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Information and communication technology in higher music education: systematic review

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ABSTRACT

Technological advances have facilitated the integration of information and communication technology (ICT) into higher music education over the past decade. However, existing literature remains fragmented and lacks an integrated understanding of this field. This study addresses four research questions concerning developmental trends, types of ICT use and their characteristics, advantages, and challenges of ICT integration in higher music education. Based on 40 articles retrieved from EBSCO, Scopus, and Web of Science (WoS), this review analyses ICT use in higher music education. The findings show that the reviewed articles are unevenly distributed geographically, with a substantial proportion originating from China. Quantitative research designs dominated the reviewed articles. Thematic analysis identified four primary categories of ICT use: network-based and distance learning technologies, digital platforms and tools, artificial intelligence (AI)-powered educational technologies, and immersive and sensor-based ICT applications. ICT can enhance teaching quality, student motivation, personalized learning, flexibility, instructional innovation, and interdisciplinary integration, while challenges include limited emotional interaction, technical barriers, unequal resource allocation, privacy concerns, and ethical risks. Drawing on the technology acceptance model (TAM) and technological pedagogical content knowledge (TPACK) framework, this study proposes an integrative framework to guide teachers and institutions in designing pedagogically meaningful, technically feasible, and context-sensitive ICT-enhanced music education practices.

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1. INTRODUCTION

Information and communication technology (ICT) has advanced rapidly, transforming many aspects of society [1] and profoundly affecting education systems [2]. ICT has been used in higher education for decades, but its role has expanded rapidly across a variety of educational contexts in recent years [3]. The role of ICT in education has evolved from the use of basic tools (e.g., computers, multimedia, interactive platforms) to more diverse forms (e-learning, media education, educational technology (EdTech), and artificial intelligence in education (AIED)) [4]–[8].

At the macro-policy level, ICT is widely regarded as an important tool for promoting educational equity and innovation. Research indicates that digital technologies have not only changed the nature and scope of education but also driven continuous adjustments within education systems in relation to ICT convergence, digital capacity building, and digital transformation [9]. At the same time, the digital transformation of education is not merely the introduction of a single technological tool, but a systemic change involving digital infrastructure, teachers' digital capabilities, learning management systems, digital assessment platforms, artificial intelligence (AI) applications, and education governance mechanisms [10], [11]. Against this backdrop, universities around the world are promoting the digital upgrade of teaching, systematically integrating ICT tools such as learning management systems, online course platforms, and intelligent recommendation systems into curriculum design and teaching practice [12], [13].

In higher music education, ICT involves not only upgrading hardware facilities and software platforms but also profound changes in access, equity, management efficiency, teaching approaches, and quality assurance [14]–[18]. Moreover, ICT has been widely integrated into higher music education through applications ranging from remote and blended teaching, mobile learning applications, digital audio workstations (DAWs), Web 2.0-based tools, and gamification platforms to more recent innovations such as virtual reality (VR), augmented reality (AR), and intelligent assessment and AI-powered recommendation systems. In this regard, these technologies are increasingly being incorporated as instructional components in music theory, instrumental performance, vocal performance, ensemble, and teacher education courses in higher music education, transforming traditional instructional methods from face-to-face teaching and on-site rehearsal to more flexible and technology-enhanced formats.

The adoption of digital technologies in instruction has reached an unprecedented level in recent years [19]. Despite existing research examining multiple ICT applications in higher music education, the literature remains largely fragmented, with limited systematic integration, longitudinal analysis, or cross-comparison. This fragmentation makes it difficult for educators to identify which ICT tools are pedagogically appropriate for specific music learning contexts, for curriculum designers to align technological resources with course objectives, and for policymakers to develop evidence-based strategies for institutional digital transformation. Consequently, a systematic synthesis is needed to clarify how ICT has been used, what educational value it offers, and what implementation challenges remain in higher music education.

To address these gaps, this study makes several contributions. While previous reviews and bibliometric studies have examined technology use in music education from broader disciplinary perspectives, specific educational stages, or particular technological domains such as AI and metaverse-based learning [20]–[22], this study focuses specifically on ICT integration in higher music education. Rather than focusing on individual technological tools, the study categorizes ICT use into four main types and analyses their characteristics, pedagogical functions, advantages, and challenges. In addition, the study develops an analytical framework to connect technological categories with educational functions and implementation constraints. Drawing on the technology acceptance model (TAM) and the technological pedagogical content knowledge (TPACK) framework, the study also offers a theoretical perspective on ICT adoption and pedagogical integration in higher music education. Overall, this research moves beyond the predominantly case-based focus of existing studies and contributes to a more structured understanding of ICT integration in this field. Accordingly, this study seeks to address the following research questions:

- What are the overall trends in the use of ICT in higher music education? (RQ1)
- What are the main categories of ICT use in higher music education, and what are their distinguishing characteristics? (RQ2)
- What are the core advantages of integrating ICT into higher music education? (RQ3)
- What are the key challenges associated with the use of ICT in higher music education? (RQ4)

2. LITERATURE REVIEW

Existing studies have primarily focused on the effects of specific types of ICT. Examples include the applicability of distance learning to instrumental education (e.g., guitar) [23], the role of mobile applications such as Vox Tools and Swiftscales Vocal Trainer in supporting vocal learning [17], the use of MIDI technology to assist rhythm and melody training [24], the supportive effect of computer vision feedback systems on students' violin pitch control [25], and the pedagogical effects of gamification tools such as Cuadernia, Kahoot, Quizizz, and Socrative in university music courses [26]. More cutting-edge technologies, such as VR, AR, and music theory analysis and recommendation models based on deep learning, are also gradually entering university classrooms [27], [28]. However, these studies have generally examined individual technologies or isolated teaching scenarios, with limited cross-context comparison of ICT applications or synthesis of their shared pedagogical implications.

Recent research has examined a wide range of ICT tools, including online learning platforms [29], mobile learning applications [17], AI [30], and immersive technologies such as VR [28] and AR [31], [32]. The body of research on ICT implementation in higher music education has gradually expanded, indicating that ICT offers many advantages. Research has shown that ICT not only enhances teaching efficiency and learning quality [18], [27], [30], [33]–[37], but also improves the flexibility and accessibility of education [14], [15], [34], [38], supports personalized learning and intelligent matching of learning resources [15], [39], encourages cross-cultural understanding among students [32], [38], and positively stimulates student autonomy and creativity [18], [40], [41]. In addition, with the introduction of technology, students' performance can be evaluated more intelligently, and teachers can then apply more precise educational interventions [15], [27]. However, while theoretical courses focus more on knowledge and concepts, music education relies more on perceptual experience and expression, which presents more challenges for the integration of ICT. For instance, unstable network connections, device incompatibility, limitations of existing platforms (such as Moodle), and teachers' unfamiliarity with tools may affect teaching effectiveness and students' learning experience [38], [42]–[45]. Furthermore, teachers often lack systematic training in the use of music technology tools, making it difficult to fully integrate technological resources into teaching [37], [46]. Some teachers report that they are not ready to use EdTech effectively [14], [33]. Taken together, these findings reveal a tension in the existing literature: ICT is often associated with greater flexibility, accessibility, and personalized learning, yet its effectiveness depends strongly on infrastructure, teacher readiness, pedagogical design, and the specific characteristics of music learning. Therefore, a systematic review is needed to compare different types of ICT use, clarify the conditions under which they are effective, and identify the challenges that constrain their implementation in higher music education.

3. THEORETICAL FRAMEWORK

To better understand the landscape of ICT use and pedagogical integration in higher music education, this study develops a theoretical framework grounded in relevant literature. This framework provides a unified conceptual foundation for understanding the types of ICT use in higher music education, their characteristics, and their core advantages and challenges. The framework draws on TAM and TPACK. TAM explains technology adoption through constructs such as perceived usefulness and perceived ease of use, which shape users' attitudes toward technology and their intention to use it in teaching and learning, thereby influencing their continued use of ICT [47], [48]. TPACK focuses on the dynamic integration of technological knowledge, pedagogical knowledge, and content knowledge, and suggests that technology integration requires more than just the tools themselves; technology must also align with subject characteristics and pedagogical strategies [49], [50].

