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Digital Innovation in the Teaching of Mugham: the Role of Artificial Intelligence

Telman Ganiyev[1*], Bayram Guluzade[2]

Abstract. *The article touches upon the issues of applying artificial intelligence technologies in the process of evaluating and improving the teaching process of mugham art, which is part of the Azerbaijani folk professional musical culture. In the context of the training model related to the performance characteristics of mugham, improvisation principles and oral tradition arising from the intonation principle, the analytical, prognostic and adaptive capabilities of artificial intelligence are analyzed, and the issues of applying digital innovative technologies are substantiated. The study comprehensively substantiates the impact of artificial intelligence on methodological transformations in mugham teaching, its training effectiveness, as well as cultural-identical and ethical limitations, and the methodology and results of performance assessment in training are practically demonstrated. As in many countries, significant changes are taking place in the education system related to the application of digital technologies and artificial intelligence. These changes inevitably lead to the transformation of pedagogical competencies and require teachers to adapt to new realities. The use of artificial intelligence in mugham lessons is a promising area of modern music education. Combining teaching methods with innovative technologies allows making lessons more effective and engaging.*

Keywords: *mugham, music pedagogy, artificial intelligence, digital innovation, improvisation, national-cultural heritage, performance assessment*

[1]Sumgayit State University, PhD in Art Studies, Sumgayıt, Azerbaijan
[2]Sumgayit College of Music under the Azerbaijan National Conservatory, Sumgayit, Azerbaijan
[*]Corresponding author. E-mail: tqeniyev71@gmail.com
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Muğamın tədrisində rəqəmsal innovasiya: süni intellektin rolu

Telman Qəniyev[1*], Bayram Quluzadə[2]

Xülasə. *Məqalədə Azərbaycan xalq professional musiqi mədəniyyətinin bir hissəsini təşkil edən muğam sənətinin tədrisi prosesinin qiymətləndirilməsi və təkminlləşdirilməsi zamanı süni intellekt texnologiyalarının tətbiqi məsələlərinə toxunulur. Muğamın intonasiya prinsipindən irəli gələn ifaçılıq xüsusiyyəyi, improvizasiya prinsipləri və şifahi ənənə ilə bağlı təlim modeli kontekstində süni intellektin analitik, proqnostik və adaptiv imkanları təhlil edilir, rəqəmsal innovativ texnologiyaların tətbiqi məsələləri əsaslandırılır. Tədqiqatda süni intellektin muğamın tədrisində metodoloji transformasiyalara təsiri, onun təlim effektivliyi, habelə mədəni-identik və etik məhdudiyyətləri kompleks şəkildə əsaslandırılır, təlimdə performans qiymətləndirmə metodikası və nəticələri praktik sərgilənir. Bir çox ölkələrdə olduğu kimi, təhsil sistemində də rəqəmsal texnologiyaların və süni*

intellektin tətbiqi ilə bağlı əhəmiyyətli dəyişikliklər baş verir. Bu dəyişikliklər qaçılmaz olaraq pedaqoji səriştələrin transformasiyasına gətirib çıxarır və müəllimlərdən yeni reallıqlara uyğunlaşmalarını tələb edir. Muğam dərslərində süni intellektin istifadəsi müasir musiqi təhsilinin perspektivli bir sahəsidir. Tədris metodlarının innovativ texnologiyalarla birləşməsi dərsləri daha təsirli və cəlbedici etməyə imkan yaradır.

Açar sözlər: *muğam, musiqi pedaqogikası, süni intellekt, rəqəmsal innovasiya, improvizasiya, performans qiymətləndirmə*

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[1]Sumqayıt Dövlət Universiteti, Sənətşünaslıq üzrə fəlsəfə doktoru, Sumqayıt, Azərbaycan
[2]Azərbaycan Milli Konservatoriyası nəzdində Sumqayıt Musiqi Kolleci, Sumqayıt, Azərbaycan
[*]Məsul müəllif. E-poçt: tqeniyev71@gmail.com
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İntroduction

Mugham, like the art of many Eastern peoples, is a branch of Azerbaijani folk professional music and represents a musical art form with a long historical history. As a folk art form, reflecting the difficulties, contradictions, and tensions that occurred in the lives and daily lives of people in different historical periods, as well as the joys and sorrows, it has been imprinted in the memories of various folk artists, and performers of mugham and has been passed down from generation to generation through oral tradition, reaching the present day (Zohrabov, 1991).

