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RESEARCH ARTICLE

The promoting effect of natural environment in music education on the cognitive and emotional development of college students: A quasi-experimental study

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ABSTRACT

This study explores the role of natural environments in promoting cognitive and emotional development in music education. Using a mixed-methods approach through a 12-week quasi-experimental design, the study comparatively analyzed the differential effects of music education activities conducted in natural environments versus traditional classroom settings on student development. The research subjects were 240 college students (120 in the experimental group, 120 in the control group), with data collected through scale assessments, behavioral observations, semi-structured interviews, and social network analysis. The results indicated that: (1) Natural environments significantly promoted the development of students' music cognitive abilities, particularly in auditory discrimination ability (d=0.82), musical memory ability (d=0.79), and musical creative thinking (d=0.87); (2) Music education in natural environments produced systematic effects on emotional development, especially in emotional recognition and expression abilities (d=0.91), emotional regulation ability (d=0.92), and musical empathy ability (d=0.93); (3) Different types of natural environments produced different effects on cognitive and emotional development, with water landscapes showing optimal effects for auditory discrimination and emotional recognition, while forest environments were more conducive to creative thinking and emotional expression; (4) Natural environments exertedted psychosocial influence through three mechanisms: enhancing social connection and sense of belonging, cultivating ecological music values, and developing sustainable learning motivation; (5) Environmental complexity, biodiversity, and sense of natural rhythm were the three key environmental factors affecting music cognitive and emotional development. The research results support the application of attention restoration theory and place attachment theory from environmental psychology in music education, providing empirical evidence for the mechanism of environmental factors in music education, and offering important implications for organically integrating natural environmental elements into music education practice to promote students' comprehensive development.

Keywords: music education; natural environment; cognitive development; emotional development; environmental psychology

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1. Introduction

The natural environment, as a fundamental domain for human survival and development, has a long-standing relationship with music as an art form. Music education, as an important pathway for cultivating human aesthetic ability and emotional expression, demonstrates unique cognitive and emotional developmental benefits when combined with natural environments. Zhao Sashuang (2024) points out that research on the design paths of educational processes and teaching environments in music education theory has a profound impact on student development, with environmental design being particularly essential for the quality of music education [1]. The natural environment, as a special teaching environment, provides multidimensional sensory stimulation for music education through its rich auditory, visual, and tactile elements, promoting learners' cognitive processing and emotional experiences. When music education extends from traditional enclosed classrooms into natural environments, learners' attention, memory, creativity, and emotional regulation abilities all show significant improvements. The psychological mechanisms behind this phenomenon and its application value in educational practice have become urgent topics to explore in the cross-disciplinary research between environmental psychology and music education.

The exploration of music education from an environmental psychology perspective not only focuses on the transmission of musical knowledge and skills but also emphasizes the profound influence of the learning environment on individual cognitive structures and emotional development. Duan Yunwei and Jiang Zhicheng (2023) emphasize in their research that integrating ecological environmental education into primary school music education can cultivate students' environmental awareness and aesthetic abilities, promoting the coordinated development of cognition and emotion [2]. The soundscapes in natural environments, such as birdsong, flowing water, and wind sounds, provide rich auditory materials for music education, enabling learners to establish connections between sounds and emotions and enhance their musical perception abilities during the process of perceiving natural sounds. Peerapong (2024) found that when percussion instrument learning in traditional music education is placed against natural environmental backgrounds, learners demonstrate higher levels of engagement and creative expression [3]. This phenomenon confirms the complementarity between natural environments and music education, namely that the sensory stimuli and contextual factors provided by natural environments can activate learners' multisensory experiences and emotional responses, thereby strengthening the cognitive processing and emotional experiences of music learning, forming a unique educational ecosystem.