In this systematic review, TAM and TPACK are employed as complementary explanatory lenses. TPACK is used to explain how different types of ICT use reshape teachers' instructional practices and students' learning experiences through the integration of technology, pedagogy, and music content knowledge. TAM is used to interpret teachers' and students' perceived usefulness, perceived ease of use, and intention to adopt ICT tools, thereby helping to explain the advantages and challenges reported in the reviewed studies. Specifically, TPACK helps clarify the pedagogical integration of different technology types in course organization, support for learning activities, intelligent feedback, and embodied music learning, while TAM helps analyze how ICT may enhance teaching quality, learning motivation, and flexibility, as well as how its adoption may be constrained by technical barriers, teacher readiness, and resource conditions.

4. METHOD

4.1. Research design

To answer the research questions, a systematic literature review (SLR) method was used in this study. SLR helps researchers precisely define research questions, retrieve literature systematically, establish explicit inclusion and exclusion criteria, and apply rigorous quality assessment methods, enabling more systematic and comprehensive integration of existing research [51]. SLR also reduces subjectivity and bias in traditional narrative reviews and provides a standardized framework for literature screening and analysis to better understand the current status and developmental trends of the research field [52]. Moreover, SLR practices are highly aligned with the practical value of social science research. By incorporating specific appraisal criteria for qualitative studies [53], SLR is particularly suitable for this study. The study conducted the literature screening based on the standardized preferred reporting items for systematic reviews and meta-analyses (PRISMA) selection flow [54], [55]. This structured process helped to clarify the research steps and findings, increasing the transparency and quality of the study [54].

4.2. Search strategy

This study followed a systematic multi-stage process of identification, screening, evaluation, and synthesis of research, as shown in Figure 1. These steps aimed to establish a rigorous and repeatable review process. In accordance with the PRISMA guidelines, an SLR typically involves searching at least three databases [54]. To obtain an extensive and representative sample of relevant literature, established practices for SLRs in EdTech were applied, and three major academic databases (EBSCO, Scopus, and Web of Science or WoS) were systematically searched [56], [57]. These databases provide extensive coverage of important education journals and help ensure that the included literature meets the requirements of an SLR. However, relying on these three databases may have excluded relevant studies indexed in regional databases, institutional repositories, conference proceedings, or non-English sources. Therefore, this limitation should be considered when interpreting the comprehensiveness and generalizability of the review findings.

Regarding the search conditions, multiple sets of keywords were adapted from existing ICT-related studies in music education, and corresponding search terms were constructed, as shown in Table 1. In terms of keyword selection, this study connected ICT and music education using the logical operator AND to ensure that the search results covered both fields. Furthermore, this study also connected music education and higher education using AND, thus forming the final search strategy framework, as in Table 1. The search covered publications from April 1st, 2015 to April 1st, 2025. This 10-year period was selected because ICT integration in higher education expanded rapidly during these years, allowing the review to capture recent developments and emerging trends in ICT-enhanced higher music education. The document type was restricted to articles, the publication language was set to English, and the search fields were limited to the titles, keywords, and abstracts. A variety of search strategies were employed during the literature retrieval process. The overall framework of the search strategy is presented in Table 1 and further detailed in Table 2.

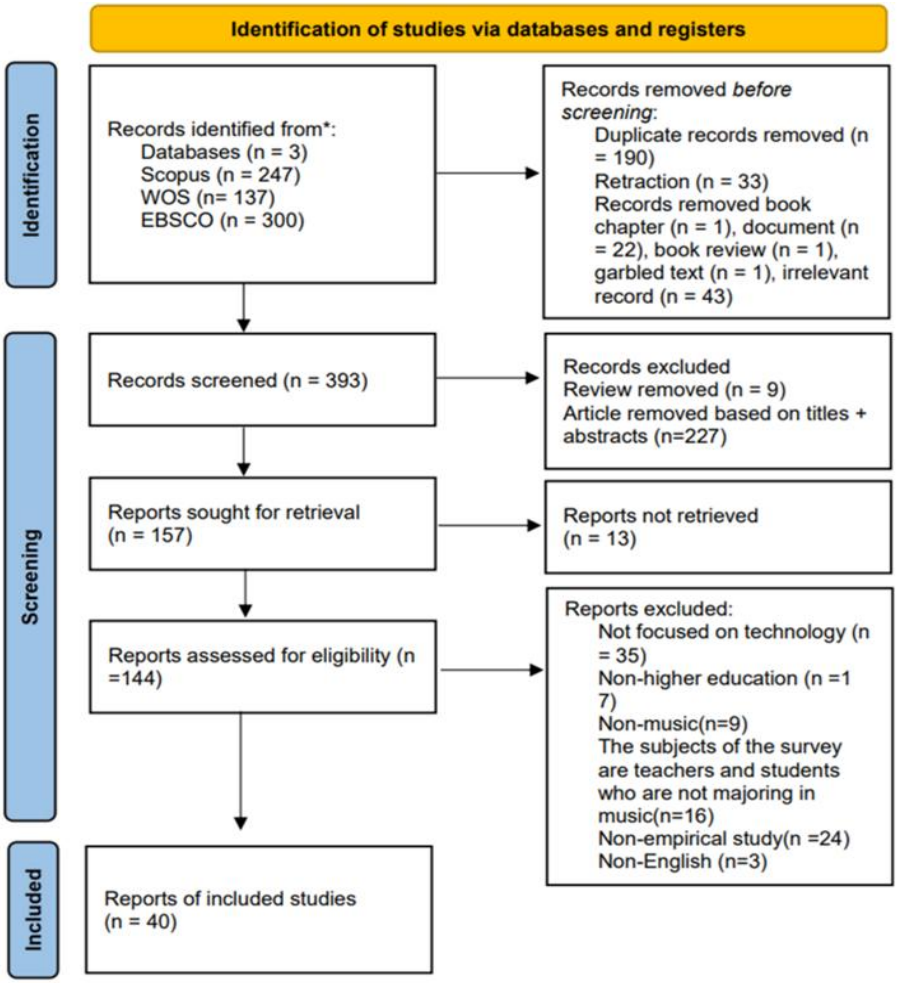

Figure 1. PRISMA flow chart

Table 1. Database search strings and keywords used

ICT	Operator	Music education	Operator	Higher education
‘ICT’ OR ‘technology’	AND	‘Music education’ OR ‘music teach*’ OR ‘music course’ OR ‘music class’ OR ‘music curriculum’	AND	‘Higher education’ OR ‘college’ OR ‘higher vocational’ OR ‘university’

Table 2. Overview of electronic search strategy: including databases and search queries

Database	Query
WoS	((TI=((‘ICT’ OR ‘technology’) AND (‘music education’ OR ‘music teach*’ OR ‘music course’ OR ‘music class’ OR ‘music curriculum’) AND (‘higher education’ OR ‘college’ OR ‘higher vocational’ OR ‘university’))) OR TS=((‘ICT’ OR ‘technology’) AND (‘music education’ OR ‘music teach*’ OR ‘music course’ OR ‘music class’ OR ‘music curriculum’) AND (‘higher education’ OR ‘college’ OR ‘higher vocational’ OR ‘university’))) OR AB=((‘ICT’ OR ‘technology’) AND (‘music education’ OR ‘music teach*’ OR ‘music course’ OR ‘music class’ OR ‘music curriculum’) AND (‘higher education’ OR ‘college’ OR ‘higher vocational’ OR ‘university’)) and Article (document types) and English (languages)
Scopus	TITLE-ABS-KEY ((‘ICT’ OR ‘technology’) AND (‘music education’ OR ‘music teach*’ OR ‘music course’ OR ‘music class’ OR ‘music curriculum’) AND (‘higher education’ OR ‘college’ OR ‘higher vocational’ OR ‘university’)) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE, ‘ar’)) AND (LIMIT-TO (LANGUAGE, ‘English’))
EBSCO	TI ((‘ICT’ OR ‘technology’) AND (‘music education’ OR ‘music teach*’ OR ‘music course’ OR ‘music class’ OR ‘music curriculum’) AND (‘higher education’ OR ‘college’ OR ‘higher vocational’ OR ‘university’)) OR SU ((‘ICT’ OR ‘technology’) AND (‘music education’ OR ‘music teach*’ OR ‘music course’ OR ‘music class’ OR ‘music curriculum’) AND (‘higher education’ OR ‘college’ OR ‘higher vocational’ OR ‘university’)) OR AB ((‘ICT’ OR ‘technology’) AND (‘music education’ OR ‘music teach*’ OR ‘music course’ OR ‘music class’ OR ‘music curriculum’) AND (‘higher education’ OR ‘college’ OR ‘higher vocational’ OR ‘university’))

These keywords were systematically combined using Boolean operators. All search results were first imported into the Zotero reference manager and then exported to Microsoft Excel for screening. From the WoS advanced search, 137 records were retrieved. After excluding 1 book chapter, 17 retracted papers, and 1 duplicate, 118 articles remained. The advanced search on Scopus retrieved 247 articles. After removing 16 retracted papers and 2 duplicates, 229 articles remained. The advanced search on EBSCO yielded 347 articles, of which 300 were exported. After excluding 43 irrelevant records and 21 duplicates, an additional 22 documents and 1 book review were removed, leaving 213 articles. In total, 560 records were identified from the three databases. After removing 166 duplicates and 1 unreadable record, 393 articles remained.

