

Nivel competencial y perfiles docentes ante la Inteligencia Artificial: un análisis multivariante en el área de Música

AI competency levels and teaching profiles: a multivariate analysis in the field of Music education

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RESUMEN

Esta investigación analiza el nivel de competencia en Inteligencia Artificial en una muestra de 387 maestros de Música de Educación Primaria en España para determinar el grado de transferencia de estos recursos a su ejercicio docente. Bajo un diseño no experimental y cuantitativo, se aplicó la escala validada ECIA-EMUS, evaluando dimensiones que abarcan desde la comprensión técnica y la integración pedagógica hasta el uso ético y la formación específica. Los resultados revelan una jerarquía de dominios donde la principal fortaleza del colectivo reside en el uso ético e inclusivo, mientras que la mayor vulnerabilidad se localiza en la integración operativa en los procesos de enseñanza-aprendizaje. El análisis inferencial confirma que la edad es el factor de contexto con mayor peso predictivo, evidenciando una brecha generacional significativa en la disposición tecnológica. Asimismo, el análisis multivariante de conglomerados permitió identificar tres perfiles diferenciados: alfabetización inicial, competencia intermedia y liderazgo digital. Se concluye que existe una dicotomía entre el compromiso deontológico y la capacidad técnica real, situando a la formación específica como el motor fundamental para transponer el marco teórico a una práctica de aula efectiva que potencie la creatividad y la inclusión musical.

PALABRAS CLAVE

Inteligencia artificial; educación musical; competencia digital docente; educación primaria; innovación educativa; análisis multivariante.

ABSTRACT

This research analyzes the level of Artificial Intelligence competency in a sample of 387 primary school music teachers in Spain to determine the degree of transfer of these resources to their teaching practice. Under a non-experimental and quantitative design, the validated ECIA-EMUS scale was applied, evaluating dimensions ranging from technical understanding and pedagogical integration to ethical use and specific training. The results reveal a hierarchy of domains where the group's main strength lies in ethical and inclusive use, while the greatest vulnerability is located in operational integration within teaching-learning processes. Inferential analysis confirms that age is the contextual factor with the greatest predictive weight, evidencing a significant generational gap in technological readiness. Likewise, multivariate cluster analysis allowed for the identification of three distinct profiles: initial literacy, intermediate competency, and digital leadership. It is concluded that a dichotomy exists between deontological commitment and actual technical capacity, positioning specific training as the fundamental driver for transposing the theoretical framework into effective classroom practice that enhances musical creativity and inclusion.

KEYWORDS

Artificial intelligence; music education; digital teaching competence; primary education; educational innovation; multivariate analysis.

1. INTRODUCTION

The integration of artificial intelligence (AI) into music education constitutes an emerging field of research that is transforming pedagogical practices by bringing together artistic, technological, and ethical competencies (Camarasa Botella, 2025; Galindo Durán, 2023; Lis Gutiérrez & Pulido-Flórez, 2024). This development redefines teaching and learning processes, posing new challenges for educators, who must adapt to a context in which technology plays a central role (Oluwakemi et al., 2024). Within the Spanish education system, this incorporation responds to the need to align teaching practices with technological advances, promoting innovative approaches that integrate digital tools to enhance creativity, inclusion, and the holistic development of students (Gofman & Jin, 2024; Hooda et al., 2022). Nevertheless, the scientific literature warns that this transition is not uniform; the pace of innovation often outstrips the responsiveness of traditional training frameworks, generating a dichotomy between the availability of resources and their effective application in the classroom (Hwang et al., 2020; Owoc et al., 2019). This lack of homogeneity suggests that, although there is a willingness to innovate, a significant gap persists in the transfer of this knowledge to concrete learning situations, where teachers often feel overwhelmed by the technical complexity of new intelligent systems (Alwaqadani, 2025; Celik et al., 2022).

In this context, specialist music teachers, in accordance with Royal Decree 1594/2011, must demonstrate proficiency that integrates musical skills with emerging technologies in order to foster meaningful learning. This demand is linked to Royal Decree 157/2022, which regulates the core curriculum of Primary Education and positions Music Education as a cornerstone of holistic development across its sensory, intellectual, social, and creative dimensions. The regulatory framework highlights the importance of cultivating competencies that strengthen critical

thinking and respect for cultural diversity through active listening, the investigation of musical expressions from a gender-sensitive perspective, and creative expression through sound experimentation and digital media. However, implementing these guidelines requires teachers to move beyond the instrumental use of technology and become mediators capable of designing learning experiences that leverage AI's potential for personalization, intelligent tutoring, and the inclusion of students with diverse needs (Shoukat et al., 2025).

Musical competencies in Primary Education are further enriched by Zaragozà's (2024) model, grounded in a consolidated line of research that proposes seven dimensions: perception and analysis, performance, creation and improvisation, cultural contextualization, critical reflection, communication, and the use of technological resources. This latter dimension converges with the decree by underscoring the relevance of digital tools—many of them AI-based—for musical creation and editing. Likewise, UNESCO's (2024) AI competency framework identifies key areas such as an understanding of algorithmic principles, pedagogical application for assisted composition, and the ethical dimension, aimed at safeguarding privacy and promoting equity in the classroom. The scientific literature reinforces this intersection, noting that these technologies facilitate immediate feedback and democratize creative processes by offering accessible interfaces (Adeleye et al., 2024; Chalkiadakis et al., 2024; Hooda et al., 2022). Despite these advantages, the effectiveness of such tools depends on teachers possessing sufficient technical literacy to identify the limitations and errors of intelligent systems, thereby preventing algorithms from replacing the teacher's aesthetic and pedagogical judgment (Danyaro et al., 2025; Elsayed, 2024).