The mugham teaching methodology is viewed as a pedagogical system that does not fully conform to classical normative models in music education. It possesses an open and flexible structure and emphasizes creative potential (Agayev, 2019). Within this system, the performer's individual interpretive strategies, mechanisms of emotional response, and aesthetic intuition are the primary shaping factors. One of the main types of creative activity that directly influences the development and growth of students' creative thinking during mugham lessons is working on mugham phrases and sections. However, this type of activity poses certain challenges for both students and teachers. The use of innovative technologies based on the latest advances in information and communication technology facilitates the resolution of any issues that arise.

Artificial intelligence tools that influence musical thinking, aesthetic taste, preferences, and cultural level open up new opportunities for improving the forms and methods of teaching, the content of music education, and the specifics of professional training in the field of musical performance, facilitating the renewal of library collections and the organization of cultural and entertainment events.

Overall, using artificial intelligence in music lessons has both advantages and disadvantages. AI acts as a teacher's assistant, significantly facilitating and automating their work. For example, it can evaluate student performance and assign grades. On the other hand, using artificial intelligence in the educational process allows for analyzing student activity and personalizing their learning path and learning parameters.

The advantages of technological progress in the era of global modernization include the emergence of new capabilities for the systematic management of complex processes, including modeling similar to human thinking, the emergence of artificial intelligence technologies, and the influence of neural networks on music education and the arts in general (Grigoryev & Osipova, 2021).

The rapid development of AI has led to significant changes in many fields, including education. Therefore, educational technologies based on artificial intelligence can adapt teaching methods, content to the individual strengths, weaknesses, and preferences of each student.

Products created using AI open up new opportunities for improving teaching methods, the content of music education, and the specifics of professional training in music performance, influencing musical thinking, aesthetic taste, preferences, and cultural level. They also contribute to the renewal of library collections and the organization of cultural and leisure events (Miranda, 2021).

Modern methods used in teaching mugham

The methodological basis of the study is based on the interrelationship and integration of music theory, music pedagogy, and modern theories of AI. Given the multifaceted, complex, and improvisational nature of mugham teaching, the study utilizes a systematic approach, structural-functional analysis, and modern modeling methods in a comprehensive manner, alongside empirical methods. The influence of AI on the teaching tradition within master's and student groups is primarily determined by the weight of various AI technology models in terms of emotionality, interpretation, intonation, sentence structure, and rhythmic features in modern performance: this includes dastgah + part (söbə) + gusha + tasnif + rang + diringa + rhythmic mugham, etc., depending on the type of mugham.

The study included a theoretical and methodological analysis, a systematic review of international scientific literature on the use of artificial intelligence technologies in music education, and a comparative study of existing conceptual approaches and methodological models. This approach also allows for the development of an adequate methodological framework that takes into account the specific characteristics of mugham teaching (UNESCO, 2019).

One of the main components of the methodology was a systems approach. Mugham teaching was viewed as a holistic pedagogical system, and the relationships between its structural elements-the content of instruction and the methods-were defined. Artificial intelligence technologies were modeled as a supporting, yet functionally important, subsystem within this system.

The research also makes extensive use of structural-functional analysis. This method has been used to identify the key structural components of mugham performance-intonation, form, the system of moments and modes, melodic development, and improvisation mechanisms-and to explore their analytical capabilities using artificial intelligence algorithms. The structural-functional approach has enabled a scientifically validated definition of the functions that artificial intelligence can perform in mugham teaching-diagnostic, analytical, prognostic, and adaptive.

Theoretical and methodological foundations of artificial intelligence

According to modern scientific approaches, artificial intelligence is characterized as a set of intelligent technologies capable of formally describing complex structured systems, performing analytical operations on large volumes of data, and constructing decision-making mechanisms in response to changing conditions (Roads, C. 2015). The application of these technologies in music education forms a methodological unity with cognitive learning models, constructivist pedagogical approaches, and adaptive learning concepts.

The complex intonation system and nonlinear, indeterminate nature of melodic development inherent in the art of mugham represent an area of research of particular scientific interest for AI algorithms (Miranda, 2021).

