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THE IMPACT OF EDUCATIONAL TECHNOLOGIES BASED ON MOTOR COORDINATION AND MULTIMODAL INTEGRATION ON THE FORMATION OF MUSICAL-PERFORMANCE COMPETENCIES IN STUDENTS OF GRADES 5–7

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Abstract

The modernization of contemporary music education requires the integration of innovative pedagogical approaches aimed at developing students' practical performance competencies. This study examines the impact of educational technologies based on motor coordination and multimodal integration on the formation of musical-performance competencies among students in grades 5–7. The research is grounded in the interdisciplinary interaction of pedagogy, psychology, neuroscience, and music methodology, emphasizing the role of embodied learning and multisensory engagement in performance development. The study substantiates the theoretical and methodological foundations of motor coordination as a psychomotor mechanism supporting rhythmic accuracy, expressive articulation, and interpretative awareness. Multimodal learning, incorporating auditory, visual, and kinesthetic modalities, is presented as a pedagogically effective framework for enhancing students' performance skills. The experimental component of the research demonstrates that the integration of movement-based exercises, digital tools, and collaborative performance activities contributes to measurable improvements in coordination, rhythmic stability, and expressive interpretation. The findings confirm that educational technologies grounded in motor coordination and multimodal integration significantly enhance students' musical-performance competencies and motivation toward music learning. The proposed methodological model provides practical implications for music educators and curriculum designers and contributes to the advancement of competency-based and performance-oriented music education.

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Keywords: Motor coordination; multimodal integration; music education; musical-performance competencies; psychomotor development; middle school students; rhythm training; embodied learning; competency-based education; sensory integration; performance pedagogy; interactive learning technologies; music methodology; creative performance; educational innovation.

Introduction

The transformation of modern education under the influence of technological progress and competency-based paradigms has significantly reshaped the goals and methods of music pedagogy. Contemporary music education increasingly emphasizes not only theoretical knowledge but also the formation of practical performance competencies, expressive abilities, and creative interpretation. In this context, the development of musical-performance skills among middle school students becomes a priority task, as this age period is characterized by intensive psychomotor, cognitive, and emotional development.

One of the central challenges in music pedagogy is the need to establish effective educational technologies that integrate sensory perception, motor coordination, and artistic expression. Musical performance is a multidimensional activity requiring the simultaneous functioning of auditory perception, visual processing, kinesthetic awareness, and rhythmic organization. However, traditional instructional approaches often separate theoretical knowledge from practical performance, limiting students' ability to internalize musical structures and express them creatively. This methodological gap necessitates the search for integrative pedagogical solutions that can bridge cognition and embodied experience.

Motor coordination plays a fundamental role in the formation of musical-performance competencies, as it enables the synchronization of movement with sound, tempo, and expressive articulation. For example, coordinated finger movements in instrumental practice or controlled breathing in vocal performance directly influence rhythmic stability and tonal quality. When these motor processes are supported by multimodal learning strategies—such as visual

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modeling, auditory feedback, and kinesthetic engagement—students demonstrate deeper understanding and more stable performance outcomes.

Multimodal integration represents a scientifically grounded approach that enhances learning efficiency through the interaction of multiple sensory channels. In music education, this approach manifests in the use of audio recordings, visual notation, body movement, and digital simulations. For instance, rhythm-training software that combines visual cues with auditory playback and physical interaction helps students internalize tempo and meter more effectively than traditional repetition methods. Such strategies align with contemporary theories of embodied cognition, which emphasize the inseparability of perception, movement, and cognitive processing in learning.

The relevance of the present study lies in the need to substantiate the pedagogical potential of educational technologies that integrate motor coordination and multimodal learning in developing musical-performance competencies among students in grades 5–7. Despite the growing interest in performance-oriented instruction, there remains a lack of systematic research that empirically demonstrates the effectiveness of such integrative approaches in middle school music education. Addressing this gap is essential for improving instructional practices and ensuring that music education responds to the demands of modern educational environments.

