Development and Implementation of an AI-based Evaluation Framework for Competency Assessment in Music Education Programs

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***Abstract*—The rapid advancement of Artificial Intelligence (AI) has necessitated a paradigm shift in music education competency assessment. This study developed and evaluated an AI-based evaluation framework for music education students using a Research and Development (R&D) design. The research was conducted in three phases: 1) needs assessment from 28 stakeholders, 2) framework development and validation by 9 experts, and 3) implementation with 32 senior music education students. Results showed a high demand for AI competency, particularly in adaptability ($\bar{X}$ = 4.59). The final framework comprises 5 dimensions and 14 primary indicators, validated by experts with high appropriateness ($\bar{X}$ = 4.51). Empirical implementation confirmed that the framework effectively assesses student competencies, with students achieving high performance across all domains ($\bar{X}$ = 2.79 on a 3.00 scale). This framework provides a robust tool for higher education institutions to integrate AI into music teacher training.**

***Keywords*—Artificial Intelligence (AI) in music education, competency framework, educational technology, music teacher training, indicator development**

I. Introduction

The rapid advancement of technology in the 21st century has propelled higher education into the era of "Education 4.0," a transformative paradigm characterized by the transition from simple digitization to intelligent automation and highly personalized learning [1–3]. Unlike previous technological shifts that focused solely on substituting analog tools with digital ones, Education 4.0 leverages Artificial Intelligence (AI) as a core engine for pedagogical innovation. In this landscape, AI functions not only as a teaching aid but also as an intelligent partner capable of generating data-driven insights, enabling educational experiences that are dynamically tailored to the unique cognitive profiles and learning paces of individual students [4–6]. For higher education institutions, particularly in professional training programs, this evolution necessitates a fundamental rethinking of how student competencies are defined, developed, and evaluated to ensure graduates are prepared for a labor market defined by human-AI collaboration [7–10].

In the specific domain of music education, the integration of AI is reshaping traditional pedagogy through the emergence of sophisticated creative and analytical tools [11, 12]. Technologies such as algorithmic composition, automated accompaniment systems, and real-time performance feedback loops are redefining the boundaries of musical instruction [13, 14]. These tools empower students to engage in complex creative tasks such as generating harmonies or analyzing acoustic structures that were previously limited by traditional technical constraints [15, 16]. However, the role of the music teacher is also shifting from being a sole source of musical authority to becoming a "technocrat" who must strategically manage AI systems to foster student creativity. Despite the potential of these tools to reduce cognitive load and enhance artistic expression, their effective use depends entirely on the educator's specialized competencies [17–19]. Recent empirical studies underscore this urgency, revealing that while 85% of educators recognize AI's potential, less than 20% feel competent in integrating these tools into specific musical curricula, often citing a lack of clear performance standards.

Despite the proliferation of AI tools in music classrooms, a critical research gap remains, as current digital competency frameworks are predominantly generic and fail to address the specific nuances of musical instruction. Established models often overlook the subjective and aesthetic requirements of music, such as auditory skill development, nuanced performance evaluation, and the ethical implications of AI-generated art [20–22]. This analytical gap creates a disconnect between theoretical technological potential and practical field implementation; while pre-service teachers may possess general digital literacy, they often lack the domain-specific skills needed to navigate AI applications such as sound synthesis or digital ensemble management. Without a structured, empirically validated framework for measuring these specialized skills, music teacher preparation programs cannot accurately assess whether their students are truly equipped to meet the challenges of a technology-driven professional environment [23–25].

The urgency of this issue is particularly evident in the Thai higher education context, where there is a significant demand for AI competency among music education students, yet a lack of standardized evaluative tools. Current research indicates that while students express a high level of awareness regarding the importance of technological adaptability, they often struggle with the technical depth required for data-driven assessment and instructional design [26, 27]. To address this, the current research explicitly formulates a problem-solving approach centered on the development of a domain-specific indicator system. This study addresses this deficiency by developing and validating a comprehensive AI competency indicator framework specifically tailored for undergraduate music education programs. By establishing a clear set of indicators spanning knowledge, application, and professional ethics, this research provides a strategic roadmap for academic institutions to bridge the gap between

technological potential and pedagogical reality.

