most frequently discussed technologies. These systems were used to generate melodies, accompaniment, arrangements, polyphonic materials, compositional prompts, and instructional examples. Their principal educational functions included supporting creative experimentation, expanding the range of musical alternatives available to learners, and facilitating autonomous exploration of musical ideas (Cooper, 2024; Zeng et al., 2022).

The reviewed studies indicated that generative systems may increase learner motivation by allowing students to compare, modify, and extend machine-generated materials. In composition and arrangement activities, artificial intelligence can function as a creative stimulus rather than as a final author. The strongest pedagogical applications were those in which teachers required students to evaluate the stylistic, structural, expressive, and contextual quality of generated materials. Such activities preserved student decision-making and positioned artificial intelligence as a partner in exploration rather than a substitute for artistic judgment (Yuan, 2024; Zeng, 2022; Cooper, 2024).

Large language models were also reported as tools for generating lesson materials, classroom prompts, explanatory texts, reflective questions, and preliminary feedback. Their usefulness was linked to speed and flexibility, but the literature repeatedly emphasized the editorial role of teachers. Generated content required verification for factual accuracy, musical appropriateness, pedagogical coherence, and ethical acceptability. These findings suggest that generative artificial intelligence is most valuable when embedded in structured pedagogical tasks rather than used as an unsupervised source of musical or instructional content.

Artificial Intelligence-Based Feedback and Assessment

Automated feedback and assessment systems formed a second major cluster of technologies. These systems were used to analyze student performances, compositions, practice records, and learning progress. The literature described their capacity to provide near-immediate comments on pitch, rhythm, intonation, timbre, tempo, and selected expressive dimensions (Patrick & Bakar, 2024; Yuan, 2024; Goncharova & Gorbunova, 2020).

A frequently reported strength was the reduction of routine teacher workload. Automated systems could identify repeated errors, provide initial diagnostic information, and support targeted remediation. In this way, teachers could allocate more time to interpretive guidance, creative mentoring, and individualized instruction. Automated feedback was also associated with increased opportunities for independent practice because learners could receive responses outside scheduled lessons (Patrick & Bakar, 2024; Yuan, 2024).

However, the literature distinguished clearly between technical measurement and authentic musical assessment. Artificial intelligence was more reliable when evaluating measurable parameters than when judging phrasing, emotional intention, stylistic appropriateness, ensemble responsiveness, or artistic communication. Several studies therefore supported hybrid assessment models in which artificial intelligence provides preliminary evidence while teachers retain authority over interpretive and high-stakes judgments ((Brdnik et al., 2023; Bryan–Kinns et al., 2023).

Learning Analytics and Personalized Learning

Learning analytics systems were used to monitor practice patterns, student trajectories, task completion, progress, and recurring difficulties. These systems enabled teachers to identify learners requiring additional support and to adapt tasks, repertoire, or practice schedules accordingly (Tatnall, 2023).

The evidence indicated that personalization commonly involved adjusting difficulty, sequencing activities, varying feedback frequency, and recommending tasks according to prior performance. Such systems were intended to align instruction with individual skill levels and learning goals (Patrick & Bakar, 2024; Tatnall, 2023). In teacher education, learning analytics also supported reflection by helping pre-service teachers interpret patterns in student engagement and progress.

Nevertheless, personalization depended on the quality of the available data and the assumptions embedded in the system. The literature cautioned that automated recommendations could narrow learning pathways when models prioritized easily measurable outcomes. Teacher mediation remained necessary to ensure that personalization included broader musical aims such as creativity, stylistic understanding, ensemble participation, and cultural awareness.

Intelligent Tutoring Systems

Intelligent tutoring systems were discussed as potential one-to-one instructional agents capable of modeling learners, adapting tasks, providing feedback, and managing progression. In music education, proposed applications included guided practice, adaptive sequencing, error-specific remediation, and automated support for theory or performance learning (Zhou et al., 2024).

Compared with general education, however, the empirical evidence for fully developed intelligent tutoring systems in music remained limited. Many publications described conceptual possibilities rather than sustained classroom implementations. This gap reflects the difficulty of designing tutoring systems that can respond adequately to embodied technique, expressive intention, stylistic variation, and collaborative performance. The evidence therefore supported the use of intelligent tutoring functions as supplementary scaffolding rather than as autonomous instruction.