The aim of this study is to theoretically substantiate and experimentally verify the effectiveness of educational technologies based on motor coordination and multimodal integration in forming musical-performance competencies in students of grades 5–7. The research focuses on identifying pedagogical mechanisms that support the integration of psychomotor development, sensory perception, and creative performance, thereby contributing to the modernization of performance-oriented music education. The study also seeks to develop methodological recommendations for educators and to provide a framework for further research in multimodal and competency-based music pedagogy.

The structure and conceptual orientation of this article are based on a comprehensive analysis of theoretical foundations, methodological modeling, and experimental validation of the proposed educational technology, which collectively demonstrate its pedagogical effectiveness and practical applicability.

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Theoretical foundations of motor coordination and multimodal integration in music education. The contemporary transformation of music education is closely connected with the recognition that musical performance is not solely a cognitive or auditory activity but a complex psychomotor, sensory, and creative process. Within this paradigm, motor coordination and multimodal integration emerge as fundamental theoretical constructs that explain how students acquire, internalize, and express musical knowledge through performance. The development of musical-performance competencies in students of grades 5–7 requires an educational framework that integrates psychological, pedagogical, and neurocognitive principles, ensuring that learning is not limited to theoretical understanding but extends to embodied musical experience.

Motor coordination in the learning process is interpreted in pedagogy and psychology as a dynamic interaction between cognitive regulation, neuromuscular activity, and sensory feedback. In music education, coordinated movements—such as finger positioning on instruments, rhythmic clapping, vocal articulation, and body movement—function as mechanisms for structuring musical perception and expression. From a pedagogical perspective, motor coordination is not merely a technical skill but a formative component of musical thinking. The development of coordinated movement patterns enhances students' ability to control tempo, dynamics, articulation, and expressive nuance. For example, when students learn to perform rhythmic patterns through synchronized hand movements and foot tapping, they simultaneously activate auditory perception, kinesthetic awareness, and cognitive timing mechanisms. This integrated activity supports the internalization of rhythm and promotes accuracy in musical performance.

Psychological interpretations further emphasize that motor coordination is closely linked with the development of executive functions, attention, and memory. When students engage in coordinated musical tasks—such as ensemble performance or instrument playing—they must regulate movement, anticipate rhythmic changes, and respond to auditory cues. These processes contribute to the formation of procedural memory, which is essential for mastering performance skills. In early adolescence, especially between the ages of 11 and 13, the nervous system demonstrates increased plasticity, enabling the effective

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development of fine motor skills and sensorimotor integration. Therefore, the pedagogical use of movement-based exercises in music lessons is scientifically justified as a means of enhancing both cognitive and artistic performance.

Multimodal learning theory provides an essential framework for understanding how students process musical information through multiple sensory channels. According to contemporary educational psychology, learning becomes more effective when auditory, visual, and kinesthetic modalities are engaged simultaneously. Music education naturally aligns with this approach, as it inherently involves sound perception, visual representation (notation, gestures), and physical performance. Multimodal integration enables students to construct meaning through the interaction of these sensory modalities, leading to deeper comprehension and more stable skill acquisition. For instance, when a teacher combines musical notation, audio recordings, and body movement exercises during instruction, students develop a more comprehensive understanding of musical structure and expressive interpretation.

In arts education, multimodal learning is particularly significant because creative expression depends on sensory diversity and experiential engagement. The use of multimedia tools, interactive software, visual demonstrations, and movement-based activities supports the formation of associative links between perception and action. For example, digital rhythm-training applications that provide visual cues alongside auditory feedback allow students to synchronize movement with sound, reinforcing both rhythmic accuracy and motor coordination. Similarly, video modeling of instrumental techniques helps learners observe movement patterns, which they then reproduce through kinesthetic imitation. Such approaches demonstrate that multimodal integration strengthens the connection between observation, perception, and performance.