The main new idea in this research is the creation of 14 main indicators and 48 sub-indicators that go beyond general digital literacy to focus on AI-Music Agency, offering benefits that earlier broad models (such as TPACK) do not provide in artistic settings. Ultimately, the development of this framework serves as a vital instrument for modernizing music teacher education, ensuring that the next generation of educators can blend the art of sound with the science of AI. By providing a robust tool for competency assessment, this study supports the transition toward a more resilient and innovative music education system. The systematic Research and Development (R&D) process used to synthesize these indicators, validate them through expert consensus, and implement them in real-world educational settings to verify their effectiveness in promoting student excellence in the digital age.

II. Literature Review

A multifaceted theoretical landscape underpins the development of the AI-based competency framework, bridging the gap between technological innovation and artistic pedagogy. To establish a rigorous foundation, this review synthesizes core concepts from artificial intelligence in education, contemporary music instructional design, and competency-based assessment models. By examining the intersection of digital literacy and musical expertise, this section explores how traditional teaching methods are evolving to accommodate intelligent automation while addressing the unique aesthetic and technical requirements of the music classroom. The following subsections detail the theoretical pillars and domain-specific challenges that inform the construction of the 14 primary indicators tailored for future music educators.

A. Theoretical Foundations of AI in Education (AIEd)

The theoretical foundation of this framework is constructed upon the intersecting pillars of Artificial Intelligence in Education (AIEd), digital transformation in music pedagogy, and the evolution of competency-based assessment. In the contemporary educational landscape, AIEd has moved beyond a peripheral support tool to become a core instructional partner, lowering cognitive load and enabling students to focus on higher-order, creative tasks. However, integrating AI into music education requires more than technical proficiency; it demands a synergy between technological prowess and aesthetic sensitivity [28–30]. This study draws upon "AI Literacy" models, which suggest that for educators to be effective, they must possess not only the knowledge of how AI works but also the "AI Agency" to ethically and creatively direct these tools within their specific professional domain. While generic AI literacy models focus primarily on computational logic, recent studies emphasize that music education requires a specialized musical-technological agency that balances algorithmic precision with artistic intuition. This study connects these two points of view by analytically linking AI agency to specific creative pedagogical outputs. This link is often left as a theoretical abstraction in other AIEd literature.

B. Competency-based Assessment

Central to the development of these indicators is the global standard for educational assessment established by the OECD, which advocates for a transition toward competency-based learning. This approach emphasizes that indicators must not merely measure rote memorization but should reflect "performance-based competency," the ability to integrate knowledge, skills, and attributes into practical action. By applying this lens to music teacher preparation, the framework ensures that indicators capture both the "process" of instructional design and the "outcomes" of student engagement and musical achievement [31–33]. This alignment with international standards positions the framework as a rigorous tool for modernizing music curricula in the digital age. A key comparison with traditional music assessment methods shows that they mainly focus on fixed performance measures; however, this study suggests a more flexible assessment approach where using data-driven feedback is an essential skill for teachers. This approach shifts the attention from what the student plays to. This framework shifts the emphasis from the student's performance to the teacher's use of AI-generated insights to improve learning.

C. Domain-specific Gaps

While general digital competency frameworks, such as TPACK or DigCompEdu, have historically guided technology integration, they often lack granularity when applied to the specialized field of music. Traditional frameworks frequently overlook domain-specific nuances such as sound synthesis, real-time auditory feedback, and algorithmic composition. Research indicates that music education students require specialized indicators that address the technical depth of music-related applications, such as using AI for acoustic analysis or digital ensemble management [34–36]. Without such specificity, evaluation tools remain too broad to provide actionable insights for music teacher training programs or to accurately reflect pre-service teachers' readiness to manage a technology-enhanced music classroom. Unlike the one-size-fits-all approach of generic models, this study systematically maps 14 primary indicators to specific musical instructional tasks. This study shows that current general tools do not measure auditory digital intelligence, and it addresses this issue by offering detailed ways to assess pre-service teachers' readiness in specific artistic settings.