4.3. Study inclusion and exclusion criteria

Given the study’s focus on the use of ICT in higher music education, inclusion and exclusion criteria were established to screen articles for the review, as shown in Table 3. According to the predefined screening rules, the titles and abstracts of 393 articles were manually screened. As a result, 227 irrelevant articles and 9 review articles were excluded, leaving 157 articles for eligibility assessment.

The remaining articles were reviewed at the full-text stage. During this process, 13 articles were found not to be fully accessible, and 3 articles were identified as not written in English, as their English titles and abstracts had initially masked this fact. Based on the inclusion and exclusion criteria, 35 articles that did not focus on technology, 17 articles not situated in higher education, 9 articles unrelated to music, 16 articles whose participants were non-music-major teachers or students, and 24 non-empirical studies were excluded. Consequently, a total of 40 articles were retained for quality appraisal.

Table 3. Study selection criteria

Inclusion criteria	Exclusion criteria
Involves music education in higher education.	Does not fall within the scope of music education in higher education.
Applies ICT or related technologies (such as AI, audio analysis, digital platforms) in teaching and learning.	No application of ICT or related technologies in teaching and learning, or only a general mention of technology.
Participants are students majoring in music or music education, including pre-service music teachers enrolled in music education programmes, and/or higher education music lecturers.	Participants come from general teacher education or other non-music majors, where music is only a marginal or illustrative context.
The study adopts an empirical research design.	The study did not employ empirical research methods.
Articles written in English with full text available.	Studies with no full-text access; non-English publications.

4.4. Quality assessment

To ensure the quality of the selected articles, this study used the mixed methods appraisal tool (MMAT) introduced by Hong *et al.* [58]. Its appraisal dimensions were integrated and simplified while retaining essential evaluative criteria, as seen in Table 4. The MMAT provides a systematic assessment framework for evaluating the key criteria of empirical papers, covering whether the research questions are clearly stated and appropriate, whether the data collection is reliable and sufficient, the alignment between data collection methods and the research objectives, the consistency of sampling strategies, the internal consistency of qualitative data sources, and the rigor and validity of data analysis or interpretation [59].

During the article evaluation, the papers were reviewed individually, and the MMAT three-level scoring system (1=yes; 0.5=partial; 0=no) was used to calculate their scores. Studies scoring less than 3 out of 5 dimensions were considered to be below the standard quality level and were excluded according to the consensus of the research group. Two other authors also evaluated methodological quality based on the study design and implementation. Discrepancies were resolved by discussion. Overall, 40 articles that met the quality criteria were included in the final analysis, as seen in Table 5.

4.5. Synthesis and analysis of results

A total of 40 articles in Table 6 were included in the review. At the data extraction stage, the full texts of the articles were reviewed. Key information was extracted using a standardized Microsoft Excel format: basic metadata (such as author and year of publication), research objectives, research methods, study subjects, types of ICT use, and research contributions, laying the foundation for subsequent in-depth analysis.

Table 4. MMAT, version 2018

Category of study designs	Key evaluation dimensions (MMAT)
1. Qualitative	Appropriateness of the qualitative approach; adequacy of data collection; findings grounded in data; substantiated interpretation; coherence across data sources, analysis, and interpretation.
2. Quantitative randomized controlled trials	Randomization procedure; baseline group comparability; completeness of outcome data; assessor blinding; adherence to intervention.
3. Quantitative non-randomized	Representativeness of participants; appropriateness of measurement; completeness of outcome data; confounding control; intervention delivered as intended.
4. Quantitative descriptive	Relevance of sampling strategy; sample representativeness; appropriateness of measurement; low risk of nonresponse bias; suitable statistical analysis.
5. Mixed methods	Justification for mixed methods; integration of components; interpretation of integrated findings; handling of inconsistencies; adherence to respective qualitative and quantitative quality standards.

Table 5. Results of quality appraisal

References	Methodology	Q1	Q2	Q3	Q4	Q5	Total score	Inclusion decision
[44]	Mixed	1	0.5	1	1	0.5	4/5	Yes
[60]	Mixed	0.5	0.5	1	0.5	1	3.5/5	Yes
[23]	Quantitative	0.5	1	1	0	1	3.5/5	Yes
[61]	Mixed	1	0.5	0.5	1	0.5	3.5/5	Yes
[17]	Quantitative	1	0.5	1	1	0.5	4/5	Yes
[24]	Quantitative	1	0.5	1	1	0.5	4/5	Yes
[29]	Qualitative	1	0.5	1	1	0.5	4/5	Yes
[25]	Mixed	1	0.5	1	0.5	1	4/5	Yes
[26]	Quantitative	1	1	1	1	0.5	4.5/5	Yes
[34]	Quantitative	1	0.5	0.5	1	1	4/5	Yes
[43]	Mixed	1	0	0.5	1	1	3.5/5	Yes
[18]	Quantitative	1	0.5	0.5	0.5	1	3.5/5	Yes
[28]	Quantitative	1	0.5	0.5	1	1	4/5	Yes
[27]	Quantitative	1	0.5	1	0.5	1	4/5	Yes
[38]	Qualitative	1	1	1	1	1	5/5	Yes
[62]	Quantitative	1	1	1	1	0.5	4.5/5	Yes
[37]	Quantitative	1	0.5	1	0	1	3.5/5	Yes
[63]	Quantitative	1	1	1	0.5	0.5	4/5	Yes
[39]	Quantitative	0.5	1	1	0	1	3.5/5	Yes
[45]	Quantitative	1	0.5	1	0.5	1	4/5	Yes
[32]	Mixed	1	1	1	1	1	5/5	Yes
[30]	Quantitative	1	0.5	1	1	1	4.5/5	Yes
[35]	Quantitative	1	1	1	0	1	4/5	Yes
[64]	Mixed	1	1	1	1	1	5/5	Yes
[42]	Mixed	1	1	1	1	0.5	4.5/5	Yes
[65]	Qualitative	1	0.5	1	0	1	3.5/5	Yes
[46]	Qualitative	1	1	1	1	1	5/5	Yes
[66]	Quantitative	1	0.5	1	1	0.5	4/5	Yes
[15]	Quantitative	1	0.5	1	1	0.5	4/5	Yes
[31]	Qualitative	1	1	1	0	1	4/5	Yes
[67]	Quantitative	0.5	0.5	1	0	1	3/5	Yes
[36]	Quantitative	1	1	1	0	1	4/5	Yes
[68]	Quantitative	1	0.5	1	0.5	1	4/5	Yes
[69]	Quantitative	1	0.5	1	0.5	1	4/5	Yes
[70]	Qualitative	1	1	0	0.5	1	3.5/5	Yes
[40]	Quantitative	1	1	1	1	1	5/5	Yes
[33]	Quantitative	1	1	0.5	0.5	1	4/5	Yes
[14]	Mixed	1	1	1	0.5	0.5	4/5	Yes
[16]	Quantitative	1	0.5	0.5	0.5	1	3.5/5	Yes
[71]	Quantitative	1	1	1	0.5	1	4.5/5	Yes