The integration of auditory, visual, kinesthetic, and rhythmic perception represents a central theoretical principle in performance-oriented music education. Musical performance requires the simultaneous functioning of multiple perceptual systems. Auditory perception enables pitch recognition and tonal balance; visual perception supports notation reading and gesture interpretation; kinesthetic perception guides movement precision; rhythmic perception organizes temporal structure. When these modalities operate in isolation, learning

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becomes fragmented. However, when they are integrated within a coherent pedagogical framework, they form a holistic performance mechanism. For example, in instrumental instruction, a student reads musical notation (visual), listens to tonal output (auditory), adjusts finger placement (kinesthetic), and maintains tempo (rhythmic). The coordination of these processes results in expressive and technically accurate performance.

Practical educational scenarios illustrate the significance of this integration. In rhythm training, combining clapping patterns, visual rhythmic diagrams, and auditory modeling enhances temporal awareness more effectively than using a single modality. In vocal training, body posture, breathing exercises, and gesture-based phrasing improve vocal control and expressive interpretation. Ensemble performance further exemplifies multimodal integration, as students must simultaneously listen to peers, observe conductor gestures, coordinate movements, and adapt rhythmically. These examples confirm that performance skills emerge through the synthesis of sensory and motor experiences rather than through isolated theoretical instruction.

Age-related characteristics of psychomotor and creative development in students aged 11–13 provide an additional theoretical justification for applying motor coordination and multimodal approaches in music education. This developmental stage is marked by increased neuromuscular control, heightened sensitivity to rhythm, and growing creative self-expression. Adolescents demonstrate a strong capacity for imitation, experimentation, and collaborative activity, which makes them particularly responsive to movement-based and interactive learning environments. At the same time, they experience rapid cognitive development, enabling them to connect abstract musical concepts with practical performance actions. For example, students at this age can effectively translate rhythmic notation into coordinated movement or interpret emotional content through expressive performance.

Pedagogically, this stage requires a balance between structured guidance and creative autonomy. Multimodal learning environments support this balance by allowing students to explore music through diverse sensory pathways while maintaining instructional direction. Movement-based improvisation, group rhythm exercises, and multimedia-supported practice encourage active

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participation and emotional engagement. As a result, musical learning becomes not only skill-oriented but also personally meaningful, contributing to sustained motivation and artistic development.

International research in music pedagogy increasingly emphasizes performance-oriented methodologies grounded in psychomotor and multimodal principles. Educational approaches such as movement-based rhythm instruction, interactive ensemble practices, and technology-enhanced performance training demonstrate the effectiveness of integrating sensory modalities and coordinated movement. Studies in educational neuroscience highlight that embodied learning—where cognition is supported by physical action—facilitates deeper understanding and long-term retention of musical skills. Performance pedagogy in many educational systems incorporates body movement, visual modeling, and digital tools as essential components of instruction rather than supplementary methods.

Methodological innovations in global music education also show a shift from teacher-centered transmission to learner-centered experiential engagement. Students are encouraged to explore sound through movement, experiment with rhythm, and construct musical interpretations through collaborative performance. Such approaches reflect the understanding that musical competence is formed through active participation and sensory interaction. The integration of technology—such as rhythm simulation software, virtual instruments, and multimedia tutorials—further enhances multimodal learning by providing real-time feedback and personalized practice opportunities.

Thus, the theoretical foundations of motor coordination and multimodal integration in music education rest upon interdisciplinary principles derived from pedagogy, psychology, neuroscience, and arts methodology. These foundations affirm that musical-performance competencies develop most effectively when learning involves coordinated movement, multisensory perception, and creative engagement. For students in grades 5–7, whose psychomotor and cognitive systems are in a phase of active development, such an approach ensures not only technical proficiency but also the formation of expressive, interpretative, and reflective musical abilities. Consequently, educational technologies grounded in motor coordination and multimodal integration represent a scientifically justified and pedagogically necessary direction for modern music education.

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Structure and pedagogical significance of musical-performance competencies. In contemporary music pedagogy, the concept of musical-performance competencies is interpreted as a complex integrative construct that reflects the learner's ability to reproduce, interpret, and creatively express musical material through coordinated cognitive, emotional, and psychomotor processes. Unlike traditional approaches that emphasize the acquisition of theoretical knowledge or technical skills in isolation, competency-based music education focuses on the formation of a holistic performance capacity that enables students to apply musical knowledge in practical artistic contexts. Within the educational environment of grades 5–7, musical-performance competencies serve as a key indicator of the effectiveness of instruction, as they reflect not only technical mastery but also the development of musical thinking, interpretative sensitivity, and expressive communication.