D. Synthesis of Indicators for Music Pedagogy

Consequently, this study synthesizes these diverse theoretical perspectives into a domain-specific set of 14 primary and 48 sub-indicators designed to bridge the gap between general AI literacy and specialized music pedagogy. The framework incorporates contemporary pedagogical concepts such as "personalized learning" and "creative learning" environments, in which AI is used to respond to the unique abilities of individual students. By grounding the indicators in both established educational theories and emerging AI research, the study provides a robust, empirically validated roadmap. This systematic mapping of the existing literature to specific indicators positions this study uniquely, moving beyond descriptive exposition to provide an actionable contribution that addresses the practical problems encountered in the field. This literature-driven approach ensures that the resulting framework is not only

technically sound but also pedagogically relevant for the next generation of digital-native music educators.

III. Materials and Methods

This research employed a Research and Development (R&D) methodology to systematically develop and evaluate an AI-based competency framework for music education [37–39]. The R&D approach was selected over purely descriptive or experimental methods as it facilitates the iterative translation of theoretical constructs into a practical, validated instrument through a continuous feedback loop between synthesis and field-testing. The study followed a structured three-phase process designed to ensure that the resulting indicators were both theoretically sound and practically effective in real-world educational settings, as illustrated in Fig. 1.

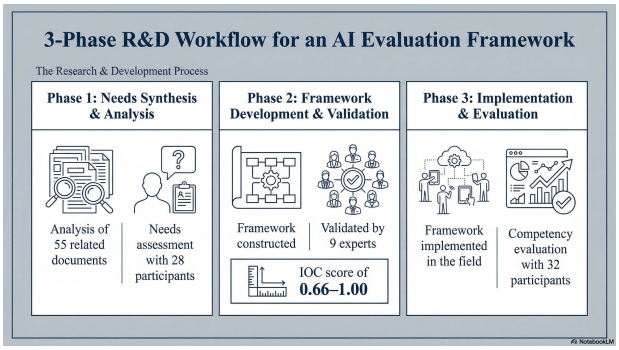

Fig. 1. The three-phase Research and Development (R&D) procedure.

A. Phase 1: The Three-phase Research and Development (R&D) Procedure

The first phase focused on analyzing core competency components. The researcher conducted a comprehensive content analysis of 55 documents on AI technology and music pedagogy to identify essential skills. Simultaneously, a needs assessment was conducted with 28 stakeholders to determine the demand for AI competencies. The stakeholder sample was selected using purposive sampling to include university administrators, music education faculty, and technology specialists, ensuring the data's relevance to current institutional demands. The findings indicated that students had a high level of awareness and demand for AI competency, particularly in technological adaptability, which showed the highest mean score of 4.59.

B. Phase 2: Framework Development and Expert Validation

In the second phase, the synthesized data were used to construct a framework consisting of 14 primary indicators and 48 sub-indicators. To ensure the academic rigor of these indicators, a panel of 9 experts specializing in music education and educational technology performed a content validity check. The choice of nine experts follows established validation protocols, providing a sufficient diversity of perspectives while maintaining consensus stability. Each indicator was evaluated using the Item-Objective Congruence (IOC) index. The results revealed IOC scores ranging from 0.66 to 1.00, with an overall appropriateness mean of 4.51 (S.D. = 0.57), indicating that the indicators were highly suitable for implementation. The reliability of the validation instrument was confirmed through internal consistency checks among expert ratings, ensuring the robustness of the derived indicators.

C. Phase 3: Field Implementation and Evaluation

The final phase involved the experimental implementation of the validated indicators with 32 senior music education students. These students were in their final year at Mahasarakham University and were chosen because they are the right group getting ready for teacher certification; this specific group size is suitable for a Research and Development (R&D) pilot study aimed at checking how well the framework works in practice, instead of trying to make broad statistical conclusions. The framework was integrated into actual teaching contexts over a full academic semester (16 weeks) to test its ability to reflect student competency in both quantitative and qualitative terms.