Table 6. The final selection of articles

Article no.	References	Country	Year	Methodology
1	[44]	Iraq	2023	Mixed
2	[60]	China	2022	Mixed
3	[23]	Turkey	2018	Quantitative
4	[61]	China	2016	Mixed
5	[17]	China	2023	Quantitative
6	[24]	Turkey	2021	Quantitative
7	[29]	South Africa	2022	Qualitative
8	[25]	Turkey	2023	Mixed
9	[26]	Spain	2022	Quantitative
10	[34]	Ukraine	2021	Quantitative
11	[43]	Russia	2023	Mixed
12	[18]	China	2024	Quantitative
13	[28]	China	2024	Quantitative
14	[27]	China	2024	Quantitative
15	[38]	South Africa	2024	Qualitative
16	[62]	China	2025	Quantitative
17	[37]	China	2024	Quantitative
18	[63]	China	2024	Quantitative
19	[39]	China	2024	Quantitative
20	[45]	China	2024	Quantitative
21	[32]	China	2024	Mixed
22	[30]	Korea	2024	Quantitative
23	[35]	China	2022	Quantitative
24	[64]	Brazil	2020	Mixed
25	[42]	United States	2021	Mixed
26	[65]	Brazil	2019	Qualitative
27	[46]	Spain	2024	Qualitative
28	[66]	China	2022	Quantitative
29	[15]	China	2022	Quantitative
30	[31]	China	2021	Qualitative
31	[67]	China	2023	Quantitative
32	[36]	China	2023	Quantitative
33	[68]	China	2022	Quantitative
34	[69]	China	2024	Quantitative
35	[70]	United States	2016	Qualitative
36	[40]	China	2023	Quantitative
37	[33]	United States	2015	Quantitative
38	[14]	Ghana	2022	Mixed
39	[16]	China	2022	Quantitative
40	[71]	China	2024	Quantitative

To systematically answer the research questions, this study adopted a multi-method analytic strategy, combining quantitative analysis with qualitative thematic analysis. To examine the overall trends in the development of ICT use in higher music education, two complementary analytical methods were implemented. First, a descriptive bibliometric analysis systematically recorded the relevant metadata for each study in a Microsoft Excel spreadsheet and employed descriptive statistics and visualization techniques to reveal the characteristics of the included studies in terms of publication year, geographic distribution, and research design.

To address the main types and characteristics of ICT use, as well as its core advantages and challenges in higher music education, this study employed the six-phase thematic analysis framework proposed by Braun and Clarke [72]. The specific procedures included familiarization with the entire body of literature through repeated reading and the use of a hybrid coding approach that combined inductive and deductive strategies. Based on the theoretical frameworks of TAM and TPACK, several broad initial categories were predefined (e.g., types of ICT use and application scenarios, instructional functions and learning processes, instructional advantages, and implementation challenges), while new codes were allowed to emerge naturally from the data during open coding without being excessively constrained by the predefined framework; intercoder reliability reached κ=0.87. The researchers then generated themes through repeated pattern identification, reviewed the internal coherence and external distinctiveness of the themes, revised or merged overlapping themes, removed weakly supported candidate themes, and precisely defined and named the final themes. This process ultimately yielded four core thematic categories, six core advantages, and seven major challenges, which were synthesized during the results presentation stage.

5. RESULTS

This section presents the findings of the systematic review. It discusses the overall trends, main types, characteristics, advantages, and key challenges of ICT use in higher music education. The results are organized according to the four research questions guiding this study.

5.1. Overall trends in ICT use in higher music education

This subsection presents the overall trends in ICT use in higher music education. It reports the distribution of the selected articles by publication year, geographical location, and research design. These descriptive results provide an overview of how this research field has developed over time.

5.1.1. Geographical distribution of publications by country

The geographical distribution map in Figure 2 illustrates the global spatial distribution of the publications included in this study. Overall, the research output is highly concentrated in a small number of countries: China accounted for the largest share of publications, substantially exceeding other countries in the sample; the United States and Turkey, together with Brazil, Spain, and South Africa, formed a second tier of contributors, while Iraq, Ukraine, Russia, South Korea, and Ghana had only a small number of publications. This pattern reveals a markedly uneven global distribution of research on ICT in higher music education.

Figure 2. Geographical distribution of publications by country

5.1.2. Year distribution

As shown in Figure 3, the number of publications remained low between 2015 and 2020. From 2021 onwards, there was a rapid increase, reaching 9 articles in 2022 and peaking at 13 in 2024. As the search was limited to April 2025, the 2025 count should be interpreted as incomplete. Overall, research publications have shown a continuous upward trend in recent years.

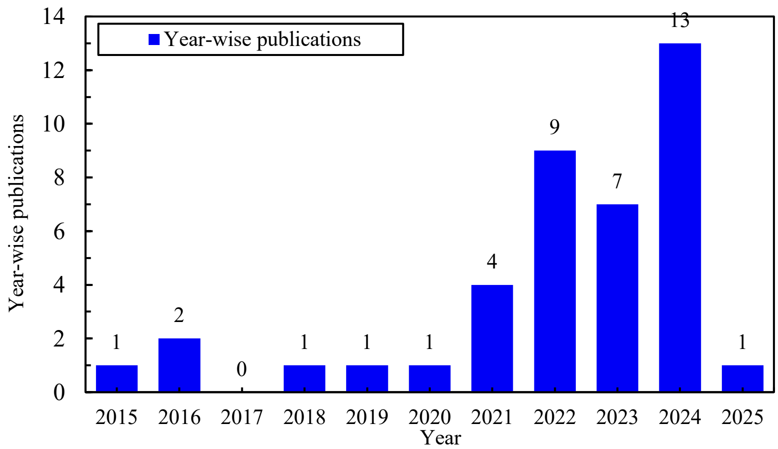

Figure 3. Year-wise publications

5.1.3. Research design type

Among the 40 selected studies, quantitative research accounted for the largest proportion, with 25 articles (62.5%), indicating that most studies adopted quantitative empirical methods. Mixed-methods research accounted for 9 articles (22.5%), suggesting the use of both quantitative and qualitative approaches. Qualitative research constituted the smallest proportion, with only 6 articles (15.0%). Overall, quantitative research dominated the field of ICT in higher music education, as shown in Figure 4.

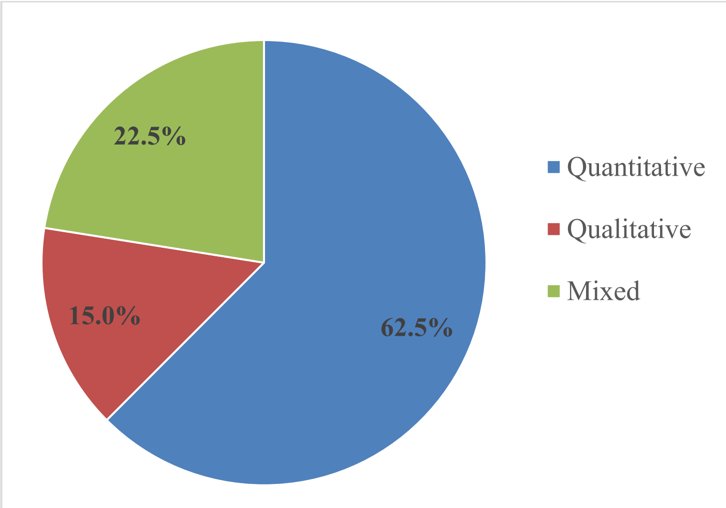

Figure 4. Research design

5.2. Categories and their characteristics of ICT use in higher music education

This study employed a thematic coding approach to analyze the 40 included articles. A total of four main themes and 13 sub-themes related to ICT use were identified, as shown in Table 7. Based on the synthesized findings on the types and characteristics of ICT use, this study further distilled several key educational functions of these technologies in higher music education (in third column of Table 7), thereby providing an intermediate analytical dimension for the subsequent construction of the integrated model.

5.2.1. Network-based and distance learning technologies

Partly accelerated by the pandemic and related policy support, teaching models in higher music education have gradually shifted from traditional face-to-face instruction to a diverse range of remote and online approaches. This shift has promoted a systemic transformation of teaching practices. The core function of this type of ICT application, which relies on networked distance and blended learning technologies, is to enable teaching activities to take place across time and space through online connections.

At the technical implementation level, this type of technology typically relies on various ICT platforms (such as Zoom, Moodle, Google Classroom, and Google Meet) to support the digital presentation and remote delivery of course content. It has been widely applied across different types of courses, including instrumental music, vocal music, choral music, and teacher education [14], [38], [43]–[45]. In teaching practice, teachers can organize different delivery modes, including synchronous, asynchronous, fully online, and blended models [35], [39], [40]. In addition, teachers often combine tools such as MIDI recordings, small private online courses (SPOCs), small-scale online classes, and video-based teaching resources [24], [42], [43] to enhance students' access to educational material and facilitate practice.