Computer Vision and Movement Analysis

Computer vision was applied to movement, gesture, posture, and technique analysis. Relevant applications included hand-position monitoring, gesture recognition, instrumental technique analysis, interactive performance environments, and the evaluation of body movement during musical activity (Nasir et al., 2024; Zeng et al., 2022).

These systems offered potential benefits for technical feedback, especially when visual information could complement audio analysis. For example, a system might identify posture-related issues that cannot be inferred from sound alone. However, such applications also introduced concerns regarding privacy, biometric data, system reliability, and the danger of standardizing bodily technique without sufficient sensitivity to individual anatomy, disability, instrument type, or pedagogical tradition.

Multimodal Artificial Intelligence

Multimodal artificial intelligence combined audio, visual, textual, notational, and contextual information. These systems were described as potentially more capable of representing the complexity of musical performance and learning than single-mode technologies (Li, 2023; Zeng, 2022; Hou, 2024).

The literature associated multimodal systems with richer feedback, interactive composition, integrated performance analysis, and collaborative music making. By combining sound, gesture, notation, and text, such systems could support more holistic instructional environments. Yet their complexity also increased the need for explainability, secure data governance, and teacher interpretation. The evidence suggested that multimodal artificial intelligence has substantial potential but remains an emerging area requiring stronger empirical validation.

Educational Tasks Supported by Artificial Intelligence

Across the reviewed literature, artificial intelligence supported six broad categories of educational tasks: content creation, feedback and assessment, personalization, performance analysis, collaborative music making, and reflective learning.

Content creation included musical prompts, accompaniments, arrangements, polyphonic sequences, exercises, lesson materials, and classroom questions (Cooper, 2024). Feedback and assessment included automated comments on performance, preliminary scoring, error detection, and recommendations for remediation (Patrick & Bakar, 2024; Goncharova & Gorbunova, 2020). Personalization involved adapting repertoire, practice schedules, task difficulty, and progression according to student needs (Patrick & Bakar, 2024; Ng et al., 2023).

Performance analysis included evaluation of gesture, posture, technique, timing, and expressive movement, particularly through computer vision and multimodal systems (Zeng, 2022; Nasir et al., 2024). Collaborative applications included artificial intelligence-assisted accompaniment, ensemble support, and polyphonic coordination (Yuan, 2024; Zeng, 2022). Reflective tasks included teacher-led interpretation of artificial intelligence-generated analyses, student evaluation

of machine outputs, and discussion of the artistic consequences of algorithmic recommendations (Tatnall, 2023; Bryan–Kinns et al., 2023).

Across all six categories, teachers retained interpretive authority. The evidence consistently suggested that artificial intelligence was most productive when teachers curated outputs, connected them to learning objectives, and ensured that efficiency did not displace musical integrity.

Comparative Strengths and Limitations

The principal strengths of artificial intelligence technologies were efficiency, personalization, feedback frequency, creative stimulation, and access to detailed learning data. Automated systems could reduce routine workload, provide targeted remediation, and support independent practice (Кравцова et al., 2022; Patrick & Bakar, 2024; Yuan, 2024). Generative systems could broaden creative possibilities, while multimodal technologies could offer more context-sensitive interaction (Li, 2023; Zeng, 2022; Hou, 2024).

The most persistent limitations concerned musical nuance, explainability, empirical maturity, infrastructure, and governance. Artificial intelligence systems frequently struggled to represent emotion, interpretation, cultural meaning, and artistic intention. The literature also showed that generic explanations were insufficient in artistic contexts; explainable artificial intelligence for music must provide musically meaningful reasons that teachers and students can interpret (Krol et al., 2022; Ridley, 2023).

Evidence for sustained learning outcomes remained limited, and uneven access to infrastructure and professional development restricted adoption (Ng et al., 2023; Sain et al., 2024; Vodiana et al., 2020; Tatnall, 2023). Overall, the literature supported a balanced interpretation: artificial intelligence offers meaningful pedagogical advantages, but these advantages depend on domain-specific design, teacher expertise, human oversight, and robust ethical governance.

Artificial Intelligence Literacy

Artificial intelligence literacy was consistently defined as a combination of conceptual knowledge, practical competence, critical evaluation, and ethical awareness. Teachers were expected to understand what artificial intelligence systems do, how they generate outputs, what limitations they possess, and how they affect privacy, bias, fairness, and equity (Tatnall, 2023; Liu, 2024).