The structure of musical-performance competencies includes several interrelated components: cognitive, psychomotor, emotional-expressive, and creative-interpretative. The cognitive component involves understanding musical notation, rhythm, tempo, dynamics, and stylistic characteristics. The psychomotor component refers to the coordination of movements necessary for instrumental playing, vocal production, and rhythmic execution. The emotional-expressive component encompasses the ability to convey musical meaning, mood, and artistic imagery. The creative-interpretative component includes improvisation, stylistic variation, and personal expression within performance. These components operate in synergy, forming a unified performance mechanism. For example, when a student performs a simple instrumental piece, successful execution requires not only reading notation but also controlling finger movements, maintaining rhythmic stability, and expressing the character of the composition. The absence of any component weakens the overall performance outcome.

Psychomotor skills play a decisive role in both instrumental and vocal performance, particularly in early adolescence, when the neuromuscular system undergoes rapid development. Instrumental performance requires precise coordination of hand movements, posture control, and motor timing. Vocal performance, in turn, depends on breathing regulation, articulation, and the

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coordination of vocal apparatus with auditory feedback. In this context, psychomotor competence becomes a bridge between intention and musical realization. For instance, when a student learns to perform rhythmic patterns on percussion instruments, the development of motor coordination directly influences tempo accuracy and expressive articulation. Similarly, in choral singing, synchronized breathing and articulation support collective sound quality and ensemble cohesion. These examples illustrate that performance skills cannot be developed solely through theoretical instruction; they must be grounded in embodied practice.

The development of rhythm, coordination, interpretation, and expressive performance abilities constitutes the functional core of musical-performance competencies. Rhythm serves as the temporal foundation of musical organization, requiring both perceptual awareness and motor precision. Coordination ensures the synchronization of sensory perception and physical action. Interpretation reflects the student's capacity to understand musical structure and convey its emotional content. Expressive performance involves dynamic control, phrasing, articulation, and stylistic nuance. These abilities evolve through systematic practice and pedagogical guidance. For example, integrating movement-based rhythm exercises into music lessons helps students internalize tempo and meter more effectively than passive listening. Visual representation of musical phrases combined with vocal imitation fosters interpretative awareness. Ensemble performance strengthens coordination and social interaction, encouraging students to listen actively and adjust their performance in real time.

From a competency-based perspective, modern music pedagogy emphasizes the formation of transferable skills rather than the reproduction of isolated knowledge. Competency-based education redefines the role of the learner from a passive recipient of information to an active participant in artistic creation. Musical-performance competencies thus become indicators of the learner's ability to apply knowledge, demonstrate technical proficiency, and engage in creative interpretation. This approach aligns with contemporary educational paradigms that prioritize student-centered learning, experiential practice, and interdisciplinary integration. In the context of music education, competency-based instruction encourages project-based learning, improvisation, collaborative

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performance, and reflective evaluation. For instance, students may be tasked with preparing a performance project that integrates instrumental practice, rhythmic improvisation, and digital accompaniment. Such activities promote autonomy, creativity, and responsibility for learning outcomes.

The pedagogical significance of musical-performance competencies is particularly evident in middle school education, where students undergo critical cognitive, emotional, and social development. At this stage, learners demonstrate increased sensitivity to artistic expression and a growing need for self-realization. Performance-oriented instruction provides opportunities for emotional engagement, identity formation, and communication through art. Moreover, the integration of motor coordination and multimodal learning enhances the accessibility of music education for diverse learners. Students who may struggle with abstract theoretical concepts often demonstrate higher engagement when learning through movement, visual cues, and practical performance tasks. For example, rhythmic body percussion, interactive ensemble activities, and multimedia-supported practice environments create inclusive learning conditions that accommodate different learning styles.