In terms of its characteristics, this type of ICT application has three main features: breaking temporal and spatial limitations, supporting course participation across regions and time periods, and ensuring the continuity of teaching in emergencies such as pandemics. It also supports different learning paces and structures, including synchronous and asynchronous modes, as well as fully online and blended modes. It enables course-level organization and management by coordinating classroom teaching, homework assignments, and the distribution of learning resources through a learning management platform. Overall, network-based and distance learning technologies mainly support course-level organization, instructional continuity, and flexible access to music learning.

Table 7. Categories and educational functions of ICT use in higher music education

Technical category	Subcategory (technology type)	Main educational functions in higher music education	Article no.
Network-based and distance learning technologies	Distance learning (virtual teaching, e-learning, online teaching)	Online and blended course delivery, maintaining instructional continuity, remote individual and group lessons, synchronous and asynchronous interaction, and access to learning resources beyond the physical classroom.	1, 3, 6, 11, 15, 20, 25, 38
Digital platforms and tools	Digital learning platforms	Learning management and course organization (e.g., uploading materials, administering tasks and assessments); structuring online music courses; tracking students' progress.	39
	Mobile platforms and applications	Individual practice and skills training (e.g., vocal and aural training apps); flexible, anytime–anywhere learning; supporting informal and self-paced music learning outside the classroom.	4, 5, 7, 35
	Web 2.0 tools	Collaborative and participatory learning (e.g., blogs, wikis, social platforms); sharing reflections and artefacts; building online music learning communities and peer interactions.	10
	Multimedia teaching tools	Enhancing demonstration and explanation of musical concepts; providing visual and auditory feedback (e.g., pitch, rhythm, dynamics); supporting instrumental/vocal skills training and repertoire learning.	8, 24, 26, 27, 33
	Gamification tools	Increasing motivation and engagement through quizzes, games, and competitive tasks; providing instant feedback; supporting active participation in music theory and aural skills learning.	9
AI-powered educational technologies	AI core technologies (e.g., machine learning and deep learning)	Automatic analysis of musical performance and audio signals; objective assessment of rhythm, intonation, and expression; adaptive practice tasks based on learner performance.	12, 14, 17, 19, 36
	AI-driven applications (e.g., recommendation systems)	Personalized learning support (e.g., recommending resources, exercises, or learning paths); intelligent classroom analytics; learning management and decision-making support for teachers.	16, 23, 28, 29
	Generative AI	Creative support for composition, arrangement, and idea generation; interactive dialogue and feedback (e.g., chatbots); scaffolding students' reflection and conceptual understanding.	22, 40
Immersive and sensor-based ICT applications	Immersive technologies (VR/AR)	Simulating performance environments and stage experiences; supporting body coordination and gesture training; providing immersive cultural and performative contexts; enhancing motivation and a sense of presence.	13, 21, 30, 31, 34
	Sensor-based motion capture technology	Accurate recording and quantitative analysis of motion parameters in Peking opera (Chinese opera) movements to support the evaluation and improvement of teaching effectiveness.	2
	Internet of things (IoT)-based sensor systems	Capturing multimodal performance data (sound, motion); monitoring learning processes; providing fine-grained, real-time feedback on performance quality and practice behavior.	32
	Metaverse information systems	Creating persistent virtual spaces for music learning and performance; supporting identity development, social interaction, and community building in virtual music environments.	18
General ICT use (no specific technical category)	Not specified	Discussing ICT integration in higher music education at a general level (e.g., perceptions, attitudes, broad pedagogical implications) without focusing on a single technical type.	37

5.2.2. Digital platforms and tools

Digital platforms and tools applied in higher music education are characterized by diverse types, well-defined functions, and varied application scenarios, providing multi-dimensional and in-depth technical support for teaching. Digital learning platforms are characterized by system integration and data-driven features. They organize teaching resources, track learning activities, and analyze students' learning progress by combining internet technologies with various algorithms [16].

Mobile applications and platforms are characterized by portability, immediacy, and strong adaptability to different contexts. They are commonly employed for personalized teaching, remote interaction, and collaborative production, and enable informal learning modes (e.g., Android-based teaching platforms [61], vocal learning apps such as Vox Tools and Swiftscales [17], WhatsApp for listening training [29], and iPads for ensemble experiences [70]). Web 2.0 technologies highlight user participation and interaction. Through online communities and collaborative platforms, they encourage knowledge sharing, peer communication, and collaborative learning. For example, the use of tools such as blogs and wikis in music education can facilitate interaction among students and support knowledge construction [34].

Multimedia teaching tools focus on visual feedback, multimodal perception, and technology-enhanced expression. They are widely used in performance training, sound analysis, and pedagogical innovation. These tools support pitch correction, electronic music creation, and performance feedback, as reflected in visual pitch feedback in violin training [25], MIDI feedback and dynamic control in piano instruction [64], [65], AI-based vocal assessment systems [68], and the integration of digital music creation in teacher education [46]. Additionally, gamification tools (e.g., Cuadernia, Kahoot, Quizizz, and Socrative) organize learning activities through mechanisms such as instant feedback, interactive competition, and task-oriented structures [26]. These platforms and tools demonstrate their technical features and pedagogical adaptability across various teaching scenarios, collectively advancing the digitalization, diversification, and personalization of music education in higher education. In summary, digital platforms and tools provide targeted support for course management, individual practice, collaboration, feedback, and engagement across formal and informal learning contexts.

5.2.3. AI-powered educational technologies

Compared with network-based technologies and digital platforms, which mainly rely on platforms and interfaces, AI-powered educational technologies are fundamentally driven by algorithms. These algorithms can automatically analyze and predict musical performance and learning processes. They can also generate musical content, thereby providing highly personalized and intelligent instructional support.

In terms of technological approaches, AI-based technologies rely on algorithms such as deep learning, convolutional neural networks (CNNs), recurrent neural networks (RNNs), and hidden Markov models (HMMs) to support intelligent content generation, accurate assessment, and personalized feedback in music education. For example, multimedia signal processing techniques include melody feature generation and rhythm recognition [18], knowledge state tracking and learning path optimization [27], music style recognition and emotion regulation [39], and note recognition for comprehensive performance evaluation [40]. The reviewed studies suggest that these techniques can improve students' rhythmic accuracy, expressiveness, and learning efficiency.

At the application level, AI-driven systems focus on optimizing resource allocation and data analysis. They are widely used in contexts such as teaching resource classification, personalized recommendation systems, and classroom emotion analysis. For example, multi-channel CNNs allow fine-grained classification of online course videos [62], multimodal knowledge graphs support personalized learning path recommendations [35], fuzzy clustering algorithms aid in the development of teaching resource management systems [66], and emotion recognition algorithms monitor classroom interaction dynamics [15]. These applications demonstrate AI's comprehensive capacity in teaching behavior recognition, feedback system design, and motivation enhancement.

In recent years, generative AI has centered on content creation and interactive feedback, fostering a shift toward intelligent expression and creative production in music education. For example, natural language processing-based systems such as ChatGPT-4 [30] and polyphonic music generation models such as DeepBach [71] support not only interactive learning but also students' musical composition, establishing a new paradigm of human–machine co-creation. Overall, AI-powered educational technologies extend ICT from content delivery to intelligent analysis, adaptive support, decision-making assistance, and human–machine co-creation in music learning.

5.2.4. Immersive and sensor-based ICT applications

Immersive and sensor-based ICT applications, centered on immersive experience and bodily engagement, extend the perceptual and assessment dimensions of music learning through multimodal sensing and real-time feedback. In relation to immersive technologies, VR and AR are used to create virtual instruments, simulate performance environments, and visualize learning contexts. For example, VR drum kits and virtual piano systems enhance performance feedback and technical training through high-precision gesture recognition [28], [67], and AR technology has been effective in developing students' cross-cultural competence and interest in learning [32]. Furthermore, metaverse platforms have positively influenced students' willingness to learn by reinforcing their 'musical self' identity and information interaction [63].

Nevertheless, some teachers still express reservations regarding the effectiveness and feasibility of AR applications, indicating that the alignment between content and technology requires further optimization [31]. Meanwhile, IoT-based sensor systems enable accurate assessments of learners' learning states through dual-channel data acquisition of sound and motion, feature fusion, and classification feedback, which reflects the deep integration of intelligent perception and educational evaluation [36].

In terms of their characteristics, this type of application is marked by high immersion and strong bodily engagement, emphasizing learning dimensions related to movement, posture, and bodily coordination. It also involves multimodal perception and real-time feedback, enabled by the integrated capture of visual, auditory, and motion data and feedback based on these data, and the reconstruction of contextual and spatial dimensions through virtual or mixed reality-based performance and practice scenarios. Overall, immersive and sensor-based ICT applications expand music learning through embodied experience, spatial simulation, multimodal sensing, and real-time feedback.