In contemporary music education practice, incorporating natural environments into instructional design has become an innovative trend, and its promoting effects on learners' cognitive and emotional development have also been supported by empirical research. Chen Jingjing and Cai Lihong (2023), through empirical and case studies of school environmental music education, confirmed the importance of environmental factors in realizing the value of music education [4]. Music education activities in natural environments, such as outdoor concerts, forest music creation, and natural sound collection, not only enrich teaching forms but also provide learners with opportunities for immersive experiences and emotional resonance. Chen (2024) points out that integrated research on music psychology and secondary school music education indicates that environmental factors have significant effects on learners' musical cognitive processing and emotional experiences [5]. Foster and Causby (2024), in their research on music education in rural areas of Mississippi, USA, found that the integration of local natural environmental elements significantly enhanced the effectiveness of instrumental education and students' learning motivation [6]. Zhuo Jia (2023) discussed the developmental strategies of college music education management in multimedia environments from another perspective, emphasizing the

systematic role of environmental factors in music education [7]. These studies collectively point to a core viewpoint: the natural environment, as a special educational resource, when organically combined with music education, can create a quality educational ecology that promotes cognitive development and emotional cultivation, providing broad space for theoretical innovation and practical expansion of music education.

Based on the aforementioned theoretical background and practical needs, this study proposes the following research questions: (1) What specific impacts does the natural environment have on the development of college students' music cognitive abilities c(including auditory discrimination, musical memory, and creative thinking)? (2) How does the natural environment promote college students' emotional development (emotional recognition, emotional regulation, musical empathy) in music education? (3) What are the differences in the effects of various types of natural environments (waterscapes, forests, open grasslands) on cognitive and emotional development? Accordingly, this study hypothesizes that: natural environments compared to traditional classroom environments can significantly promote college students' music cognitive abilities and emotional development; different types of natural environments have differentiated effects on specific cognitive and emotional dimensions; natural environments exert positive effects through specific social-psychological mechanisms (such as enhancing social connections, cultivating ecological values, and developing sustainable learning motivation). This study aims to verify these hypotheses through a quasi-experimental design, providing scientific basis for effectively integrating natural environment elements into music education practice.

2. Literature review

The research on the connection between music education and natural environments has garnered widespread attention in academia in recent years, gradually shifting from a single-disciplinary perspective to an interdisciplinary integrated perspective, forming rich theoretical frameworks and practical models. Current research mainly focuses on the influence mechanisms of natural environments on music cognitive development, the pathways of emotional cultivation, and innovative models of educational practice. From a cognitive psychology perspective, the natural environment, as a learning domain with restorative qualities, has significant promoting effects on music learners' attention, memory, and creative thinking. Zhu Ting and Zhang Yuhong (2023), based on research on the theoretical framework of music education in special education schools constructed on ICF (International Classification of Functioning, Disability, and Health), indicate that environmental factors are one of the key variables affecting learning outcomes, and appropriate natural environments can effectively alleviate learning pressure for children with special needs, promoting the development of their music perception and expression abilities [8]. This viewpoint was also confirmed in Lin's (2025) research on refugee students, whose proposed "trauma-sensitive teaching" model emphasizes the healing function of natural environments in music education, which can help students who have experienced trauma rebuild a sense of security through musical activities, promoting the recovery and development of cognitive abilities [9].

The natural environment, as a special educational resource, demonstrates differential value for music education in different educational settings. Mao Shihan (2023), in research on music education issues in township primary schools, points out that although rural natural environments are rich in resources, these resources have not been effectively transformed into educational advantages due to limitations in educational concepts and methods [10]. In contrast, urban schools often introduce natural elements through artificial creation to compensate for the lack of natural environments. Chen Xiaohong (2020) explored the role of creating a good music environment in optimizing music teaching in vocational high schools, emphasizing the influence of environmental factors on student engagement and learning outcomes [11]. This urban-rural difference reflects

the uneven distribution of natural environmental resources in music education and also provides a research direction for resource integration and optimization. Hildén et al. (2025) examined the process by which music education creates opportunities for young families from a social work perspective, finding that musical activities in natural environments can significantly enhance family cohesion and community belonging, providing a comprehensive support system for children's development [12]. Jones and Bannerman (2025), through narrative research on first-generation college students, found that music practice activities in natural environments can help students establish identity and a sense of belonging, promoting their social integration and academic development [13].