During this instructional period, students engaged in specific competency-building activities, including AI-driven lesson planning, utilizing algorithmic tools for automated music composition, and applying real-time AI performance feedback systems during their classroom practicum. Evaluation was conducted through scores from mentors and supervisors, along with student reflections. To ensure the results were trustworthy, we collected data carefully by reviewing performance evaluations, conducting structured observations, and analyzing themes in reflection journals. Data were collected using a 3.00-point scale instrument spanning "Knowledge" to "Analysis and Adaptability" to assess the efficacy of the indicators in promoting student excellence. The analysis of the numbers used averages ($\bar{X}$) and standard deviation (S.D.) to measure skill levels in five areas, making it easy for others to repeat this method in different teacher-training. Although this small group of 32 participants gives detailed information about how effective the framework is, the authors recognize that the specific setting may restrict how widely the results can be applied, which is explained in the next section.

IV. Result and Discussion

By synthesizing quantitative data from a panel of experts with performance metrics from senior-level practitioners, this study provides a critical examination of how AI-based competencies can be standardized and measured within the specialized domain of music education. The discussion further bridges these empirical findings with contemporary educational theories, exploring the framework's potential to modernize teacher preparation and reduce the technological barriers inherent in digital-age pedagogy.

A. Framework Development and Validation

The development of the AI-based evaluation framework was executed through a rigorous synthesis of existing pedagogical models and emerging technological requirements. This process resulted in a multidimensional structure designed to capture the holistic competency of music education students by bridging the gap between general AI literacy and specialized musical pedagogy. The finalized framework, which integrates technical proficiency with pedagogical intelligence, is illustrated in Fig. 2.

To ensure the framework's academic integrity and practical utility, it underwent a formal validation process by a panel of nine experts in music education and educational technology. The expert panel assessed the appropriateness of

each dimension based on a 5-point Likert scale, ensuring that each indicator met the high standards required for international publication. The statistical validation confirmed that all dimensions achieved a "High" or "Highest" level of suitability, with an overall average mean of 4.51 (S.D. = 0.57). These results, detailed in Table 1, signify that the framework is a robust and valid instrument for evaluating student readiness in the AI era.

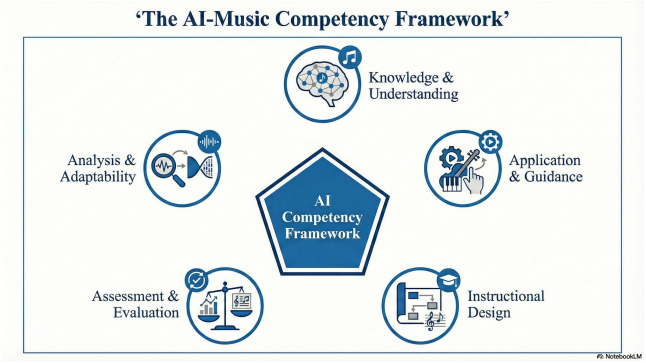

Fig. 2. The proposed AI-based competency evaluation framework.

The high appropriateness score for Knowledge & Understanding ($\bar{X}$ = 4.59) reflects the experts' consensus that foundational AI literacy is the prerequisite for all subsequent musical applications. Furthermore, the Application & Guidance dimension received the highest individual score ($\bar{X}$ = 4.60), highlighting the critical role of the music educator in facilitating AI-enhanced learning environments rather than merely acting as a passive user. While Assessment & Evaluation received a slightly lower mean ($\bar{X}$ = 4.37), it remains significantly high, indicating that experts believe AI can provide precise data-driven feedback for musical performance, though it must be balanced with human aesthetic judgment.