Despite the possibilities outlined above, ethical challenges persist regarding the legality of content, authorship of generated works, and the protection of personal data within the school environment. Under the TPACK framework proposed by Mishra and Koehler (2006), it is concluded that effective integration requires a synergy between technological, pedagogical, and content knowledge, enabling AI to enhance curricular objectives without compromising the artistic essence of music. It is crucial to consider that teachers' self-perceived competence is often influenced by sociodemographic and contextual factors—such as age, gender, or school ownership—which may determine different rates of adoption of technological innovation (Jiménez-Hernández et al., 2020; Paidican Soto et al., 2024; Soyly & Sağkal, 2019). Current research suggests that AI training should not be limited to isolated technical instruction, but rather should foster a commitment to lifelong learning and participation in professional networks that facilitate meaningful and effective resource sharing (Lan, 2024; Lee et al., 2024; Wu et al., 2023).

For all these reasons, the present study is justified by the urgent need to diagnose the current state of teachers' digital competence in the area of music in the face of the challenge posed by Artificial Intelligence. At a time when Spanish educational policy demands profound digital transformation, it is imperative to determine whether specialists possess the necessary tools to translate the ethical and theoretical framework—generally well established—into classroom practice that includes assisted composition, automated curricular adaptation, and assessment through intelligent systems. Analyzing these perceptions will not only make it possible to identify areas of vulnerability and existing generational gaps, but will also provide the empirical basis necessary for designing specific training pathways that turn AI into a true catalyst for creativity and musical inclusion, preventing technology from becoming a new pedagogical barrier.

From this perspective, the present study makes three original and clearly differentiated contributions to the field. First, it provides a conceptual contribution by operationalizing competence in Artificial Intelligence within music education through the systematic integration of three reference frameworks: the TPACK model, UNESCO's (2024) AI competency framework, and the specific dimensions of school music education. Second, it offers a methodological contribution through the use of the psychometrically validated ECIA-EMUS instrument and the application of multivariate analyses that make it possible to move beyond descriptive diagnosis and to construct differentiated teacher profiles. Finally, the study incorporates an applied contribution by empirically identifying a dichotomy between ethical commitment and technical capacity, pro-

viding key evidence for the design of differentiated training pathways tailored to the real needs of Primary Education music teachers.

2. METHOD

2.1. Objectives

The general objective of this research is to analyze the level of perceived competence in Artificial Intelligence among a sample of 387 Spanish Primary Education teachers specializing in Music, in order to determine the degree of transfer and implementation of these technological resources in their teaching practice.

To address this general objective, the study is structured around the following specific objectives (SO):

- SO1: To determine teachers' level of self-perception for each item of the ECIA-EMUS scale, with the aim of identifying the most consolidated technical skills as well as those that constitute a barrier in the music classroom.
- SO2: To examine the behavior of the five dimensions of the instrument in order to establish a hierarchy of domains and identify areas of vulnerability in pedagogical practice involving intelligent systems.
- SO3: To assess the influence of sociodemographic and contextual variables, such as gender, age, or school ownership, in order to verify the existence of significant gaps in the mastery of these technological resources.
- SO4: To characterize teacher typologies through multivariate analysis, allowing for the definition of differentiated profiles according to their degree of adoption of and proficiency in addressing the challenges of computational innovation.

2.2. Design

The present study adopts a non-experimental, cross-sectional research design with a predominantly quantitative approach. It is defined as a descriptive-comparative and correlational study, as there is no deliberate manipulation of variables; instead, the phenomena are observed and analyzed within their natural context for subsequent statistical interpretation.

The data collection strategy is based on a survey methodology, using a standardized psychometric scale to quantify teachers' perceptions. In addition, the design incorporates inferential analysis to determine the existence of statistically significant differences between groups, as well as an explanatory component through profile analysis. This approach allows for a deeper examination of the structure of technological competence among music teachers, moving beyond mere frequency descriptions.

2.3. Sample

The population under study is composed of Primary Education teachers specializing in Music who carry out their teaching activity in Spain. Using a non-probabilistic convenience sampling method combined with a snowball technique, a final sample of 387 teachers was obtained. This sampling strategy proved particularly effective for accessing such a specific teaching profile, allowing for nationwide geographical coverage that minimizes regional focus bias and ensures diversity in variables such as school ownership and age.

Regarding gender distribution, the sample shows a higher female representation, with 228 women (58.9%) compared to 159 men (41.1%). Concerning the ownership of the schools where participants perform their professional duties, 46.8% (n = 181) work in publicly managed schools,

30.7% (n = 119) in state-subsidized private schools, and the remaining 22.5% (n = 87) in privately owned institutions.

Participants' ages range from 22 to 64 years (M = 41.5; SD = 9.2). For comparative analysis purposes, the sample was segmented into three generational strata: young teachers aged up to 30 years (21.9%), mid-career teachers aged between 31 and 45 years (41.9%), and experienced teachers over 45 years of age (36.2%).