Effective formation of musical-performance skills in middle school students depends on several pedagogical conditions. First, instruction must be systematically organized, progressing from simple motor tasks to complex performance activities. Second, the learning environment should encourage active participation and collaboration, allowing students to experiment with sound and movement. Third, feedback mechanisms—both teacher-guided and technology-assisted—are essential for refining performance accuracy. Fourth, emotional support and motivational strategies play a significant role in sustaining students' interest and confidence. Finally, the integration of multimodal teaching tools, such as visual modeling, interactive rhythm software, and movement-based exercises, strengthens the connection between perception and action.

Analytical observation of classroom practice demonstrates that when these conditions are implemented, students show significant improvement in performance accuracy, rhythmic stability, and expressive articulation. For instance, students who regularly engage in coordinated movement exercises tend to demonstrate better timing and phrasing during instrumental practice. Similarly,

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those exposed to visual and auditory modeling develop stronger interpretative skills and confidence in performance. The collaborative nature of ensemble learning further enhances responsibility, listening skills, and mutual coordination among learners.

Thus, the structure and pedagogical significance of musical-performance competencies extend beyond technical mastery and encompass cognitive understanding, psychomotor development, emotional expression, and creative interpretation. These competencies represent the core outcome of music education, reflecting the learner's readiness to participate in artistic activity and cultural communication. Within the framework of educational technologies based on motor coordination and multimodal integration, the formation of musical-performance competencies becomes more systematic, accessible, and effective. Such an approach not only improves performance quality but also contributes to the holistic development of the learner, reinforcing the educational value of music as a multidimensional art form and a powerful pedagogical tool.

Methodological model for developing musical-performance competencies through motor coordination and multimodal integration. The development of musical-performance competencies in students of grades 5–7 requires a scientifically grounded methodological model that integrates pedagogical, psychological, and technological approaches within a unified educational framework. In contemporary music pedagogy, methodological modeling is understood as the systematic design of instructional processes that ensure the purposeful formation of competencies through structured learning environments, appropriate teaching strategies, and empirically validated assessment tools. Within this study, the methodological model is based on the integration of motor coordination and multimodal learning principles, which together provide the foundation for effective performance-oriented music instruction.

The research object of the methodological model is the process of teaching musical performance in general secondary education, where students engage in vocal, instrumental, and rhythm-based activities as part of their formal music curriculum. This process encompasses both classroom instruction and guided practice, focusing on the development of technical, expressive, and interpretative

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performance skills. The research subject is the methodology for forming musical-performance competencies through educational technologies grounded in motor coordination and multimodal integration. The methodological focus is not limited to the acquisition of isolated skills but aims at constructing a comprehensive system that supports the coordinated development of sensory perception, psychomotor activity, and creative expression.

The design of the methodological model is based on the creation of a multimodal-psychomotor learning environment that combines movement-based exercises, audio-visual resources, and interactive technological tools. Such an environment reflects the principle that musical performance is an embodied activity involving coordinated sensory and motor engagement. Movement-based exercises play a central role in this system, as they help students internalize rhythmic structures, develop coordination, and connect musical perception with physical action. For example, structured rhythm exercises involving clapping patterns, stepping sequences, and body percussion support the synchronization of auditory perception and motor execution. These activities not only improve rhythmic accuracy but also enhance students' concentration and temporal awareness.

Audio-visual tools constitute another essential component of the methodological model. Visual demonstrations of instrumental techniques, digital representations of rhythmic patterns, and video recordings of exemplary performances enable students to observe, analyze, and reproduce performance behaviors. When combined with auditory modeling, these tools facilitate multisensory learning, allowing students to link visual information with sound and movement. For instance, a lesson may include the use of interactive software that displays rhythmic notation while simultaneously providing auditory playback. Students follow the visual cues, reproduce the rhythm through coordinated movement, and receive immediate feedback, thereby reinforcing the connection between perception and performance.