Table 1. Expert evaluation results of the framework (n = 9)

Competency Dimension	Mean ($\bar{X}$)	S.D.	Interpretation
1. Knowledge & Understanding	4.59	0.51	Highest
2. Application & Guidance	4.60	0.53	Highest
3. Instructional Design	4.52	0.58	Highest
4. Assessment & Evaluation	4.37	0.64	High
5. Analysis & Adaptability	4.51	0.57	Highest
Overall Average	4.51	0.57	Highest

B. Empirical Implementation Results

Following the formal validation of the indicators, the framework was empirically tested with a target group of 32 senior music education students. This phase was critical for verifying whether the theoretical constructs could be effectively translated into measurable student performance in a real-world instructional context. The field implementation provided a data-rich environment where the framework's 14 primary indicators were used to assess the digital readiness and practical AI skills of future music educators. The aggregate performance across all dimensions is visually represented in the radar chart in Fig. 3, illustrating the high levels of proficiency attained by the participants.

The quantitative data collected during this phase demonstrated that the students achieved near-perfect competency scores, with mean ratings ranging from 2.78 to 2.96 on a 3.00 scale. These results indicate a strong foundational grasp of AI tools and their pedagogical applications among the senior-level cohort. As shown in Table 2, the "Knowledge & Understanding" dimension recorded the highest achievement ($\bar{X}$ = 2.86), suggesting that students possess a robust theoretical understanding of AI concepts. At this stage, the study mainly used descriptive statistics (mean and S.D.) to analyze the data because it didn't use inferential analysis due to the single-cohort sample; these measures clearly identify specific skill gaps. Conversely, while the "Application & Guidance" dimension still fell within the "High" interpretation ($\bar{X}$ = 2.73), it is the most significant area for further development, particularly in real-time instructional facilitation.

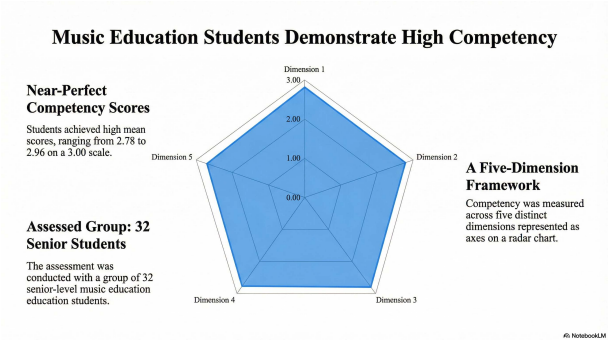

Fig. 3. Student competency achievement results across five dimensions.

Table 2. Student competency levels post-implementation (n = 32)

Competency Dimension	Mean ($\bar{X}$)	S.D.	Interpretation
1. Knowledge & Understanding	2.86	0.35	Highest
2. Application & Guidance	2.73	0.42	Highest
3. Instructional Design	2.80	0.39	Highest
4. Assessment & Evaluation	2.74	0.43	Highest
5. Analysis & Adaptability	2.82	0.38	Highest

C. Discussion

The findings of this research underscore a critical shift in the pedagogical landscape of music education, driven by the transition toward Education 4.0 [1, 2]. The expert validation phase confirmed that the proposed framework is highly appropriate for modernizing music teacher preparation, with the "Application & Guidance" dimension receiving the highest endorsement ($\bar{X}$ = 4.60). This reflects a consensus among experts that future music educators must evolve from being mere consumers of technology to becoming "technocrats" who can strategically leverage AI to foster student creativity [12, 21]. The high appropriateness scores for "Knowledge & Understanding" ($\bar{X}$ = 4.59) further validate the premise that foundational AI literacy is a non-negotiable prerequisite for specialized musical applications in the digital age [3, 25].

Empirical implementation with 32 senior music education students demonstrated that the framework effectively identifies and promotes high-level competencies. The achievement of near-perfect competency scores, with mean ratings ranging from 2.73 to 2.86 on a 3.00 scale, indicates a strong foundational grasp of AI tools and their pedagogical applications among the senior-level cohort. This direct correlation between expert-validated indicators and actual student performance achieves the research objective of creating a measurable, domain-specific evaluation tool. In particular, students excelled at using AI for lesson content creation and the automation of repetitive musical exercises [13, 14]. This aligns with contemporary educational

neuroscience theories, suggesting that AI-driven tools can successfully reduce "cognitive load," thereby allowing students to devote more mental resources to higher-order creative tasks and aesthetic expression [19, 29].