In the educational environment, artificial intelligence functions as systems that imitate certain functions of human cognition, structure information, and generate situationally adaptive responses. In music pedagogy, these technologies are developing in conjunction with theoretical approaches such as cognitive psychology, systems theory, and constructivism.

From a methodological perspective, artificial intelligence serves as an analytical and diagnostic tool in music education. The core of this tool is to analyze a student's performance based on objective indicators, track their developmental trajectory, and formulate pedagogical decisions based on scientific evidence.

The concept of adaptive learning occupies a special place in the theoretical and methodological model of AI. Adaptive systems dynamically adjust the learning process, taking into account the individual characteristics of the student, their level of knowledge, and their pace of development. In the context of mugham training, this approach ensures the gradual development of the student's technical and theoretical preparation.

At the same time, the methodological potential of artificial intelligence is not limited to technical analysis. Students' analysis of their performance using AI-based systems creates conditions for developing self-assessment skills, which positively influences the development of a conscious and purposeful improvisation process in mugham teaching.

The concept of ethical responsibility also occupies an important place in the theoretical and methodological framework of artificial intelligence. The dominance of technology in the educational process can weaken the teacher's pedagogical role and limit creative subjectivity. In this context, the methodological approach views artificial intelligence not as an independent decision-maker, but as an intelligent tool supporting the pedagogical process.

Discussion

The widespread use of mugham among our people, the emergence of numerous scientific studies on this topic and its profound influence on our professional school of composition have had a significant impact on the creation of works of various genres, such as songs, romances, cantatas, etc. Beginning with the works of the U. Hajibeyli and until the beginning of the last century, Azerbaijani composers, when writing and creating new musical works, mainly relied on the influence of the maqam-lad system that arose in the art of mugham (Hajibeyov, 1985).

Mugham art, as an art form rooted in the way of life of our people, form carries complex ideas, and emotional meaning, expressing profound thought, artistic inspiration, and the development of diverse musical images (Badalbeyli, 1969).

In this context, the creation of an image reveals the issue of emotionality, and thus all the emotions inherent in the image are conveyed through performance. This aspect is linked to many means of expression in the mugham tradition, namely mimicry, interpretation, and the influence and reaction of the listener. The aspects we have examined are merely the means used in the art of mugham from an artistic perspective. However, the influence or reaction of interpretation on the listener also depends on the audience. What is the technical aspect of the artistic performance of the mugham tradition in teaching contemporary mugham performance? This question can be approached from various angles.

In modern era, alongside the theoretical aspects of mugham art, the study of its instrumental or vocal-instrumental performance also requires an examination of its cognitive properties. Here, the study of

mugham as a result of its influence on human cognitive processes comes to the fore. Computer modeling, artificial intelligence, and other cognitive science tools play a vital role in this understanding. In our modern era, globalization, the rapid development of innovative digital technologies, and the expansion of the information and communication environment require the application of new methodological approaches to music education, including the teaching of mugham, as in many other areas of education.

In music pedagogy, artificial intelligence offers significant potential for structural and semantic analysis of the performance process, monitoring student development, and making scientifically based pedagogical decisions (Roads, 2015; Grigorieva & Osipova, 2021). The complex and melodic structure of mugham, its subtle intonation system, and the somewhat ambiguous principles of improvisation make the application of these technologies particularly important. AI algorithms enable the analysis of scale trajectories, intonation stability, and the logic of improvisation during mugham performance, creating the conditions for the development of qualitatively new stages in the learning process (Miranda, 2021).

Today, the development of digital technologies and artificial intelligence systems has opened up new opportunities for mugham instruction. AI algorithms analyze student performance, determining fret consistency, intonation stability, melodic development trajectory, and rhythmic indicators based on objective parameters. This technological approach serves as a scientifically valid diagnostic tool for teachers and enables them to plan individual development strategies throughout the learning process.

The use of digital technologies also creates the conditions for the development of virtual master models in mugham teaching. These models provide students with various improvisation scenarios, making the learning process interactive and multifaceted. At the same time, this approach serves to preserve mugham as a national cultural heritage by ensuring the systematic archiving of classical performance examples in a digital environment (Agayev, 2019).

The scientific and pedagogical specifics of mugham training are determined by its improvisation-oriented, subjective, multi-level pedagogical system, rich in cultural and spiritual values. The integration of artificial intelligence technologies into this system makes the learning process more analytical, individualized, and objective, while simultaneously ensuring the preservation of traditional pedagogical principles and the performer's freedom of emotional and artistic expression.