Interactive technologies further expand the methodological possibilities by introducing simulation-based and feedback-oriented learning. Digital rhythm trainers, virtual instruments, and multimedia learning platforms allow students to practice independently while maintaining engagement. These tools provide real-time evaluation of tempo accuracy, articulation, and coordination, which supports

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self-regulated learning. In ensemble contexts, technology can simulate accompaniment or provide metronomic guidance, enabling students to maintain synchronization and develop collaborative performance skills.

Teaching strategies within the methodological model are designed to promote active participation, creativity, and the integration of sensory modalities. Rhythmic movement tasks serve as the initial stage of performance training, allowing students to internalize musical structures through physical engagement. Ensemble practice constitutes the next stage, where students learn to coordinate their actions with others, listen attentively, and adjust performance parameters. Digital simulations provide opportunities for individualized practice and experimentation, while creative performance assignments encourage interpretative thinking and artistic expression. For example, students may be assigned to create short rhythmic compositions using body percussion and digital accompaniment, thereby combining motor coordination, auditory perception, and creative decision-making.

Another essential strategy involves scaffolding, where learning progresses from simple coordinated movements to complex performance tasks. At the introductory level, students perform basic rhythmic patterns through clapping and stepping. At intermediate stages, they apply these skills in instrumental or vocal practice, focusing on articulation and phrasing. At advanced stages, they engage in interpretative performance, combining technical accuracy with emotional expression. This gradual progression ensures the systematic formation of competencies and prevents cognitive overload.

The methodological model also incorporates collaborative learning, recognizing that musical performance is inherently social. Ensemble activities, group improvisation, and peer feedback sessions foster communication, responsibility, and shared artistic experience. Through these interactions, students develop not only technical skills but also social competencies, such as cooperation and empathy. For example, during group performance tasks, students must listen to each other, synchronize movements, and collectively interpret musical material, which enhances both coordination and expressive unity.

The effectiveness of the methodological model is verified through a комплекс of research methods, ensuring empirical validity and scientific reliability. A

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pedagogical experiment forms the core of the research design, involving experimental and control groups to compare traditional and multimodal-psychomotor approaches. Psychomotor diagnostics are employed to assess students' coordination, reaction speed, and motor precision. Observation provides qualitative insights into classroom dynamics, engagement levels, and performance behavior. Video analysis allows for detailed examination of movement patterns, posture, and synchronization during performance activities, offering objective data for interpretation.

Performance assessment criteria are developed to evaluate the level of musical-performance competencies. These criteria include rhythmic accuracy, coordination of movements, expressive articulation, interpretative depth, and technical proficiency. Each criterion is measured through structured rubrics that allow for both qualitative and quantitative evaluation. Statistical analysis is applied to determine the significance of observed changes in performance skills, ensuring that conclusions are grounded in empirical evidence. Comparative data analysis reveals the degree to which motor coordination and multimodal integration influence students' performance outcomes.

Practical examples from experimental implementation demonstrate the viability of the methodological model. Students who participated in movement-based rhythm training exhibited improved tempo stability and coordination during instrumental practice. Learners engaged in multimodal digital environments demonstrated higher motivation and greater accuracy in reproducing musical material. Ensemble activities supported the development of expressive phrasing and interpretative awareness, as students learned to adjust their performance in response to group dynamics. These observations confirm that the integration of motor coordination and multimodal learning produces measurable improvements in musical-performance competencies.

In methodological terms, the model reflects a shift from knowledge-centered instruction to competency-oriented, experiential learning. It emphasizes the importance of embodiment, multisensory engagement, and creative participation as fundamental mechanisms for skill development. By aligning instructional strategies with students' developmental characteristics and sensory learning preferences, the model ensures accessibility and effectiveness in music education.

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Thus, the proposed methodological model represents a comprehensive pedagogical system that integrates movement, perception, and technology to support the formation of musical-performance competencies in middle school students. It provides a structured framework for instructional design, practical implementation, and empirical evaluation. Through the integration of motor coordination and multimodal learning principles, the model enhances not only technical proficiency but also interpretative sensitivity, expressive capacity, and creative engagement, thereby contributing to the modernization of performance-oriented music education.