Taken together, the four categories represent different pathways through which ICT supports course organization, learning activities, intelligent feedback, embodied experience, and contextualized learning. From a TPACK perspective, these pathways reflect different ways of aligning technology, pedagogy, and music content. Meanwhile, TAM helps explain how perceived usefulness and perceived ease of use may shape teachers' and students' adoption of these technologies.

5.3. Core advantages of integrating ICT into higher music education

Based on a systematic analysis, this study analyzed 40 articles on ICT use in higher music education. The findings revealed several recurring benefits across the selected studies. As shown in Table 8, six core advantages were identified.

Table 8. Related themes of ICT core advantages in higher music education

Serial number	Core advantages of ICT	Article no.
1	Improving teaching quality and learning outcomes	1, 2, 4, 5, 7, 8, 10, 12, 13, 14, 16, 17, 19, 22, 24, 29, 32, 33, 34, 36, 37, 38, 39, 40
2	Enhancing learning motivation, participation, and interactivity	4, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 21, 22, 24, 25, 27, 31, 33, 35, 37, 38, 39
3	Supporting personalized learning and autonomous ability development	7, 8, 11, 12, 13, 14, 16, 18, 20, 21, 22, 23, 24, 25, 28, 29, 32, 33, 39, 40
4	Enhancing pedagogical flexibility and accessibility	1, 4, 5, 7, 10, 12, 15, 16, 20, 21, 25, 26, 34, 38, 40
5	Promoting interdisciplinary integration and creativity development	10, 21, 22, 27, 35, 40
6	Promoting pedagogical innovation	12, 26, 29, 31, 34, 39, 40

5.3.1. Improving teaching quality and learning outcomes

Blended learning, mobile apps, massive open online courses (MOOCs), and multimedia platforms can improve teaching efficiency, continuity, and student achievement [14], [17], [29], [34], [44], [62], [68]. AI, deep learning, and CNNs enhance the scientific rigor and accuracy of teaching assessment [15], [27], [30], [36], [39]. Meanwhile, emerging technologies such as VR/AR, motion capture, and HMMs enhance skill development, learning performance, and the quality of feedback [28], [37], [40], [60]. In general, ICT contributes to improving music teaching quality and learning effectiveness by promoting diversified teaching modes, accurate evaluation, and efficient resource integration.

5.3.2. Enhancing learning motivation, participation, and interactivity

ICT has effectively enhanced students' learning motivation, classroom participation, and willingness to collaborate through the use of interactive platforms, immersive technologies, and personalized feedback [28], [30], [32], [34], [43], [62]. Meanwhile, mobile tools and online systems enhance the flexibility of teaching interactions and create a more engaging and supportive learning atmosphere [18], [29], [37], [46], [61], [68]. Therefore, ICT not only enhances student engagement but also reshapes interaction patterns and students' motivation in music education.

5.3.3. Supporting personalized learning and autonomy development

Different digital tools and platforms, including SPOCs, MOOCs, AR/VR, AI systems, and ChatGPT, can support differentiated instruction based on students' abilities, interests, and learning pace, enhancing their autonomy and learning effectiveness [15], [18], [27], [30], [32], [35], [43], [62], [63]. In addition, technology-supported personalized feedback and self-monitoring mechanisms (e.g., the MIDI feedback system and knowledge tracking model) support students' self-regulation and active learning [16], [25], [36], [64], [68]. Hence, ICT facilitates students' personalized growth and autonomy in music education through flexible, intelligent, and data-driven design.

5.3.4. Enhancing pedagogical flexibility and accessibility

Digital platforms such as MOOCs, SPOCs, mobile apps, and AR/VR systems enhance the temporal and spatial flexibility and content diversity of teaching and learning, enabling students to personalize their learning at their own pace [17], [32], [34], [38], [42], [44], [45], [62]. Furthermore, the scalability and compatibility of these technologies, such as Android, 6G sensing, and DAWs, ensure that teaching methods can be applied and updated across contexts [41], [61], [69]. ICT has therefore expanded the reach of music education by breaking down the constraints of time and space, and has promoted equity and diversity in education.

5.3.5. Promoting interdisciplinary integration and creativity development

Some studies indicate that technological tools, including ChatGPT-4, AR, DAWs, and a range of digital audio platforms, offer students diverse creative spaces and modes of expression, thereby stimulating artistic innovation [30], [34], [46]. The immersive experience of AR helps enhance students' cross-cultural understanding [32], and DAW tools can also aid interdisciplinary integration across music, technology, and critical thinking [41]. These technologies transcend the boundaries of traditional music education, emphasizing the educational value of creativity, creative freedom, and cross-disciplinary collaboration.

5.3.6. Promoting pedagogical innovation

ICT drives pedagogical innovation by breaking traditional constraints, broadening teaching methods, and enhancing immersive and cognitive learning experiences. Specifically, VR, AI, and 6G sensing technologies [15], [67], [69] enable immersive and intelligent teaching; cloud classrooms and data-driven algorithms [16], [18] enhance teaching flexibility and decision-making accuracy; and DAWs and technology-enabled feedback [41], [65] support project-based and visual teaching. Together, these technologies promote a shift in teaching models from teacher-led approaches to technology-enabled and diversified forms of instruction.

In summary, these core advantages may help teachers and students perceive higher levels of usefulness and ease of use, which may promote more favorable attitudes toward ICT use and stronger intentions to continue adopting these technologies (TAM). These benefits also tend to occur when technological affordances are appropriately aligned with music content and pedagogical strategies. When technological, pedagogical, and content knowledge are effectively integrated (TPACK), ICT becomes not merely an external tool but an integral component that underpins both curriculum objectives and the learning process.

5.4. Key challenges in implementing ICT in higher music education

Despite the growing use of ICT in higher music education, several challenges remain in its implementation. Table 9 summarizes these challenges. The subsections discuss each challenge in detail.

Table 9. Themes related to the key challenges of ICT use

Serial number	Key challenges of ICT use	Article no.
1	Limited emotional interaction and classroom atmosphere	11, 15, 20, 25, 35
2	High technical thresholds and complexity of use	9, 14, 16, 19, 24, 27, 33, 35
3	Unequal resource allocation and the digital divide	9, 11, 15, 17, 25, 27, 33, 37, 38, 40
4	Increased teacher workload and difficulties in instructional adaptation	1, 17, 20, 25, 30
5	Immature platform and system design	1, 4, 5, 11, 14, 22, 24, 30, 33
6	Over-reliance on technology and declining depth of learning	13, 22, 24, 27, 33
7	Privacy and ethical risks	22, 29

5.4.1. Limited emotional interaction and classroom atmosphere

Online music instruction, lacking face-to-face interaction, reduces the emotional connection between teachers and students and weakens the classroom environment, which affects learning motivation and expressive experience [38], [42], [43], [45]. When students feel isolated, their engagement may decrease, especially if they are in environments where group rehearsals and real-time feedback are absent. Meanwhile, insufficient digital skills exacerbate reliance on traditional training methods and emotional disconnection [70].

5.4.2. High technical thresholds and complexity of use

Complex data preprocessing, model architectures, and computational demands raise the technical threshold for adoption [27], [39], [62]. Educational staff or students may need to spend time learning multimedia methods, deep learning tools, or innovative software; otherwise, teaching effectiveness and learning experiences may suffer [26], [64], [68]. Novices frequently encounter confusion when using devices such as iPads or digital creation tools, diminishing their motivation to engage [46], [70].

5.4.3. Unequal resource allocation and the digital divide

Network instability, restricted accessibility of equipment, and inadequate technological support present significant barriers to the effective adoption of ICT in education [14], [37], [43]. The digital divide can worsen educational inequality, and low-income students often have limited access to the internet and technological devices, restricting their participation in online music learning [38], [42]. In addition to barriers to access, schools often face hardware incompatibility, resource constraints, and inadequate power supply, all of which undermine the continuity and quality of teaching and learning processes [26], [33], [46], [68], [71].

5.4.4. Increased teacher workload and difficulties in instructional adaptation

Digital instruction significantly increases the burden of lesson planning and providing feedback for teachers. Traditional music courses are also challenging to implement effectively in online instructional formats [42], [44], [45]. Insufficient platform personalization and difficulties in addressing student diversity also constrain teaching effectiveness [31], [37].