The integration of technological environments and natural environments has become an important topic in contemporary music education research. Han Feng (2022) points out that music education innovation in the "Internet" environment needs to focus on the organic combination of technology and nature, tradition and modernity [14]. Lan Zhu and Wang Gaoyuan (2022) analyzed the opportunities and dilemmas faced by school music education in the new media environment, proposing optimization paths and emphasizing the importance of natural experiences empowered by technology [15]. With the development of artificial intelligence, big data, and other technologies, the environmental boundaries of music education have further expanded. Wang (2025) explored the application prospects of AI and machine learning in personalized music education, pointing out that intelligent technology can simulate and enhance the learning effects of natural environments, providing students with immersive music experiences [16]. Jiang and Tao (2024) studied the application of big data technology in higher education music programs, revealing the promoting effect of data-driven environmental awareness on music learning [17]. Bai Xiaomo (2020) analyzed the application of artificial intelligence technology in music teaching, emphasizing the inspirational role of natural sound collection and analysis assisted by technology for music creation [18]. Nevertheless, Zou Yazhou (2022), in reviewing "Practice and Theoretical Research in Music Education," reminds that the inheritance and development of traditional music culture in the new media environment still needs to maintain reverence for and reference to the natural environment [19].

The promoting effect of natural environments on the emotional development of music learners has been supported by multiple studies. He Jiarun and Li Guochao (2022), in their research on college students' music literacy education against the background of the "double reduction" policy, point out that music activities in natural environments can reduce student stress and promote the development of emotional expression and interpersonal communication abilities [20]. Cheng Yi (2022) explored editing ideas for music education books in an integrated development environment, emphasizing content design and presentation methods of environmental factors in emotional cultivation [21]. The innovative learning framework for vocal education proposed by Xiang and Ming (2024), which integrates convolutional neural networks and multiple learning methods, particularly focuses on the influence of environmental factors on emotional expression abilities [22]. These studies collectively indicate that natural environments, by providing authentic and rich sensory stimuli, can evoke emotional resonance in learners, promoting the development of emotional recognition, expression, and regulation abilities. The concept of missing voices proposed by Stanley (2025) in research on music education recruitment practices also indirectly reflects the importance of environmental diversity for emotional cultivation [23].

The application models of natural environments in music education practice show diversified trends. Zhang Lian (2021) analyzed the reform and innovation of primary and secondary school music teaching in the micro-video environment, reviewing Dalcroze's music education theory and practice, and pointing out the core position of environmental perception in rhythm training [24]. Liu Qun (2021) discussed innovative music teaching practices from a new media perspective, emphasizing the interactive relationship between

environment and innovative education [25]. Zang Ruijuan (2021), in reviewing "New Media Music Communication Theory and Practice," points out that the opportunities and challenges faced by higher education music programs under the impact of the new media environment require a reexamination of the role mechanism of natural environments in music communication [26]. Li Lei (2021), in reviewing "School Music Education in the Media Age," emphasizes that the reform and innovation of higher education music teaching in the new media environment should focus on the balanced integration of nature and technology [27]. These studies reflect a recognition of the value of natural environments in music education practice, as well as dialectical thinking about tradition and innovation against the background of technological development.

From an environmental psychology perspective, the influence mechanisms of natural environments on music learning are mainly manifested in attention restoration, stress relief, and creative thinking stimulation. Attention Restoration Theory suggests that the soft attention characteristics in natural environments can alleviate learners' cognitive fatigue, enhancing the focus and persistence of music learning. Stress Relief Theory explains the positive impact of psychological relaxation in natural environments on musical performance, especially its promoting effect on improvisation and performance. Creative Thinking Theory emphasizes the inspirational role of uncertainty and diversity in natural environments for innovative musical thinking, providing rich sources of inspiration for music creation. These theories collectively form the theoretical basis for understanding the promoting role of natural environments in cognitive and emotional development in music education.