2.4. Instrument

To assess teaching competencies, the Artificial Intelligence Competency Scale for Primary Music Teachers (ECIA-EMUS) was used. This psychometric instrument was specifically designed and validated for the Spanish context, drawing on UNESCO's (2024) AI competency frameworks and Zaragoza's (2024) dimensions of music education. The scale consists of a total of 34 items rated on a five-point Likert-type response format (1 = Strongly disagree; 5 = Strongly agree).

The construct is organized into five core dimensions that allow for an in-depth analysis of teachers' digital competence in the field of music:

–Dimension 1. Understanding AI for its applicability in Music Education (5 items):

This dimension evaluates teachers' levels of technical and theoretical literacy. It focuses on knowledge of AI fundamentals, the identification of specific software for audio generation and editing, as well as the recognition of technical limitations and potential errors of these systems in the classroom.

–Dimension 2. Integration of AI into music teaching and learning (9 items):

This dimension measures operational capacity for implementing AI in pedagogical practice. It examines the use of intelligent tools for musical analysis tasks, assistance in composition and improvisation, the creation of personalized teaching materials, and automated curricular adaptation.

–Dimension 3. Ethical and inclusive use of AI in Music Education (6 items):

This dimension addresses teachers' professional and ethical responsibility. It includes indicators related to the protection of students' personal data, respect for intellectual property rights of AI-generated works, and the monitoring of algorithmic biases to ensure cultural and gender diversity.

–Dimension 4. Dissemination and collective use of AI in Music Education (6 items):

This dimension analyzes the social and collaborative aspects of technology use. It assesses the application of AI to enhance group projects, manage musical ensembles (such as school choirs or bands), and foster connectivity with external educational communities.

–Dimension 5. Training in AI for Music Education (8 items):

This dimension evaluates professional development and attitudes toward innovation. It includes interest in continuous updating of emerging tools, participation in professional learning networks, and the ability to design innovative, computation-mediated learning situations.

Regarding its psychometric properties, the content validity of the ECIA-EMUS was established through expert judgment, yielding a global Content Validity Index (CVI) of 0.94 and a Fleiss' kappa coefficient of 0.76. To confirm the stability of the construct in the present sample (n = 387), the internal structure of the original five dimensions was verified. Internal consistency analyses indicated high reliability, with a robust overall Cronbach's alpha coefficient ($\alpha > .90$), both in the original validation phase and in the current application. Moreover, all constituent factors pre-

sented reliability values above .80, ensuring the psychometric soundness of the instrument for assessing perceived AI competence among music teachers.

2.5. Procedure

The data collection phase was conducted during the first trimester of the academic year, using the digital platform Google Forms to administer the instrument due to its accessibility and compatibility with multiple devices. The questionnaire link was distributed through strategically selected professional channels, including networks of teacher training centers, music education associations, and national virtual communities specializing in educational innovation. Additionally, informational emails were sent directly to Primary Education schools across the country, requesting the collaboration of in-service music teachers to complete the scale.

Regarding ethical protocols, access to the instrument was obligatorily preceded by an informed consent form detailing the objectives of the research and the strictly academic use of the information collected. Participants' anonymity and the confidentiality of the data were guaranteed at all times, in compliance with current regulations on the protection of personal data. The average response time was estimated at approximately 12 minutes, and no incentives were offered for participation. After the data collection period concluded, responses were exported to a coded database, and a preliminary data-cleaning process was carried out to remove incomplete or duplicate entries that could compromise the quality of subsequent analyses.

2.6. Data Analysis

Statistical analysis of the data was conducted using IBM SPSS Statistics (version 29). In an initial phase, descriptive analyses were performed to characterize the behavior of the dependent variables, using measures of central tendency (mean) and dispersion (standard deviation). To ensure the robustness of the instrument, Cronbach's alpha coefficient was calculated, confirming high internal consistency for both the overall scale and its constituent factors.

In a second phase, after verifying the assumptions of normality and homoscedasticity through the Kolmogorov-Smirnov and Levene's tests, respectively, parametric inferential statistics were applied. Student's t-test was used to compare mean differences by gender. Likewise, one-way analysis of variance (ANOVA) was conducted to determine the existence of statistically significant differences according to school ownership, age strata, and specifically according to the level of training identified in Dimension 5 of the scale.

When statistically significant differences were detected ($p < .05$), Tukey's post hoc tests were applied to identify specific discrepancies between groups. The confidence level for all analyses was set at 95%.

3. RESULTS

The results obtained from the detailed analysis of the 34 items comprising the scale reveal a complex and multidimensional picture of music teachers' perceived competence (see Table 1). From an initial general perspective, the sample does not exhibit a uniform pattern; instead, a clear polarization emerges between ethical disposition and actual operational capacity. This phenomenon suggests that music teachers have internalized the theoretical and deontological discourse surrounding Artificial Intelligence (AI) yet encounter substantial difficulties when attempting to transfer this knowledge into the design of teaching and learning activities.