5.4.5. Immature platform and system design

Current tools often fall short of the professional requirements of music teaching, particularly regarding sound quality, interactivity, recognition accuracy, and personalized recommendations [27], [30], [31], [43], [44]. Some systems designed for beginners have limited functionality and are poorly suited for advanced learners [31], while multimedia and AI technologies also face issues such as misclassification and unbalanced feedback [64], [68]. Furthermore, the pedagogical effectiveness of many apps and platforms remains unverified over the long term [17], [61].

5.4.6. Over-reliance on technology and declining depth of learning

Over-reliance on digital tools may hinder emotional expression and fundamental understanding in music learning, influencing the depth of learning and artistic literacy [28], [30], [46], [64], [68]. It may also impair students' command of traditional methods, such as sheet music and teacher-led instruction, resulting in limited progress without technological support [46], [64]. Meanwhile, teachers who depend too heavily on technology may overlook the value of humanistic care and face-to-face interaction [68].

5.4.7. Privacy and ethical risks

AI systems carry significant risks of privacy breaches and data misuse when collecting voice, image, and behavioral data, particularly in the absence of robust data-protection mechanisms [15], [30]. In music learning contexts, such data may include vocal recordings, performance videos, and behavioral traces generated during online or AI-supported learning. These issues highlight the need for clearer ethical guidelines and more responsible data governance in ICT-supported music education.

Correspondingly, from a TAM perspective, challenges such as weakened emotional interaction, high technical barriers, immature platform design, and privacy and ethical risks tend to diminish teachers' and students' perceived usefulness and perceived ease of use of these technologies. These challenges may negatively influence their attitudes toward using ICT and their intentions to continue adopting it. From a TPACK perspective, challenges such as increased teacher workload, difficulties in adapting teaching methods, and reduced learning depth suggest that technological knowledge has not been effectively integrated with content knowledge and pedagogical knowledge. As a result, ICT may function more as an additional burden or superficial innovation than as an intrinsic element genuinely embedded in the curriculum and its learning objectives.

5.5. Integrative framework of ICT use in higher music education

Building on the thematic synthesis of ICT use types and their characteristics in Table 7, core advantages in Table 8, and key challenges in Table 9, this study further develops an integrated framework of ICT use in higher music education, as presented in Figure 5. This framework begins with four main types of ICT use, proceeds through several key educational functions across contexts, and ultimately leads to both positive outcomes and implementation challenges. At the same time, TAM and the TPACK framework are employed as interpretive lenses for understanding the integration mechanisms and conditional effects of different technological pathways in higher music education.

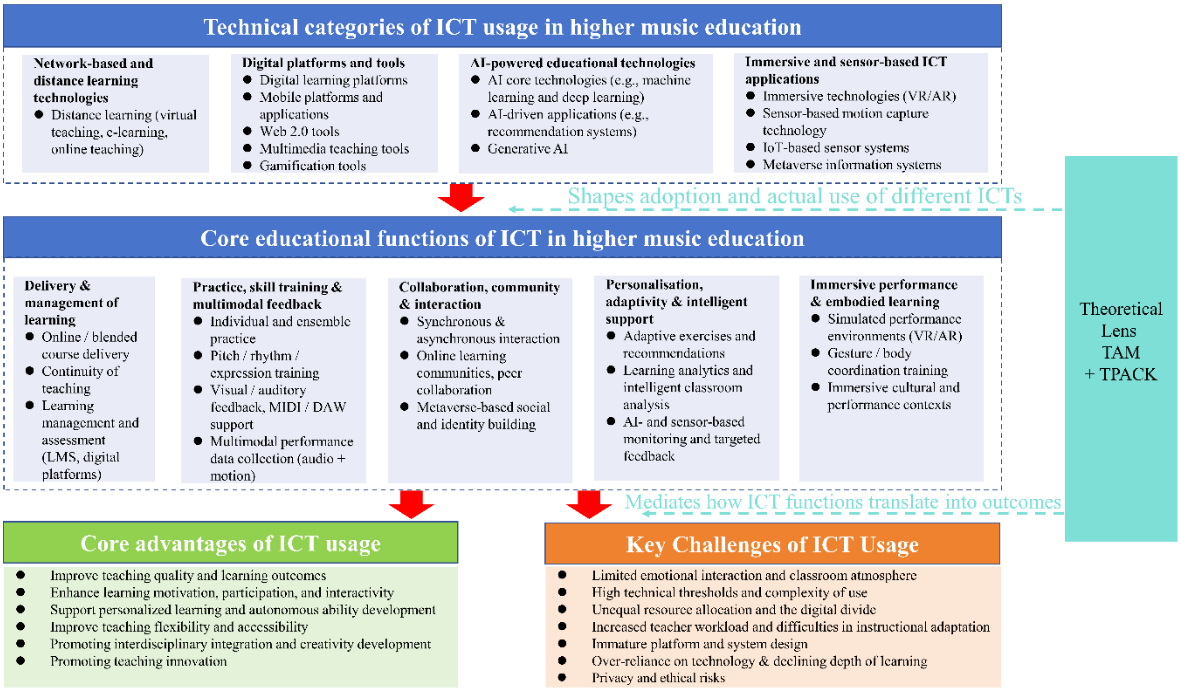

Figure 5. Integrative framework of ICT use in higher music education

6. DISCUSSION

Overall, most of the included studies reported positive effects of ICT integration in music education, particularly in studies on mobile learning, gamified learning, AI-assisted learning, and music creation support [17], [26], [30], [71], suggesting a success narrative in the literature. This trend reflects the research focus on technological effects and may also be related to research design characteristics. Many included studies adopted quantitative designs and focused on measurable indicators of learning effectiveness or attitudes, which may have made positive outcomes more visible in the literature [23], [24], [30].

Such studies are useful for evaluating the immediate effects of short-term experiments or classroom interventions, but pay relatively less attention to longer-term educational dimensions such as the long-term restructuring of curriculum structures, the ongoing development of musical competence, and the evolution of teachers' professional identities. In existing research, technical interventions have primarily occurred in short-term classroom settings and course projects [46], [64], [65]. In the context of music education that emphasizes the long-term accumulation of skills and aesthetic cultivation, significant short-term effects do not necessarily indicate the long-term sustainability of teaching practices. Therefore, it is necessary to maintain a distinction between the demonstration of technological effects and educational structural reform.

Meanwhile, in the process of technological integration, issues such as technical failures, students' resistance to technology-mediated learning, or failure to achieve the expected outcomes are rarely systematically presented in existing studies. Some studies have highlighted that online music teaching, virtual vocal coaching, and the use of ICT during the pandemic may be accompanied by challenges such as learning difficulties, difficulties in adapting to technology, a lack of interaction, and an increased workload for teachers [14], [38], [44]. Future studies should report negative or neutral findings more systematically and employ qualitative and mixed-methods approaches to further understand contextual factors such as institutional context, cultural background, and teachers' beliefs through interviews, classroom observation, and narrative analysis. Such work would provide more explanatory theoretical and practical guidance for the contextual implementation of ICT in higher music education.

The synthesized results of this study show that educators' viewpoints appear scattered rather than systematic. Several studies indicate that teachers may lack sufficient technological competence, encounter difficulties in adapting their teaching practices [31], [37], and experience increased workloads [39], but there is a lack of in-depth analysis of their attitudes and belief structures, as well as their professional development needs. Based on TAM and TPACK, teachers' perceived usefulness and ease of use, self-efficacy, and understanding of what constitutes good music teaching are likely to influence their willingness to continue integrating ICT and shape whether the technology merely reinforces existing teaching practices or promotes the transformation of pedagogical concepts and curriculum goals [47], [49]. Overall, existing research mostly focuses on the technical level, while paying insufficient attention to the connection between ICT and deep-seated educational factors such as curriculum goals, teaching beliefs, evaluation mechanisms, and changes in the roles of teachers and students. In the future, a systematic perspective should be adopted to explore how ICT can be integrated into curriculum design, support learning objectives, and reshape teaching interactions. This shift is key to moving from tool usage to teaching reform.

From a practical perspective, ICT integration should be closely aligned with specific music learning objectives. The TPACK framework emphasizes that the use of technology can truly support learning only when it is effectively integrated with subject content and pedagogy [49], [50]. For example, performance teachers can use video feedback, mobile practice applications, or audio analysis tools to help students monitor pitch, rhythm, articulation, and expression [17], [25], [64], [65]; theory and composition teachers can use digital platforms, DAWs, or AI-supported tools to provide interactive exercises, personalized resources, and preliminary compositional feedback [41], [46], [71]. These examples suggest that ICT should not be treated as an add-on, but as a pedagogical resource selected according to course goals, student needs, and the characteristics of music learning.