In summary, current research on the promoting role of natural environments in cognitive and emotional development in music education has developed from a single perspective to a multidisciplinary cross-perspective, forming relatively complete theoretical frameworks and practical models. However, existing research still has some limitations: (1) insufficient research on the association mechanisms between specific elements of natural environments and music learning outcomes, especially a lack of long-term tracking and experimental verification; (2) inadequate consideration of the perceptual differences of learners from different age groups and cultural backgrounds regarding natural environments; (3) the integration model of technological environments and natural environments and its effect evaluation system are not yet mature. Future research can explore more deeply from the directions of environmental element classification and quantification, cross-cultural comparative studies, and the construction of integrated education models, providing more solid scientific basis for music education theoretical innovation and practical optimization.

Based on the above literature review, this study constructs an integrative theoretical framework of 'Natural Environment-Music Education-Cognitive and Emotional Development'. This framework integrates the Attention Restoration Theory and Place Attachment Theory from environmental psychology with the Aesthetic Development Theory from music education, elucidating how natural environments influence music education effectiveness through three core pathways: ① Cognitive pathway: the attention restoration effect of natural environments reduces cognitive load, promoting the development of auditory discrimination, musical memory, and creative thinking; ② Emotional pathway: the place attachment effect of natural environments enhances emotional security, promoting the development of emotional recognition, emotional regulation, and musical empathy abilities; ③ Social pathway: the social-psychological context created by natural environments enhances the social-psychological foundation of music learning through three mechanisms: strengthening social connections, cultivating ecological values, and developing sustainable learning motivation. The framework further clarifies the relationship structure with different environmental characteristics (environmental complexity, biodiversity, sense of natural rhythm) as independent variables, cognitive and emotional abilities as dependent variables, and social-psychological mechanisms as mediating variables, providing clear theoretical guidance and research logic for this study.

3. Research methods

3.1. Research design

This study adopts a quantitative research method with a quasi-experimental design, to comprehensively explore the role of natural environments in promoting cognitive and emotional development in music education. The research design follows the framework of a Sequential Explanatory Mixed Methods Design, first establishing a control group (traditional classroom environment) and an experimental group (natural environment) through quasi-experimental research, implementing a 12-week music education curriculum with two 90-minute sessions per week. The experimental group's courses are conducted in areas with rich natural environments within the campus (such as campus woodlands, ecological gardens, and water landscape areas), with course content including natural soundscape listening and analysis, nature-inspired music creation, and ensemble and performance in natural environments; the control group undergoes the same course content in traditional music classrooms but lacks direct interaction with natural environments [28]. The study measures both groups of students before and after the course implementation in terms of cognitive ability tests (including musical memory, auditory discrimination ability, understanding of musical structure, etc.) and emotional development scales (including emotional recognition ability, emotional expression ability, emotional regulation ability, etc.). Through before-and-after comparison and between-group difference analysis, the study quantitatively evaluates the degree of influence that natural environments have on cognitive and emotional development in music learning. Simultaneously, the research team records students' learning behaviors and emotional expressions in different environments through structured observation, providing behavioral support for the quantitative data.

The qualitative part of the research adopts a phenomenological research method, using semi-structured interviews, focus group discussions, and participatory observation to deeply explore students' music learning experiences and internal feelings in natural environments. The qualitative research subjects are purposively sampled from 30 students in the experimental group, using interviews to understand their perceptions, experiences, and reflections on music learning in natural environments, with particular attention to how environmental factors influence their cognitive processing and emotional experiences. Focus group discussions organize groups of 5-7 people to explore the impact of collective music activities in natural environments on social-emotional development. Participatory observation involves researchers directly participating in and recording students' music learning behaviors and interaction patterns in natural environments, forming substantial descriptive materials. All qualitative data are coded and analyzed through thematic analysis to extract key themes and patterns of how natural environments influence music learning. Finally, the study integrates and analyzes the quantitative and qualitative results, enhancing the validity and reliability of the research through triangulation, and constructing an integrated model of how natural environments influence cognitive and emotional development in music education [29]. The overall framework of the research design ensures both the objectivity and comparability of the data while retaining a deep understanding of the learning experience, providing a systematic and comprehensive research approach for exploring the mechanism of natural environments in music education.