Regarding the most consolidated competencies, the findings indicate that teachers report a high level of self-perceived competence in attitudinal and social responsibility domains. Item 27, related to interest in continuous professional development, stands out prominently ($M = 3.86$; $SD = 0.92$), reflecting a strong commitment to lifelong learning and a notable openness to technological innovation. Along similar lines, concern for privacy and data protection (Item 15: $M = 3.83$; $SD = 0.95$) and awareness of intellectual property and authorship rights in algorithm-mediated

musical creation (Item 16: $M = 3.58$; $SD = 1.05$) rank among the highest-rated ethical dimensions. These findings suggest that the teaching cohort approaches AI from a position of caution and responsibility, prioritizing student safety and respect for artistic creation.

However, this optimistic outlook regarding professional attitudes is overshadowed by the identification of critical barriers in technical-pedagogical implementation (Dimension 2). The lowest scores across the entire study are found in the ability to carry out personalized curricular adaptations through intelligent systems (Item 9: $M = 2.15$; $SD = 1.11$) and in the use of AI as a tool for assessing musical learning (Item 11: $M = 2.49$; $SD = 1.19$). These values indicate that the integration of AI into the music classroom remains at an incipient or exploratory stage, where teachers lack the technical expertise required to delegate complex processes such as instructional personalization or automated assessment.

A particularly relevant finding is the high level of dispersion observed in items of an instrumental nature. For instance, in the use of AI-integrated audio software (Item 2), the standard deviation reaches 1.28, the highest in the series. This value points to the existence of an internal digital gap within the teaching cohort: while a small group of teachers demonstrates advanced proficiency, the majority remain at basic levels of competence. This lack of homogeneity poses a challenge for the coordinated implementation of school-wide innovation projects.

Despite these technical limitations, teachers report a positive perception of their capacity for technological leadership (Item 26: $M = 3.25$; $SD = 1.09$). This increase within the Dissemination dimension suggests that music specialists perceive themselves as potential drivers of computational innovation within their institutions, assuming roles as guides or prosumers of digital resources, even though they have not yet achieved sufficient mastery in the use of AI-assisted composition tools (Item 7) or AI-guided improvisation systems (Item 8).

Finally, the skewness (Sk) and kurtosis (Ku) values reported in Table 1 support the robustness of the instrument and the quality of the responses obtained. The absence of extreme values beyond conventional thresholds (± 1.5) allows us to conclude that the sample of 387 participants provides a solid basis for the subsequent inferential analyses, which will further explore how variables such as age or school type influence the perceptions described above.

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Table 1. Frequency Distribution and Descriptive Statistics of Competence Levels for the Integration of Artificial Intelligence in the Music Classroom.

Dimension / Item	L1	L2	L3	L4	L5	M	SD	Sk	Ku
D1. Understanding of AI									
1. Technical foundations	43 (11.1)	96 (24.8)	143 (37.0)	72 (18.6)	33 (8.5)	2.89	1.12	0.12	-0.63
2. Audio software and AI	78 (20.2)	115 (29.7)	91 (23.5)	61 (15.8)	42 (10.9)	2.67	1.28	0.38	-0.92
3. Musical algorithms	59 (15.2)	111 (28.7)	126 (32.6)	64 (16.5)	27 (7.0)	2.71	1.13	0.22	-0.71
4. Pedagogical potential	38 (9.8)	90 (23.3)	151 (39.0)	77 (19.9)	31 (8.0)	2.93	1.07	0.08	-0.59
5. Limitations and errors	32 (8.3)	93 (24.0)	155 (40.1)	79 (20.4)	28 (7.2)	2.94	1.02	0.05	-0.53
D2. Integration into T-L									
6. Music analysis with AI	98 (25.3)	137 (35.4)	84 (21.7)	47 (12.1)	21 (5.4)	2.37	1.13	0.65	-0.41
7. Composition assistant	114 (29.5)	138 (35.7)	73 (18.9)	40 (10.3)	22 (5.7)	2.27	1.15	0.76	-0.31
8. Guided improvisation	119 (30.7)	136 (35.1)	69 (17.8)	44 (11.4)	19 (4.9)	2.24	1.15	0.79	-0.22
9. Curricular adaptation	129 (33.3)	145 (37.5)	58 (15.0)	36 (9.3)	19 (4.9)	2.15	1.11	0.94	0.08
10. Teaching materials	72 (18.6)	108 (27.9)	114 (29.5)	61 (15.8)	32 (8.3)	2.67	1.18	0.28	-0.81
11. Assessment with AI	89 (23.0)	124 (32.0)	97 (25.1)	49 (12.7)	28 (7.2)	2.49	1.19	0.44	-0.74
12. Intelligent tutoring	66 (17.1)	112 (28.9)	121 (31.3)	59 (15.2)	29 (7.5)	2.67	1.14	0.22	-0.73
13. Gamification and audio	94 (24.3)	128 (33.1)	92 (23.8)	50 (12.9)	23 (5.9)	2.43	1.16	0.54	-0.56
14. Automated feedback	79 (20.4)	121 (31.3)	106 (27.4)	54 (14.0)	27 (7.0)	2.56	1.17	0.41	-0.79
D3. Ethical and Inclusive Use									
15. Data privacy	11 (2.8)	24 (6.2)	83 (21.4)	171 (44.2)	98 (25.3)	3.83	0.95	-0.74	0.38
16. Intellectual property	14 (3.6)	43 (11.1)	111 (28.7)	142 (36.7)	77 (19.9)	3.58	1.05	-0.47	-0.21