Experimental results and evaluation of the effectiveness of the proposed educational technology. The experimental verification of the effectiveness of educational technologies based on motor coordination and multimodal integration constitutes a central stage in assessing the formation of musical-performance competencies among students in grades 5–7. The experimental component of the study was designed to ensure methodological validity, empirical reliability, and pedagogical relevance, focusing on the systematic observation of changes in students' performance skills, psychomotor development, and learning engagement. The research was conducted within the framework of general secondary education, where music lessons provided a natural context for implementing and evaluating the proposed instructional model.

The organization of the experimental study followed a structured multi-stage design, including diagnostic, formative, and evaluative phases. During the diagnostic stage, baseline data were collected to determine students' initial levels of musical-performance competencies, rhythmic perception, coordination, and expressive abilities. Psychomotor diagnostics, performance assessments, and observational protocols were employed to establish objective indicators of skill development. At this stage, students demonstrated varying levels of readiness, with many showing limited coordination between auditory perception and motor execution, as well as inconsistent rhythmic accuracy during performance tasks.

The formative stage involved the implementation of the proposed multimodal-psychomotor educational technology within the experimental group, while the control group continued to receive instruction through traditional music teaching methods. Instructional interventions included movement-based rhythm exercises,

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ensemble coordination activities, digital simulations, and creative performance tasks integrating auditory, visual, and kinesthetic modalities. The purpose of this stage was to create a learning environment that encouraged active participation, embodied musical understanding, and multisensory engagement.

The evaluative stage focused on measuring changes in performance competencies and psychomotor development following the intervention. Performance assessment rubrics, video analysis, and psychomotor tests were used to capture improvements in coordination, tempo control, expressive articulation, and interpretative awareness. Comparative data were collected from both experimental and control groups to ensure objectivity in determining the effectiveness of the educational technology.

A comparative analysis of traditional and multimodal-psychomotor approaches revealed substantial differences in learning outcomes. Students exposed to traditional instruction demonstrated improvement primarily in theoretical knowledge and basic performance accuracy; however, their expressive interpretation, coordination, and rhythmic stability developed more gradually. In contrast, students participating in the multimodal-psychomotor learning environment showed accelerated progress in synchronizing movement with sound, maintaining tempo, and performing with greater expressive confidence. For instance, during ensemble practice tasks, students in the experimental group were able to coordinate entries and phrasing more consistently, demonstrating improved listening skills and collaborative responsiveness.

The assessment of students' performance skills and psychomotor progress highlighted the integral relationship between coordinated movement and musical expression. Students who regularly engaged in rhythmic movement exercises exhibited greater motor precision and control during instrumental and vocal performance. Video analysis revealed improved posture, synchronization of hand movements, and more accurate articulation. Psychomotor diagnostics indicated enhanced reaction speed and coordination, which translated into more stable performance outcomes. For example, learners who practiced body percussion and movement-based rhythm exercises showed measurable improvement in tempo consistency when performing on instruments or participating in choral activities.

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The development of interpretative abilities also became more evident within the experimental group. Students demonstrated increased sensitivity to dynamics, phrasing, and emotional content, suggesting that multimodal engagement supported deeper artistic understanding. Creative performance tasks encouraged learners to experiment with expressive elements, leading to more individualized interpretations. Observational data indicated that students became more confident and actively involved in performance activities, reflecting the motivational impact of the proposed educational technology.

Quantitative analysis of the experimental results confirmed statistically significant improvements in several key indicators, including rhythmic accuracy, coordination, expressive articulation, and overall performance quality. Comparative measurements between pre- and post-intervention assessments showed higher growth rates in the experimental group than in the control group. These findings suggest that the integration of motor coordination and multimodal learning creates favorable conditions for accelerated skill development. Statistical processing of performance scores demonstrated that students exposed to the proposed methodology achieved more consistent progress, with reduced variability in performance outcomes.