Models of applying artificial intelligence in teaching mugham

The use of artificial intelligence in mugham teaching can be based on various scientifically proven models. This aspect has specific functions in terms of pedagogical, technological, and cultural contexts. This section presents the results of a detailed analysis of analytical and diagnostic, adaptive learning, digital-cultural, and virtual models of artificial intelligence, as well as ethical and cultural constraints. Figure 1 presents a conceptual model for the application of artificial intelligence technologies in mugham teaching in the form of a flowchart. The diagram reflects the gradual integration of artificial intelligence into the educational process, starting from analytical and diagnostic functions to adaptive learning mechanisms, a digital-cultural model, and the concept of a virtual teacher.

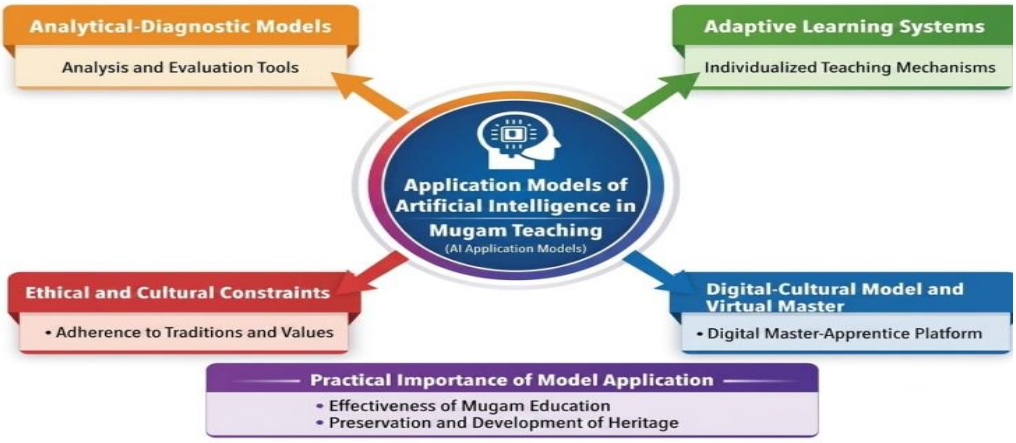


Figure 1

Conceptual model of the application of artificial intelligence technologies in teaching mugham

Analytical and diagnostic models

The analytical and diagnostic model enables artificial intelligence to perform primarily diagnostic and analytical functions during the learning process. Using this model, mugham samples performed by students are analyzed for intonation accuracy, melody, phrasing, sentence structure, melodic movement, and rhythmic harmony within the scale. The analytical and diagnostic approach provides objective assessment for both teacher and student. The teacher can track the student's developmental stages and make appropriate pedagogical adjustments, while the student systematically evaluates their performance and identifies development strategies. In this model, artificial intelligence analyzes the sonic, rhythmic, and intonational aspects of performance samples, primarily using neural networks and machine learning algorithms. The analytical and diagnostic model systematically represents complex fret and intonation structures, as well as the patterns of mugham improvisation, allowing students to develop their knowledge and skills based on scientific principles (Ghvinjilia, 2025).

Adaptive learning systems. An adaptive learning model dynamically adjusts the learning process, taking into account the individual characteristics, technical skills, and learning pace of the student (Aliyeva, 2021). In mugham teaching, these systems create individualized training plans, develop improvisation skills, and provide feedback tailored to the student's performance style. The adaptive approach also provides the teacher with analytical data and allows for the optimization of the learning process. The use of adaptive systems that take into account the complexity of mugham teaching ensures the individualization of the teaching process and maximizes the student's creative potential. This approach simultaneously develops technical skills and aesthetic sensibilities.

Digital cultural model and the concept of the virtual master. The digital cultural model utilizes artificial intelligence to preserve the national cultural heritage of mugham and enrich the educational process. In this model, the semantic and melodic structure of classical mugham performances is simulated in a digital environment using fuzzy algorithms, creating virtual master systems and providing interactive learning opportunities. The virtual master concept offers students various improvisation scenarios, analyzes their performance, and provides feedback in real time. This approach, in addition to enhancing the effectiveness of the educational process, preserves the cultural and aesthetic foundations of mugham and enables the digital archiving of classical performance examples (Dzhanegizova, 2023; Fedotova, & Smirnova, 2020).