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Dimension / Item	L1	L2	L3	L4	L5	M	SD	Sk	Ku
D1. Understanding of AI									
17. Cultural diversity	17 (4.4)	57 (14.7)	128 (33.1)	123 (31.8)	62 (16.0)	3.40	1.07	-0.27	-0.53
18. Algorithmic bias	21 (5.4)	54 (14.0)	132 (34.1)	124 (32.0)	56 (14.5)	3.36	1.07	-0.25	-0.53
19. Educational inclusion	15 (3.9)	50 (12.9)	133 (34.4)	129 (33.3)	60 (15.5)	3.44	1.04	-0.31	-0.47
20. Social responsibility	13 (3.4)	43 (11.1)	113 (29.2)	140 (36.2)	78 (20.2)	3.59	1.05	-0.45	-0.26
D4. Dissemination and Collective Use									
21. Collaborative projects	56 (14.5)	113 (29.2)	142 (36.7)	53 (13.7)	23 (5.9)	2.67	1.06	0.31	-0.44
22. Ensemble management	72 (18.6)	127 (32.8)	120 (31.0)	45 (11.6)	23 (5.9)	2.53	1.09	0.42	-0.58
23. Institutional networks	83 (21.4)	135 (34.9)	103 (26.6)	44 (11.4)	22 (5.7)	2.45	1.10	0.52	-0.43
24. Resource sharing	69 (17.8)	121 (31.3)	125 (32.3)	51 (13.2)	21 (5.4)	2.57	1.08	0.34	-0.61
25. External communities	77 (19.9)	133 (34.4)	114 (29.5)	40 (10.3)	23 (5.9)	2.48	1.10	0.44	-0.51
26. Technological leadership	28 (7.2)	64 (16.5)	131 (33.9)	112 (28.9)	52 (13.4)	3.25	1.09	-0.18	-0.55
D5. AI Training									
27. Continuous updating	8 (2.1)	21 (5.4)	91 (23.5)	164 (42.4)	103 (26.6)	3.86	0.92	-0.81	0.51
28. Learning networks	38 (9.8)	83 (21.4)	143 (37.0)	92 (23.8)	31 (8.0)	2.99	1.08	0.06	-0.60
29. Innovative design	34 (8.8)	80 (20.7)	149 (38.5)	90 (23.3)	34 (8.8)	3.02	1.05	0.02	-0.56
30. Technical self-learning	32 (8.3)	76 (19.6)	153 (39.5)	93 (24.0)	33 (8.5)	3.05	1.03	-0.05	-0.52
31. MOOC participation	84 (21.7)	122 (31.5)	98 (25.3)	56 (14.5)	27 (7.0)	2.53	1.20	0.46	-0.74
32. Ethics in training	23 (5.9)	58 (15.0)	139 (35.9)	113 (29.2)	54 (14.0)	3.30	1.06	-0.16	-0.58
33. Action research	47 (12.1)	101 (26.1)	142 (36.7)	66 (17.1)	31 (8.0)	2.82	1.10	0.18	-0.61
34. Classroom transfer	35 (9.0)	87 (22.5)	152 (39.3)	84 (21.7)	29 (7.5)	2.96	1.04	0.07	-0.54

Note. M = Mean; SD = Standard Deviation; Sk = Skewness; Ku = Kurtosis. Values for the Likert scale levels (L1–L5) are expressed as frequencies and percentages in parentheses (n and %).

The aggregated analysis by dimensions (see Table 2) makes it possible to establish a hierarchy of competencies that defines music teachers' technological profile in relation to AI. The results confirm that Dimension 3 (Ethical and Inclusive Use) emerges as the main strength of the cohort ($M = 3.54$; $SD = 0.78$), followed by Dimension 5 (AI Training) ($M = 3.13$; $SD = 0.82$). The predominance of deontological and training-related aspects over purely instrumental ones suggests that teachers have developed a solid theoretical framework of digital responsibility, displaying an attitude of openness and awareness that precedes technical expertise. In this regard, the high ranking of the ethical dimension acts as a protective factor against potential biases and risks associated with the use of algorithms in educational settings.

At an intermediate level lies Dimension 1 (Understanding of AI) ($M = 2.83$; $SD = 0.86$), reflecting a moderate command of the concepts and foundational principles underlying these technologies, although without reaching levels of specialization. By contrast, scores decline significantly when examining Dimension 4 (Dissemination and Collective Use) ($M = 2.66$; $SD = 0.89$) and, most critically, Dimension 2 (Integration into Teaching–Learning Processes) ($M = 2.39$; $SD = 0.94$). The latter is identified as the area of greatest teacher vulnerability, indicating that the transition from “knowing” and “being willing” to “doing” represents the main pedagogical obstacle. The gap detected between Dimension 3 and Dimension 2 (a difference of 1.15 points on the scale) underscores the urgent need for training programs that not only inform teachers about AI, but also provide them with practical strategies for its effective implementation in the music classroom.

Table 2. Descriptive Analysis by Dimensions: Hierarchy of Domains and Areas of Teacher Vulnerability.

Dimension	Items	M	SD	Range	Rank
D3. Ethical and Inclusive Use	15–20	3.54	0.78	1.15 – 5.00	1º
D5. AI Training	27–34	3.13	0.82	1.00 – 5.00	2º
D1. Understanding of AI	1–5	2.83	0.86	1.00 – 4.85	3º
D4. Dissemination and Collective Use	21–26	2.66	0.89	1.00 – 5.00	4º
D2. Integration into T–L	6–14	2.39	0.94	1.00 – 4.65	5º

Note. Theoretical range of the scale: 1–5.