Qualitative interpretation of the results further emphasized the pedagogical value of the approach. Teachers reported increased student engagement, greater willingness to participate in ensemble activities, and improved self-regulation during practice sessions. Students displayed stronger motivation and a more positive attitude toward music lessons, often expressing interest in experimenting with movement and digital tools. The learning environment became more dynamic and interactive, supporting both cognitive and emotional involvement. Classroom observations showed that students were not only performing tasks more accurately but also demonstrating a deeper understanding of musical structure and expressive intent.

The discussion of pedagogical effectiveness indicates that the proposed educational technology provides a comprehensive framework for integrating psychomotor development and multimodal learning into music education. The combination of movement-based exercises, sensory integration, and technological support enhances both technical and expressive dimensions of

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performance. The approach aligns with contemporary competency-based education, emphasizing active participation, experiential learning, and individualized development.

Practical implications of the findings are significant for music educators and curriculum designers. The results suggest that incorporating motor coordination exercises into regular music lessons can improve performance accuracy and rhythmic stability. The use of multimedia tools and digital simulations enhances students' interpretative awareness and independent practice. Ensemble-based activities strengthen social interaction and collaborative skills, contributing to a more holistic educational experience. Moreover, the methodology can be adapted to different educational contexts, providing flexibility in instructional design.

The experimental findings also underscore the importance of early intervention during middle school years, when psychomotor and cognitive development are particularly responsive to structured learning. By integrating multimodal and movement-based strategies at this stage, educators can establish a strong foundation for future musical training and artistic growth. The results demonstrate that performance-oriented competencies develop more effectively when learning is grounded in coordinated sensory and motor experiences rather than isolated theoretical instruction.

Overall, the evaluation of the experimental data confirms the effectiveness of educational technologies based on motor coordination and multimodal integration in forming musical-performance competencies among students in grades 5–7. The proposed methodological approach not only enhances technical proficiency but also fosters expressive creativity, motivation, and collaborative engagement. These outcomes support the broader pedagogical objective of modern music education: the formation of competent, confident, and creatively active performers capable of meaningful artistic participation.

Conclusion

The findings of this study confirm that the integration of motor coordination and multimodal learning represents a scientifically grounded and pedagogically effective approach to developing musical-performance competencies among students in grades 5–7. The research demonstrates that musical performance is a

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holistic process that involves cognitive understanding, psychomotor regulation, emotional expression, and creative interpretation. Educational technologies that support the interaction of these components create favorable conditions for the formation of stable performance skills and artistic awareness.

The experimental results indicate that students exposed to movement-based exercises, multisensory instructional strategies, and interactive digital tools exhibit significant improvement in rhythmic accuracy, coordination, expressive articulation, and interpretative competence. These outcomes highlight the importance of embodied learning in music education, where coordinated movement functions as a mediator between perception and performance. Moreover, the use of multimodal learning environments increases student motivation, engagement, and confidence, transforming music lessons into dynamic spaces for creative exploration.

The study also confirms that middle school age represents a critical period for developing musical-performance competencies, as students demonstrate heightened sensitivity to rhythm, movement, and emotional expression. When instructional processes align with these developmental characteristics, learning becomes more effective and meaningful. The proposed multimodal-psychomotor instructional model provides a structured framework for integrating sensory perception, motor activity, and technological tools into music education practice.

From a pedagogical perspective, the implementation of this model contributes to the transition from knowledge-centered instruction to competency-oriented and experiential learning. It supports the development of students' autonomy, creativity, and collaborative skills while enhancing technical proficiency. Music educators can apply the findings by incorporating rhythm-based movement, visual modeling, and interactive technologies into their teaching practice to strengthen performance outcomes.

The research has broader implications for curriculum design and educational policy, emphasizing the need to modernize music education through interdisciplinary integration and innovation. Future studies may explore the long-term impact of multimodal-psychomotor approaches, their adaptability across different educational contexts, and their influence on professional musical development.

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In conclusion, educational technologies based on motor coordination and multimodal integration provide a powerful methodological tool for enhancing musical-performance competencies and ensuring the holistic artistic development of learners. These approaches not only improve performance quality but also reinforce the role of music education as a multidimensional pedagogical system that supports cognitive, emotional, and creative growth.

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