In addition, most existing studies focus on students' or pre-service music teachers' use and perceptions of specific technologies, while empirical research on in-service university teachers remains relatively limited [23], [24], [26], [38]. Teachers are central to the effective integration of ICT, and their digital literacy, teaching beliefs, and practical experience are key factors [73], [74]. Further research should focus on in-service university music teachers, investigating their strategies for selecting and adapting technology in authentic teaching contexts.

From a geographical perspective, the reviewed studies show a clear regional concentration, with many originating from China and covering areas such as AI, internet technologies, cloud classrooms, VR, and distance music education [15], [16], [18], [28], [45]. This pattern may reflect regional advances in educational digitalization, as well as differences in research funding, policy priorities, and publication practices. Therefore, the evidence should be understood as shaped by specific institutional and policy contexts rather than as a globally balanced summary. Since music education is influenced by cultural traditions, educational systems, and aesthetic values, the findings should be interpreted as context-sensitive and applied with caution internationally.

Some studies included in this review have touched on emerging technologies such as generative AI, the metaverse, and immersive environments [30], [63], [67], [71]. Yet the broader literature still tends toward technological optimism and pays insufficient critical attention to potential risks and their educational implications. Research on tools such as ChatGPT and DeepBach, for example, has mainly highlighted their value for composition support, practice feedback, and resource recommendation, while giving far less attention to their possible effects on musical originality, copyright ownership, aesthetic diversity, and students' over-reliance on such tools [30], [71]. Meanwhile, systematic examination of newer learning contexts such as cloud classrooms, online collaboration, remote performance, Web 3.0, decentralized platforms, and the metaverse remains relatively limited, suggesting a gap between current empirical research and digital education policy. Future research should therefore draw on digital ethics, critical music education, and digital education strategy to examine how students and teachers develop critical AI literacy [75]. It should also examine how these technologies, in contexts such as collaborative online composition, remote training, and virtual orchestra rehearsal, may support educational equity, learner-centered education, and lifelong learning while also sustaining originality, aesthetic judgement, and artistic agency.

Methodologically, although this study strictly followed the PRISMA procedure, the number of included studies was relatively limited due to stringent inclusion criteria, including the time range, language restrictions, and the specific context of higher music education. This reflects the limited scale of empirical research in this field and suggests that the trend analysis in this paper should be regarded as exploratory rather than conclusive. Meanwhile, several core themes recurred across different studies, indicating a degree of thematic stability within the existing literature [72]. However, the external representativeness of these findings still needs further validation through larger-scale reviews. Language and database limitations may also introduce some selection bias. Furthermore, although all included studies met the minimum MMAT quality criteria, the evidence base remains constrained by the limited use of longitudinal designs [23], [25], [31], insufficient reporting of effect sizes [23], [25], and incomplete descriptions of study contexts and implementation processes [31], [67]. These issues may affect the comparability, transferability, and long-term interpretation of the findings.

Overall, future research in this field should move beyond testing isolated technological effects and shift toward more structured, contextualized, and critical lines of inquiry. Existing research indicates that the educational impact of digital technologies is not determined solely by technology adoption or the inherent attributes of the technology itself, but rather depends on how technology is integrated with teachers' knowledge, instructional design, organizational support, and specific pedagogical contexts [49], [50], [53].

At the theoretical level, this means going beyond technology adoption perspectives such as TAM and making fuller use of pedagogical integration frameworks such as TPACK [49], [50]. This can help researchers understand the long-term impact of ICT on higher music education from multiple perspectives, including teacher practice, curriculum structure, and learning culture. At the same time, future studies should not only recognize the potential of technology but also clarify its scope of application and the cultural conditions that shape its use. In this way, research on ICT in higher music education can move toward a more mature, diverse, and reflective stage.

7. RESEARCH IMPLICATIONS

7.1. Theoretical implications

From a theoretical perspective, this study builds on TAM and TPACK to develop an integrative framework of technology types, instructional functions, advantages, and challenges in Figure 5, providing a discipline-sensitive map for understanding ICT integration in higher music education. This framework not only reveals the systematic correspondences between four types of ICT use and various instructional functions; it also shows that technology acceptance is shaped by both perceived usefulness and perceived ease of use, and by music-specific dimensions such as emotional expression, embodied experience, and aesthetic fit. In doing so, it provides a theoretical foundation for adapting TAM and TPACK to artistic and music education contexts. Furthermore, by juxtaposing advantages and challenges, as well as positive and potential negative outcomes of ICT use, this study suggests that future theory building should explicitly incorporate failure cases, contextual constraints, and publication bias, and address the complexity of digital transformation in music education across three levels: classroom, curriculum, and policy.

7.2. Practical implications

This study provides action-oriented recommendations for teachers, administrators, technology developers, and policymakers in higher music education. First, university music teachers and curriculum designers should select ICT tools according to learning objectives rather than adopting technology for its own sake. Remote platforms can support flexible learning; mobile applications, DAWs, and AI tools can support practice, creative production, and personalized feedback; and VR/AR technologies can enhance immersive and embodied learning. Meanwhile, technology use should be combined with face-to-face demonstrations, ensemble rehearsals, and emotional communication to preserve the artistic and interpersonal features of music education. Second, universities and departments should strengthen digital infrastructure, including stable networks, high-quality audio equipment, low-latency systems, and digital learning spaces, to reduce the digital divide and improve the reliability of ICT-supported music learning. They should also provide continuous TPACK- and digital-literacy-based training to improve teachers' technical competence, reduce integration pressure, and embed ICT more effectively in music teaching. Finally, technology developers and policymakers should address privacy, copyright, originality, and responsible AI use. ICT products and policies should support musical creativity, embodied learning, teacher–student interaction, and curriculum development, rather than merely emphasizing technical efficiency. Music students and educators should develop critical digital literacy, maintaining creative agency, musical judgement, and deep learning while using technological support.

8. LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

It should be acknowledged that the SLR conducted in this study has a number of methodological limitations. First, the search was conducted in a limited number of mainstream databases, and thus some studies on ICT use for higher music education may not have been captured in the search. Second, researcher subjectivity can be difficult to fully eliminate when choosing keyword combinations and search strings; the review may have overlooked relevant publications that use different terminology but are nevertheless closely related to the study topic. Third, this study limited its inclusion to English-language literature. This language restriction limits the visibility of research conducted within other linguistic and cultural contexts and may affect the comprehensiveness of the review and generalizability of its conclusions.

Future studies could further expand databases and literature sources, enhance linguistic diversity, and incorporate interdisciplinary and regional indices. Keyword design could also be improved through preliminary searches, expert consultation, and snowballing to reduce retrieval bias and improve comprehensiveness and representativeness. In addition, combining meta-analysis with quantitative modelling may provide a stronger evidence base for ICT-related research in higher music education.

9. CONCLUSION

Through a systematic review of 40 empirical articles, this study maps the overall landscape of ICT use in higher music education. Related research has expanded rapidly in recent years. Within the reviewed corpus, China has the largest number of publications. Research designs are dominated by quantitative approaches. ICT use mainly falls into four categories: network-based and distance learning technologies, digital platforms and tools, AI-powered educational technologies, and immersive and sensor-based ICT applications. These categories were associated with several reported advantages in enhancing teaching quality, learning outcomes, learning motivation, personalized learning, and instructional flexibility. At the same time, several challenges persist, including limited emotional interaction, high technological entry barriers, unequal resource distribution, increased teacher workload, immature platform design, over-reliance on technology, and privacy and ethical risks, all of which constrain meaningful or sustained ICT integration into higher music education.

Overall, ICT is moving higher music education toward a data-driven, intelligent, and blended ecosystem, with implications for policy and curriculum. Policy efforts should invest in infrastructure, teacher development, ethical governance, and equitable access, while curricula should integrate ICT to support performance, creativity, collaboration, and digital literacy. Future research should expand linguistic and regional scope, strengthen qualitative and longitudinal inquiry, and address equity, ethics, and teacher development to build a sustainable integration pathway.

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AUTHOR CONTRIBUTIONS STATEMENT

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Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Yangyang Wang	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓			
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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors confirm that there are no competing interests related to this work.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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