Once the descriptive hierarchy of the dimensions had been established, the internal cohesion of the construct was examined through a Pearson intercorrelation matrix. This analysis is essential for determining whether the domains of teachers' digital competence in AI-based music education (ECIA-EMUS) operate as an integrated system or as isolated components. The results obtained (see Table 3) confirm the existence of positive and statistically significant associations across all variable pairings ($p < .01$), thereby supporting the robustness and internal validity of the instrument.

Particularly noteworthy is the strong correlation found between Training (D5) and Classroom Integration (D2) ($r = .75$), suggesting that the practical deployment of AI in music education is inextricably linked to the level of specific training attained by teachers. Likewise, Theoretical Understanding (D1) shows a solid association with Integration capacity (D2) ($r = .68$), reinforcing

the premise that conceptual mastery acts as a necessary precursor to genuine operational competence.

By contrast, the Ethical Dimension (D3) exhibits more moderate correlations with the remaining domains (r ranging between .25 and .34). This finding is particularly revealing, as it indicates that music teachers' deontological commitment and social responsibility constitute a transversal value axis that remains relatively independent of their technical skills or level of training. Consequently, this relational structure justifies progression toward inferential analysis, confirming that the ECIA-EMUS model is a coherent and suitable tool for assessing the complexity of AI competence within the music education context.

Table 3. Pearson Intercorrelation Matrix Between Dimensions.

Dimensions	D1	D2	D3	D4	D5
D1. Understanding	1				
D2. Integration	.68**	1			
D3. Ethics	.32**	.28**	1		
D4. Dissemination	.54**	.61**	.25**	1	
D5. Training	.72**	.75**	.34**	.59**	1

Note. ** $p < .01$ (two-tailed).

The analysis of potential differences in perceived digital competence according to contextual variables reveals significant findings that help to further nuance the profile of music teachers in relation to AI (see Table 4). With regard to gender, despite the higher representation of women in the sample (58.9%), the independent-samples Student's t -test identified a statistically significant difference in favor of men ($M = 3.12$; $SD = 0.73$) compared to their female counterparts ($M = 2.95$; $SD = 0.71$), with a value of $t(385) = 2.31$ ($p = .021$). However, the calculated effect size yielded a value of $d = 0.24$, indicating that although the gender gap exists and is statistically significant, its magnitude is small in practical terms. This suggests that gender is not the sole or decisive factor in the acquisition of these competencies.

Regarding school ownership, the results of the one-way ANOVA show a notable convergence across different models of educational management. No statistically significant differences were found ($F = 0.84$; $p = .431$) among teachers working in public ($M = 2.99$), state-subsidized private ($M = 3.06$), or privately owned schools ($M = 3.03$). This homogeneity is further supported by a negligible effect size ($\eta^2 = .004$), indicating that the level of AI-related digital competence is a transversal phenomenon that does not depend on the resources or organizational structure of the institution in which teaching takes place.

By contrast, age emerged as the variable with the greatest predictive weight and discriminatory power in the study. The ANOVA confirmed highly significant differences among the three generational strata ($F = 6.91$; $p < .001$). Younger teachers aged ≤ 30 years reported the highest levels of competence ($M = 3.28$; $SD = 0.65$), followed by those aged 31–45 years ($M = 3.01$; $SD = 0.72$), and finally teachers over 45 years of age, who presented the lowest scores ($M = 2.85$; $SD = 0.78$). In this case, the effect size ($\eta^2 = .035$) reached a medium level, indicating that generational turnover accounts for a substantial portion of the variance in technological self-perception. These findings validate the existence of an inversely proportional relationship between chronological age and openness toward AI-based musical tools, underscoring the need to design continuing professional development strategies specifically tailored to teachers with longer professional trajectories.

Table 4. Results of Student's t-tests and One-Way ANOVA According to Sociodemographic Variables.

Variable	Groups	n (%)	M	SD	Statistic (df)	p	Effect size
Gender	Male	159 (41.1)	3.12	0.73	$t(385) = 2.31$.021*	d = 0.24
	Female	228 (58.9)	2.95	0.71			
School ownerships	Public	181 (46.8)	2.99	0.77	$F(2, 384) = 0.84$.431	$\eta^2 = .004$
	State-subsidized private	119 (30.7)	3.06	0.69			
	Private	87 (22.5)	3.03	0.72			
Age	≤ 30 years	85 (21.9)	3.28	0.65	$F(2, 384) = 6.91$	<.001**	$\eta^2 = .035$
	31-45 years	162 (41.9)	3.01	0.72			
	> 45 years	140 (36.2)	2.85	0.78			

Note. df = degrees of freedom. * p <.05; ** p <.001. Effect size magnitudes are interpreted as follows: d (0.2 = small, 0.5 = medium, 0.8 = large) and η^2 (.01 = small, .06 = medium, .14 = large).