Ethical and cultural limitations. The use of artificial intelligence requires a cautious approach to preserving cultural authenticity. Technological models do not fully capture the emotional and metaphysical layers of mugham and pose a serious limitation in this area (Bunyadzade, 2017). Therefore, artificial intelligence should not replace the role of a teacher, but should only provide

methodological support. An ethical approach also ensures the preservation of mugham as a national cultural heritage, the creative subjectivity of the performer, and the individuality of their interpretation.

Practical implications of using these models. These models offer a number of practical advantages in mugham teaching: individualized learning opportunities, objective assessment, development of improvisation skills, preservation of performance style, and the preservation of national and cultural heritage. The analytical-diagnostic and adaptive approaches reduce the teacher's workload during the teaching process, while the virtual master concept ensures interactive learning. The combined model integrates all functions comprehensively and is adapted to the complex structure of mugham teaching.

Thus, the use of artificial intelligence models in teaching mugham optimizes all aspects of the pedagogical process from a scientific and technical perspective, improves the quality of education at both the theoretical and practical levels, and preserves and develops the effectiveness of traditional methods.

Artificial ıntelligence-based analytical learning model
The diagram developed to visualize and formally express the analytical potential of artificial intelligence in teaching mugham is presented in Figure 2. The diagram depicted in the figure clearly demonstrates the step-by-step application of artificial intelligence in teaching mugham and the combination of analytical, adaptive and interactive functions in the educational process.

As shown in Figure 2, the musical data collection stage creates a basic database for training. The system collects audio and musical notation for mugham performances. This serves as the initial basis for subsequent technical and aesthetic analysis using AI. In the data analysis section (intonation, rhythm, mode), the collected musical data is analyzed by artificial intelligence. Here, the system measures intonation accuracy, traces the melodic line within the mode, and evaluates rhythmic flexibility. This stage enables an objective and scientific analysis of the student's performance skills. The analytical and diagnostic evaluation section evaluates the quality of the student's performance both quantitatively and qualitatively (Ismayilov, 1991; Jules, 2025). AI analyzes the performance using various parameters and provides objective feedback, which assists the teacher in decision-making. Development of individualized curricula. Based on the analytical and diagnostic results, individualized learning strategies are developed for each student. This approach enables the harmonious development of technical skills and artistic expression and personalizes the learning process.

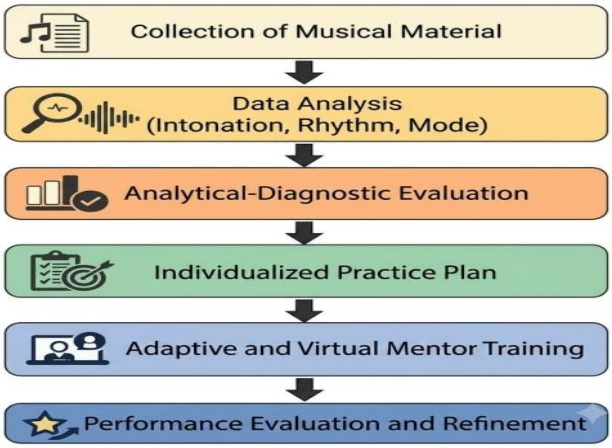


Figure 2
Application of artificial intelligence in teaching mugam

Finally, at the stage of adaptive and virtual mentor functions, artificial intelligence acts as a virtual mentor. The student tries out various improvisation scenarios in an interactive environment, and the system provides feedback in real time.

Performance evaluation and improvement. It is possible to use mathematical models and functions for the analysis of mugham performance through artificial intelligence, for example, the following performance evaluation function can be used to evaluate intensity and pitch compatibility: Q (performance + emotionality + interpretation + impact and feedback) = l (intonation + motivation + phrase + sentence structure) + L (pitch + orientation + modulations) + R (rhythm + altitude + power + tempo) model parameter weight (the purpose of the model is determined individually by the teacher: dastgah + part (shobe) + gushe + tasnif+reng + diringa + rhythmic mugham, etc.)

$$Q = \alpha \cdot I + \beta \cdot L + \gamma \cdot R \tag{1}$$

here $Q -$ the student's performance quality; $I -$ intonation accuracy index; $L -$ fret compatibility index; $R -$ rhythmic flexibility index; $\alpha, \beta, \gamma -$ weights for each parameter of the model (determined by the teacher in accordance with the teaching objective).