The evidence positioned artificial intelligence literacy as a prerequisite for informed pedagogical decision-making. Literate teachers were better able to assess the credibility of outputs, determine when artificial intelligence was appropriate, and distinguish pedagogically useful support from superficial technological adoption (Tatnall, 2023; Ng et al., 2023; Yeter et al., 2024; Gray, 2020; Alhazzani, 2024).

Professional Competencies for Effective Integration

Artificial Intelligence-Enhanced TPACK

The literature consistently associated successful implementation with a discipline-specific extension of technological pedagogical content knowledge. Music teachers required integrated knowledge of artificial intelligence technology, musical content, instructional design, and assessment (Ng et al., 2023; Alhazzani, 2024).

Artificial intelligence altered technological knowledge by requiring teachers to understand probabilistic systems and automated decision-making. It altered pedagogical knowledge by introducing new possibilities for feedback, generation, analytics, and personalization. It also affected content knowledge because artificial intelligence systems influenced repertoire, composition, performance analysis, and the representation of musical style and culture (Goncharova & Gorbunova, 2020; Tatnall, 2023; Yuan, 2024; Zeng, 2022).

Ethical and Data-Governance Competence

Responsible implementation required competence in privacy, data protection, bias recognition, transparency, copyright, authorship, and equitable access. These competencies were especially important when systems processed student recordings, movement, compositions, or assessment data (Sain et al., 2024; Vodiana et al., 2020; Bryan–Kinns et al., 2023).

Reflective and Collaborative Practice

Professional collaboration, continuing development, and reflective practice were repeatedly associated with stronger implementation. Teachers benefited from professional learning networks in which they could compare tools, discuss ethical dilemmas, evaluate classroom experiences, and revise pedagogical strategies (Sain et al., 2024; Tatnall, 2023).

Institutional and Technology-Acceptance Competence

Teachers also required an understanding of infrastructure, institutional policy, curriculum alignment, and implementation conditions. Sustainable adoption depended not only on individual knowledge but also on access to technical support, professional development, reliable systems, and appropriate governance (Ng et al., 2023; Yeter et al., 2024).

Evidence Gaps

Four major gaps emerged. First, longitudinal studies linking artificial intelligence use to sustained musical and pedagogical outcomes were scarce. Second, cross-cultural evidence remained limited, particularly for traditional, Indigenous, and non-Western music education. Third, few studies examined the long-term effects of artificial intelligence on teacher identity, professional autonomy,

and pedagogical relationships. Fourth, artificial intelligence literacy and artificial intelligence didactic integration were not consistently operationalized or measured.

These gaps indicate that the field has developed a broad conceptual and technological foundation but has not yet established sufficiently robust evidence concerning long-term effectiveness, cultural validity, and professional consequences. Future research therefore requires longitudinal, comparative, cross-cultural, and practice-based designs that evaluate not only whether artificial intelligence can be used, but whether its use produces educationally meaningful, ethically defensible, and professionally sustainable outcomes.

The findings indicate that responsible artificial intelligence integration in music teacher education cannot be explained adequately through a single technological or pedagogical framework. The evidence instead supports a composite, human-centered model that combines explainable artificial intelligence, artificial intelligence literacy, AI didactic integration, technological pedagogical content knowledge, technology acceptance, ethical governance, and institutional readiness. Human-centered artificial intelligence and explainable artificial intelligence are particularly important because music teaching involves performance, interpretation, creativity, and aesthetic judgment that cannot be reduced to technical accuracy alone. In this context, explanations must be meaningful to teachers and learners, connected to musical concepts, and sufficiently transparent to support pedagogical decisions (Alpsancar et al., 2024; Ghajargar et al., 2022). The literature on explainable artificial intelligence in the arts reinforces the need for explanations to be co-designed with domain practitioners rather than constructed solely according to computational criteria (Krol et al., 2022; Bryan–Kinns et al., 2024). For music teacher education, this means that systems should explain why a performance was judged inaccurate, how a generated accompaniment was constructed, or which musical features informed a recommendation.