The analysis of the impact of self-perceived training (Dimension 5) on the remaining domains of the scale reveals critical findings for understanding the AI implementation gap in music education (see Table 5). The results of the one-way ANOVA confirm the existence of highly significant differences ($p <.001$) across all evaluated dimensions according to teachers' training level. The most substantial impact is observed in Dimension 2 (Teaching-Learning Integration), which displays the largest effect size in the entire study ($\eta^2 = .103$). This finding is particularly relevant, as it reveals a clear linear progression: while teachers with a low level of training barely reach a mean score of 1.85 in practical integration, those situated at a high level surpass the minimum proficiency threshold with a mean of 3.12. This difference of 1.27 scale points demonstrates that technical training is the primary catalyst for transforming theoretical interest into effective classroom practice.

Similarly, Dimension 1 (Understanding) shows a strong dependence on the level of training achieved ($\eta^2 = .087$), with mean scores ranging from 2.14 at low training levels to 3.65 at high levels. This pattern suggests that the foundational concepts of AI in music education are not acquired through mere technological exposure, but rather require structured and intentional training. By contrast, Dimension 3 (Ethical and Inclusive Use), while still statistically significant ($F = 9.56$; $p <.001$), presents the most moderate effect size in the table ($\eta^2 = .047$). This result is particularly revealing, as it indicates that ethical awareness represents a transversal and pre-existing value among music teachers; even those who acknowledge limited technical training maintain a relatively high mean score of 3.21 in ethical responsibility.

In conclusion, the data demonstrate that ethics constitutes a shared foundational baseline across the teaching cohort, whereas operational integration capacity and collective dissemination ($\eta^2 = .074$) depend strictly on the level of digital literacy attained. This finding positions teacher training as the key variable for reducing the vulnerability identified in Specific Objective 2 (SO2) and for enabling a meaningful and effective integration of AI into music education practice.

Table 5. Impact of Perceived Training Level (D5) on the Dimensions of Digital Competence.

Dimension	Low (n = 102)	Medium (n = 195)	High (n = 90)	F (2, 384)	p	Effect size (η^2)
D1. Understanding	2.14 (0.65)	2.82 (0.71)	3.65 (0.78)	18.42	<.001**	.087
D2. Integration	1.85 (0.54)	2.41 (0.68)	3.12 (0.85)	22.15	<.001**	.103
D3. Ethics	3.21 (0.82)	3.58 (0.74)	3.82 (0.71)	9.56	<.001**	.047
D4. Dissemination	2.02 (0.73)	2.71 (0.81)	3.28 (0.88)	15.34	<.001**	.074

Note. Values in the training level columns (Low, Medium, High) are expressed as M (SD). D5 levels were calculated using percentiles (Low < P33; Medium = P33–P66; High > P66). * p <.05; ** p <.001.

Once the critical impact of training on competence development had been established (see Table 5), the analysis was completed with a multivariate cluster analysis (K-means clustering). This procedure makes it possible to move beyond the examination of isolated variables in order to identify concrete teacher profiles, grouping music teachers according to the convergence of their responses across all dimensions of the ECIA-EMUS model. The results (see Table 6) reveal the existence of three clearly differentiated teacher typologies ($p <.001$), thereby confirming the heterogeneity of the teaching cohort with respect to Artificial Intelligence.

Profile 1: Initial Literacy (32.0%) identifies teachers with the highest level of digital vulnerability. Consistent with the previously analyzed “Low” training level, this group shows critical scores in Integration ($M = 1.62$) and Dissemination ($M = 1.78$), maintaining only a basic level of ethical awareness as an anchoring point.

Profile 2: Intermediate Competence (44.5%), the most numerous group, describes teachers in a transitional phase who possess a solid ethical foundation ($M = 3.55$) and a moderate level of training ($M = 3.12$), yet still experience significant difficulties in translating this knowledge into genuine pedagogical integration ($M = 2.25$).

Finally, Profile 3: Digital Leadership (23.5%) represents the reference segment. This group is composed of teachers who achieve mean scores above 4.0 in Understanding and Training, assuming roles as prosumers and technological guides within their educational contexts.

This final categorization not only validates the findings reported in Table 5 but also demonstrates that digital competence in music education is not a static state, but rather an evolutionary process, in which technical training acts as the primary driver of mobility between profiles.

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Table 6. Centroids of Teacher Profiles Identified Through K-Means Cluster Analysis.

Dimension	PIINC: (32%)	P2INT: (44.5%)	P3AVN: (23.5%)	F	p
D1. Understanding	1.95	2.84	4.12	115.4	<.001
D2. Integration	1.62	2.25	3.68	142.1	<.001
D3. Ethics	3.10	3.55	4.22	45.3	<.001
D4. Dissemination	1.78	2.58	4.05	98.6	<.001
D5. Training	1.88	3.12	4.54	134.8	<.001

Note. Sample distribution: Profile 1 Initial (PIINC) (n = 124), Profile 2 Intermediate (P2INT) (n = 172), and Profile 3 Advanced (P3AVN) (n = 91).

4. DISCUSSION Y CONCLUSIONS

The integration of Artificial Intelligence (AI) into music education in Spain emerges as a phenomenon marked by contrasts, in which ethical awareness and interest in professional development collide with a still incipient technical reality. The findings of this study confirm that, although music teachers have internalized the need for profound digital transformation, a significant dichotomy persists between the availability of resources and their effective application in classroom practice (Hwang et al., 2020; Owoc et al., 2019). This gap suggests that the pace of innovation continues to outstrip the responsiveness of traditional training frameworks (Hwang et al., 2020; Owoc et al., 2019), generating a scenario in which teachers often feel overwhelmed by the technical complexity of new intelligent systems (Alwaqadani, 2025; Celik et al., 2022).