This expression allows for quantitative modeling of student performance and scientific justification of the analytical analysis of artificial intelligence. The presented mathematical expression was conceptually developed by the author and shows the mathematical representation of the analytical model based on artificial intelligence. The goal is to quantitatively evaluate various aspects of student performance and optimize the teaching process on a scientific basis.

In order to understand better the given methodology, let's perform its approbation on a practical example. Suppose we analyze a student's mugham performance and receive the grades shown in the table below.

Now, let's calculate the

N	Parameter	Measured price	Weight coefficients (α, β, γ)
1	Intonation accuracy, I	85/100	0,4
2	Fret compatibility, L	90/100	0,35
3	Rhythmic flexibility, R	80/100	0,25

Student's overall performance (Q) using the mathematical expression (1):

$$Q = \alpha \cdot I + \beta \cdot L + \gamma \cdot R = 0{,}4 \cdot 85 + 0{,}35 \cdot 90 + 0{,}25 \cdot 80 = 85{,}5$$

Thus, $Q = 85{,}5/100$ it is evaluated as a student performance index. This calculated score visually and analytically shows the strengths and weaknesses of the student to the teacher and the system, allowing them to individualize the curriculum. In other words, the student performance index acts as a complex and integrative assessment indicator. This index systematically reflects the level of knowledge and skills acquired by the student within the framework of educational activities, the quality of task performance, the degree of mastery of topics and the dynamics of the learning process. The calculated indicator forms a structured analytical picture of the student's academic performance for the teacher and learning management systems and allows them to identify their strengths areas requiring development.

Presenting this indicator with visual analytics tools (graphics, comparative tables and rating models) increases the transparency and interpretability of the assessment process. As a result, this artificial intelligence-based learning approach strengthens the scientific foundations of personalized teaching, strengthens learning motivation and serves to increase the overall effectiveness of the educational process.

Conclusion

The study's results demonstrate that the integration of artificial intelligence technologies into mugham teaching, if scientifically substantiated, could create the conditions for a qualitatively new stage in music pedagogy. The optimal pedagogical model presupposes a dialectical unity between the traditional teacher-apprentice system and innovative approaches based on artificial intelligence.

This clearly demonstrates the pedagogical and technological significance of using artificial intelligence in mugham teaching. The use of analytical, diagnostic, adaptive, and virtual master models leads to an objective assessment of student performance, the development of improvisation skills, and expanded opportunities for personalized learning.

An analytical and diagnostic approach has demonstrated that artificial intelligence systems can accurately assess student performance in terms of fret and intonation harmony, melodic line development, and rhythmic accuracy. These results provide an objective feedback mechanism for teachers and enable scientifically based decision-making optimization during the learning process.

Adaptive learning models have shown systems that take into account the individual characteristics of the student consistently develop their technical and aesthetic skills, significantly increase the effectiveness of personalized learning in teaching mugham, and have a positive impact on the development of improvisation skills.

A discussion of ethical and cultural aspects demonstrates the importance of AI not replacing the role of the pedagogical subject. Technological systems serve only a supporting function, while the teacher's methodological and artistic guidance remains. This approach promotes the preservation of the national and cultural values of mugham and the creative subjectivity of the performer.

Artificial intelligence is not only a technological tool but also a conceptual foundation for structuring and optimizing the pedagogical process based on scientific evidence. The results confirm that, while maintaining the traditional teacher-student model of mugham teaching, innovative digital technologies and artificial intelligence can improve learning effectiveness.

Thus, the obtained results demonstrate that the use of AI in mugham teaching requires an interdisciplinary approach and offers comprehensive solutions from pedagogical, cultural, and technological perspectives. The digital transformation of mugham teaching based on artificial intelligence confirms the scientific novelty and practical significance of the research, and creates strategic opportunities for preserving, developing, and transmitting mugham to future generations.

Furthermore, the use of artificial intelligence technologies in educational institutions offers significant opportunities for developing students' musical skills and creativity. Music lessons based on innovative teaching methods not only help them better understand music but also develop their creativity, composition, and musical analysis skills.

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