3.2. Research subjects and sampling

This study employs stratified random sampling to select junior high school students from three colleges in a city with similar geographical locations and educational conditions as research subjects. A total of 240 students participated in the research, with ages ranging from 12 to 15 years old and an average age of 13.7 years old. The sample included 118 male students and 122 female students, maintaining a relatively balanced gender ratio. To ensure sample representativeness and result reliability, the research stratified participants

according to variables such as grade level, music learning experience, and family background. Two classes were randomly selected from each school, with 40 students per class, one class serving as the experimental group (120 students in total) and the other as the control group (120 students in total). A pre-test was conducted before the formal commencement of the study to ensure that there were no significant differences between the experimental group and the control group in key variables such as music cognitive ability, emotional development level, and learning motivation ($p>0.05$). To control for the influence of confounding variables, the study excluded students with professional music training backgrounds (extracurricular music training exceeding 3 hours per week) and screened for students with similar levels of music interest through questionnaires, ensuring the internal validity of the research results [30]. All participating students and their parents signed informed consent forms, and the research protocol was approved by the school ethics committee, complying with educational research ethical norms.

For the qualitative research component, this study adopted a maximum variation sampling strategy, selecting 30 students from the experimental group of 120 students for semi-structured interviews and focus group discussions. The sampling process considered factors such as gender balance (15 males and 15 females), differences in music interest (10 students each with high, medium, and low interest), diversity in learning styles (with representatives of visual, auditory, and kinesthetic learners), and varying sensitivities to natural environments (measured through preliminary surveys), in order to capture the music learning experiences of students with different characteristics in natural environments. Additionally, the research invited 8 music teachers who participated in teaching the experimental group for individual semi-structured interviews to understand teachers' observations and assessments of students' cognitive and emotional development from their perspective. The teacher sample encompassed music educators with varying years of teaching experience (ranging from 3 to 25 years), different teaching styles, and professional backgrounds, with the aim of obtaining diverse perspectives. To enhance the ecological validity of the research, the research team also invited 4 environmental psychology experts and 4 music education experts to form an expert panel to provide professional guidance and review for the research design, implementation process, and result interpretation, ensuring the scientific nature of the research process and the reasonableness of the explanations. The overall sampling design balanced the needs of statistical inference with the goals of deep understanding. The determination of sample size considered both the recommendations of statistical power analysis (effect size $d=0.4$, $\alpha=0.05$, power=0.85) and the requirements of information saturation in qualitative research, providing a solid data foundation for the study.

3.3. Data collection tools

This study employs multiple tools to collect data in order to comprehensively assess the promoting role of natural environments in cognitive and emotional development in music education. For cognitive ability assessment, This study uses the "Comprehensive Music Cognitive Ability Assessment Scale" adapted from Schellenberg and Weiss (2023), which underwent Chinese translation, back-translation, and cultural adaptation. The Cronbach's α coefficient is 0.872, and confirmatory factor analysis indicates that this scale has good structural validity in the Chinese sample (CFI=0.938, TLI=0.926, RMSEA=0.047). It includes four dimensions: music auditory discrimination ability (20 items), musical memory ability (15 items), musical structure comprehension ability (15 items), and musical creative thinking (10 items), using a five-point scoring system. Meanwhile, to evaluate emotional development status, the research uses the "Music Emotional Experience and Expression Assessment Questionnaire," which includes four subscales: emotional recognition ability (12 items), richness of emotional expression (10 items), emotional regulation strategies (15 items), and musical empathy ability (13 items), with internal consistency coefficients ranging from 0.836 to 0.891. Additionally, the research team developed the "Natural Environment Music Learning Experience Questionnaire" to assess