It is particularly revealing that the main strength of the teaching cohort lies in the ethical and inclusive dimension. Teachers demonstrate a high level of awareness regarding data protection, intellectual property, and equity, indicating that UNESCO's (2024) AI competency framework and the guidelines established in Royal Decree 157/2022 have been effectively internalized within teachers' professional responsibility. This stance functions as an essential protective mechanism: teachers do not adopt technology uncritically but instead prioritize pedagogical judgment in order to prevent algorithms from replacing their own aesthetic criteria (Danyaro et al., 2025; Elsayed, 2024). Nevertheless, this strong ethical commitment appears to operate independently of technical proficiency, reinforcing the notion that social and ethical awareness, while transversal in nature, does not in itself guarantee successful didactic integration.

The area of greatest vulnerability is located in operational integration, particularly in tasks such as automated curricular adaptation and the use of AI as intelligent tutoring systems (Shoukat et al., 2025). This "pedagogical wall" highlights that the transition from knowledge to action constitutes the most critical challenge. Within the TPACK framework proposed by Mishra and Koehler (2006), it becomes evident that effective integration requires a synergy between technological, pedagogical, and content knowledge that has yet to be consolidated in everyday practice. While teachers feel confident as mediators of values, they lack sufficient technical literacy to identify system limitations (Danyaro et al., 2025; Elsayed, 2024), thereby restricting the pedagogical use of AI-based tools for musical creation and editing advocated in Zaragoza's (2024) model.

Moreover, the study confirms that AI adoption is not a uniform process, as it is influenced by sociodemographic factors such as age and gender (Jiménez-Hernández et al., 2020; Paidican Soto et al., 2024; Soylu & Sağkal, 2019). The inverse relationship observed between age and perceived competence suggests that generational renewal explains a substantial portion of technological

adoption. These findings underscore that AI training should not be limited to isolated technical instruction, but rather should promote a commitment to lifelong learning and participation in professional networks (Lan, 2024; Lee et al., 2024; Wu et al., 2023), in order to prevent technology from becoming a new pedagogical barrier (Alwaqadani, 2025; Celik et al., 2022).

Overall, it can be concluded that the perceived AI competence of music teachers in Spain is currently in a critical transitional phase, characterized by a strong ethical foundation alongside significant shortcomings in practical classroom transfer. The results indicate that specific technical training constitutes the primary driver of change and the key differentiating factor enabling teachers to move from initial literacy toward genuine digital leadership, thus overcoming the minimal threshold of pedagogical integration. At the same time, the ethical dimension is confirmed to act as a transversal and pre-existing axis of values that safeguards the artistic essence of music, regardless of teachers' technical skill levels. Nevertheless, the persistence of a pronounced generational gap confirms age as the most influential contextual predictor, calling for the design of training pathways specifically adapted to teachers with longer professional trajectories.

Despite the psychometric robustness of the ECIA-EMUS instrument and the representativeness of the sample, the cross-sectional nature of the design constitutes an inherent limitation, as it prevents observation of the longitudinal evolution of digital competence as AI systems mature within the school environment. In addition, the use of a self-perception scale—although validated through expert judgment—may be subject to social desirability bias or an overestimation of ethical capacities relative to operational skills, given the low scores obtained in technical integration. Consequently, the cross-sectional design precludes the establishment of causal relationships and limits understanding of teachers' competence development over time, particularly in a field as dynamic as Artificial Intelligence. These limitations suggest that the results should be interpreted as an initial diagnostic approximation rather than a direct reflection of actual classroom performance.

Future research should therefore complement this quantitative approach with qualitative and observational studies that examine the real use of AI in music classrooms, as well as explore students' perceptions of its impact on creativity and musical learning. Similarly, longitudinal research designs would allow for the analysis of teachers' competence development following the implementation of specific training programs. Finally, it would be particularly valuable to empirically assess the impact of AI-assisted composition and personalized learning systems on the creative and inclusive development of Primary Education students.

Regarding implications, at a theoretical level, the findings reinforce the need to address AI competence through an integrated perspective that transcends reductionist approaches focused solely on technical skills. The empirical identification of a gap between ethical awareness and operational integration contributes relevant evidence to current debates on teachers' digital literacy, particularly in artistic disciplines, where pedagogical and aesthetic judgment play a central role.

From an applied perspective, the results provide clear guidance for the planning of AI-focused teacher training programs, demonstrating that specific professional development constitutes the main predictor of effective classroom integration. The identified typology of teacher profiles enables the design of differentiated training pathways tailored to varying competence levels, thereby avoiding homogeneous approaches that prove ineffective in contexts of digital transformation.

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AUTHOR CONTRIBUTIONS

Santiago Pozo-Sánchez: Conceptualization, methodology, investigation, data curation, project administration, supervision, and writing – original draft.

Jesús López-Belmonte: Conceptualization, methodology, software, validation, and writing – review and editing.

Gonzalo Benítez-Aguilar: Supervision, formal analysis, resources, validation, and writing – review and editing.

Rui-Manuel Nunes-Corredeira: Supervision, validation, and writing – review and editing.

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