The results also suggest that artificial intelligence should be understood not as an autonomous instructional authority but as a mediated pedagogical resource. Music teachers retain responsibility for interpreting automated feedback, selecting repertoire-appropriate tools, evaluating generated materials, and deciding whether a system's output is musically and pedagogically valid. This role is especially important because artificial intelligence may identify technical features such as pitch, rhythm, or tempo while failing to represent phrasing, stylistic intention, ensemble balance, or expressive communication adequately (Yuan, 2024; Goncharova & Gorbunova, 2020). Consequently, the teacher's role is evolving from that of information provider toward that of curator, mediator, co-designer, evaluator, and ethical steward. Such a transition does not diminish professional authority; rather, it places greater emphasis on professional judgment. Autonomy is preserved when teachers remain able to accept, revise, contextualize, or reject artificial intelligence-generated feedback and creative outputs.

Artificial intelligence literacy is foundational to this evolving professional role. Teachers require conceptual knowledge of how artificial intelligence works, awareness of its limitations, and practical competence in selecting and applying tools. They must also understand hallucination, bias, privacy, authorship, uncertainty, and the potential consequences of automated decision-making (Tatnall, 2023; Gentile et al., 2023). However, literacy alone is insufficient. It must be connected to music-specific pedagogical content knowledge so that teachers can determine

whether a tool supports authentic learning goals. A teacher who understands generative artificial intelligence technically but cannot evaluate its stylistic, theoretical, or cultural appropriateness remains inadequately prepared for classroom use.

The evidence therefore supports extending the TPACK framework through artificial intelligence-specific competencies and AI didactic integration. Artificial intelligence changes technological knowledge because teachers must understand probabilistic outputs and data-driven systems. It changes pedagogical knowledge because teachers must design learning around automated feedback, adaptive pathways, generative tools, and analytics. It also influences content knowledge because artificial intelligence may shape repertoire selection, compositional processes, performance analysis, and conceptions of musical quality (Ng et al., 2023). In music education, this extension must remain discipline-specific. An AI-supported activity should be evaluated according to whether it strengthens listening, interpretation, creativity, ensemble awareness, or reflective practice rather than merely whether it increases efficiency.

Technology acceptance adds another necessary dimension. Perceived usefulness, ease of use, confidence, infrastructure, and institutional support influence whether teachers adopt artificial intelligence tools (Ng et al., 2023; Yeter et al., 2024; Tatnall, 2023). Yet acceptance should not be equated with readiness. A teacher may be willing to use artificial intelligence without possessing the knowledge required to verify outputs or manage ethical risks. Conversely, a teacher may resist potentially valuable tools because of inadequate training or unclear policy. A unified framework must therefore distinguish behavioral intention from responsible capability. Sustainable adoption requires calibrated trust rather than uncritical enthusiasm or categorical rejection.

Ethical awareness and institutional readiness are equally central. Music education may involve the collection of voices, images, movements, compositions, performance recordings, and other forms of potentially sensitive data. Institutions must therefore establish policies concerning consent, privacy, storage, access, deletion, copyright, authorship, disclosure, and accountability (Sain et al., 2024; Vodiana et al., 2020). Algorithmic bias is also a significant concern, particularly when systems are trained predominantly on Western tonal repertoires and standardized performance conventions. Such systems may misinterpret ornamentation, local tuning systems, traditional instruments, improvisation, or culturally specific expressive practices. Ethical competence in music teacher education must therefore include cultural responsiveness and the capacity to question whose musical standards are embedded in automated systems.

Taken together, the findings support a Responsible Artificial Intelligence Readiness Framework in which artificial intelligence literacy, music-specific TPACK, AI didactic integration, technology acceptance, ethical awareness, explainability, institutional support, and professional autonomy operate as interdependent components. Artificial intelligence literacy enables informed understanding; TPACK connects technology with music content and pedagogy; acceptance influences implementation; institutional readiness provides resources and governance; explainability supports trust and accountability; and professional autonomy ensures that teachers remain responsible for final decisions. The framework is human-centered because it positions artificial intelligence as a support system within pedagogical relationships rather than as a replacement for them.