However, the lower comparative scores in "Application & Guidance" ($\bar{X}$ = 2.73) and "Assessment & Evaluation" ($\bar{X}$ = 2.74) highlight a significant pedagogical gap. While students demonstrate a strong theoretical understanding, they encounter challenges in the real-time application and data-driven evaluation of musical performance [31, 34]. This finding suggests that while AI can provide precise, automated feedback, it must be balanced with human aesthetic judgment to be truly effective in a musical context [16, 21]. These results indicate that future curricula must move beyond basic digital literacy and prioritize field-based workshops that focus on the nuanced integration of AI results with qualitative artistic instruction [36, 39].

This study proves the novelty and importance of a domain-specific evaluation framework. Unlike generic digital competency models like TPACK or DigCompEdu, this framework addresses the unique aesthetic and technical requirements of music, such as sound synthesis and digital ensemble management [20, 36]. While previous research often focused on general teacher readiness, this study's synthesis of 14 primary indicators provides the granular detail necessary for professional music education programs. The high levels of student performance verified through this R&D process suggest that the 14 developed indicators serve as a robust and practical roadmap for academic institutions [37, 38]. Nevertheless, the small sample size (n = 32) at a single institution limits the broader generalizability of the scores, though it establishes a valid prototype for replication. Ultimately, this research provides the necessary tools for higher education to bridge the gap between technological potential and pedagogical reality, ensuring that the next generation of music educators is well-equipped to lead in an AI-driven environment [7, 8].

V. Conclusion

The study successfully established and validated a comprehensive AI-based competency evaluation framework specifically tailored for undergraduate music education programs. This study addresses a critical gap in domain-specific assessment tools by moving beyond generic digital literacy to address the unique aesthetic, technical, and pedagogical nuances of music instruction in the Education 4.0 era. Through a systematic three-phase Research and Development (R&D) process, the framework was refined into five core dimensions: Knowledge and Understanding, Application and Guidance, Instructional Design, Assessment and Evaluation, and Analysis and Adaptability. By fulfilling the research objective of developing a domain-specific indicator system, this work presents a novel AI-Music Agency model that provides the granularity required for professional artistic training, thereby advancing beyond existing generic digital competency models.

Expert validation confirmed the framework's high academic rigor and appropriateness, with an overall mean score of 4.51. Additionally, real-world testing with senior students showed that the 14 main indicators accurately reflect students' readiness, as they performed well across all assessed areas. The results show that students have a decent theoretical understanding of AI technologies, but they still need more training in the field to improve real-time instruction and data-driven music assessment. These findings indicate that although the framework works well for assessing current readiness, its main practical use is to identify specific areas, such as instructional guidance and aesthetic-technological balance, where music programs need to be updated.

The developed framework serves as a strategic roadmap for higher education institutions to modernize their music teacher curricula. By providing standardized, empirically validated indicators, this research ensures that the next generation of music educators is equipped to function as "technocrats" who can harmoniously blend the art of music with the science of artificial intelligence.

Despite these contributions, the study acknowledges significant limitations. The implementation phase was confined to a single institutional cohort, potentially limiting the generalizability of the performance scores to broader cultural or educational contexts. Also, using only descriptive statistics makes it challenging to determine whether certain teaching methods actually improve skills. To address these limitations, subsequent studies should investigate multiple centers longitudinally to assess the impact of the framework on music teaching efficacy and student learning across diverse educational contexts. Suggestions include creating specialized workshops that combine human teaching with AI and exploring how the framework can be adapted for other performing arts, while ensuring teacher training keeps pace with digital advancements.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

BC conducted the primary research, designed the study methodology, and performed the data collection. KJ analyzed the statistical data and contributed to the interpretation of the results. BC and SC wrote the initial manuscript and prepared the figures and tables. SC supervised the project and provided critical revisions to the manuscript for intellectual content. All authors have read and approved the final version of the manuscript.

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