The findings also have direct implications for teacher education. Pre-service programs should embed artificial intelligence across music pedagogy, assessment, composition, performance instruction, curriculum design, research methods, and professional ethics. Training should involve authentic tasks such as comparing automated and expert feedback, identifying hallucinated or culturally inappropriate outputs, evaluating artificial intelligence-generated compositions, and designing disclosure and privacy protocols. In-service professional development should be sustained, collaborative, music-specific, and evidence-based. Professional learning communities can support teachers in evaluating new tools, sharing implementation experiences, and reflecting on effects on student motivation, creativity, interpretation, and autonomy (Ng et al., 2023; Sain et al., 2024; Tatnall, 2023).

Future research should prioritize longitudinal evaluation because current evidence does not establish whether short-term gains in engagement, efficiency, or confidence lead to sustained musical and pedagogical improvement (Willet & Na, 2024). Cross-cultural studies are also required to assess whether artificial intelligence systems remain valid across diverse repertoires, traditions, and institutional contexts. Inclusive design should address students and teachers with disabilities as well as linguistic, cultural, and socioeconomic diversity (Bryan–Kinns et al., 2023; Ghajargar et al., 2022). Music-specific explainable artificial intelligence requires further development, particularly multimodal explanations that combine textual, sonic, visual, and notational information (Krol et al., 2022; Bryan–Kinns et al., 2024). Finally, research should operationalize and measure artificial intelligence literacy, AI-TPACK, trust, professional autonomy, and pedagogical usefulness over time. These priorities are necessary to move the field from technological possibility toward educationally meaningful, culturally responsive, and ethically defensible practice.

CONCLUSION

Artificial intelligence is becoming an increasingly significant component of music education, with applications in lesson planning, content generation, performance analysis, feedback, assessment, personalization, learning analytics, composition, and professional reflection. The reviewed literature indicates that these technologies can support teachers by reducing routine workload, expanding instructional resources, enabling more frequent feedback, and providing new opportunities for creative and individualized learning. However, the educational value of artificial intelligence is not determined by technological capability alone. It depends on how teachers interpret, adapt, and govern its use within authentic musical and pedagogical contexts.

The findings demonstrate that music teacher readiness is a multidimensional construct. Effective integration requires artificial intelligence literacy, music-specific technological pedagogical content knowledge, critical evaluation skills, ethical awareness, calibrated trust, and professional autonomy. Teachers must understand both the capabilities and limitations of artificial intelligence systems and be able to distinguish between technically measurable features of musical performance and more complex dimensions such as expression, interpretation, cultural meaning, and artistic communication. Artificial intelligence can provide useful preliminary analysis, but it cannot

independently replace the contextual judgment, relational feedback, creative guidance, and ethical responsibility of the music teacher.

The review also shows that institutional readiness is essential for sustainable implementation. Infrastructure, professional development, technical support, funding, curriculum integration, leadership, policy, and equitable access shape whether artificial intelligence can be used responsibly. Without these conditions, adoption may remain uneven, superficial, or ethically problematic. Institutions must therefore establish clear frameworks for privacy, consent, authorship, copyright, assessment, transparency, data governance, and accountability, particularly when artificial intelligence systems process student voices, images, movements, compositions, and performance data.

The main contribution of this study is the proposed Responsible Artificial Intelligence Readiness Framework for Music Teacher Education. The framework integrates artificial intelligence literacy, AI-enabled TPACK, AI didactic integration, technology acceptance, explainability, ethical awareness, institutional support, human oversight, and professional autonomy. It positions the teacher as the central mediator between technological capability and educational practice. Within this model, artificial intelligence is most appropriately understood as a pedagogical tool, assistant, limited tutor, analytical aid, or creative partner rather than as an autonomous instructional authority.

The implications of this review extend to teacher education, professional development, curriculum design, and educational policy. Pre-service and in-service programs should embed artificial intelligence across music pedagogy, assessment, performance, composition, research methods, and ethics rather than treating it as an isolated technical skill. Training should emphasize output verification, culturally responsive evaluation, privacy protection, authorship disclosure, and critical decisions about when artificial intelligence should or should not be used.

Future research should test the proposed framework through longitudinal, cross-cultural, and practice-based studies. Greater attention is needed to the long-term effects of artificial intelligence on teacher identity, professional autonomy, musical creativity, assessment validity, and student development. Research should also advance music-specific explainable artificial intelligence, inclusive design, and culturally responsive systems capable of representing diverse musical traditions. These directions are essential for ensuring that artificial intelligence strengthens rather than diminishes the human, artistic, and ethical foundations of music education.

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