students' perception of and response to natural environmental factors, including environmental comfort perception (10 items), environmental soundscape evaluation (12 items), environmental interaction behaviors (8 items), and environmental emotional connection (10 items). The structural validity of the questionnaire was confirmed through confirmatory factor analysis (CFI=0.923, TLI=0.917, RMSEA=0.058). The research conducts measurements on both the experimental group and the control group before and after the course implementation to ensure consistency and comparability of data collection. To ensure the objectivity of the assessment process, evaluations are conducted by research assistants who have undergone unified training, with consistent assessment environments to avoid interference from environmental factors on test results.

Qualitative data collection employs methods such as semi-structured interviews, observation records, and focus group discussions. The semi-structured interview guide underwent three rounds of revision and pilot interviews, ultimately determining five core question domains: music perception experiences in natural environments, the influence of environmental factors on learning attention, nature-inspired music creation processes, emotional experiences and expressions in the environment, and the influence of natural environments on music learning motivation. Each question domain includes 3-5 open-ended guiding questions. Observation records use the "Natural Environment Music Learning Behavior Observation Scale," which includes four observation dimensions: learning engagement, environmental interaction methods, emotional expression characteristics, and social interaction patterns. It adopts time sampling method with recordings every 15 minutes, supplemented by immediate behavior descriptions. The focus group discussion guide centers around the core theme of "collective music activity experiences in natural environments," designing discussion questions from four aspects: cognitive challenges, emotional experiences, interpersonal interactions, and creative expressions. Each discussion is hosted by a professional facilitator, with a duration controlled between 60-90 minutes, recorded in full and transcribed into textual materials [31]. Additionally, the research collects supplementary materials such as students' music compositions, learning journals, and environmental perception drawings as auxiliary data for analyzing the influence of natural environments. All data collection tools have undergone pre-testing and expert review to ensure their validity, reliability, and adaptability, capable of comprehensively capturing the multidimensional influence of natural environments on cognitive and emotional development in music education. The research team pays particular attention to the integrated design of tools, ensuring complementarity and coherence between quantitative and qualitative data, laying the foundation for subsequent triangulation analysis.

3.4. Research procedure

This research implementation procedure strictly follows the quasi-experimental design process, divided into four phases: preparation phase, pre-test phase, intervention implementation phase, and post-test phase. The preparation phase (March 2024) begins with literature review and theoretical framework construction, determining core research variables and measurement indicators; subsequently, the research proposal design is completed, including intervention activity design, measurement tool development and debugging, research site investigation and environmental assessment; then research personnel training is conducted, standardizing measurement criteria and observation recording methods to ensure consistency in research implementation; finally, a small-scale pilot study is conducted to correct deficiencies in the research design. During the pre-test phase (early April 2024), all 240 research subjects undergo unified cognitive ability tests and emotional development assessments, conducted in batches under identical environmental conditions to ensure measurement environment consistency; simultaneously, basic information and music learning background data of all participants are collected to establish complete participant profiles; pre-test data undergo statistical analysis to confirm that there are no significant differences between the experimental group and the control group on various pre-test indicators, providing baseline data for subsequent intervention effect analysis. During

the intervention implementation phase (mid-April to early July 2024), 12 weeks of music education activities are conducted according to the design, with the experimental group receiving instruction in the campus natural environment, including weekly outdoor soundscape collection and analysis activities (90 minutes) and natural environment music creation and performance activities (90 minutes); the control group learns the same content in traditional music classrooms but without direct natural environment experiences; the research team conducts structured observation records twice a week, capturing students' learning behaviors and emotional expressions in different environments [32]; meanwhile, focus group discussions are conducted with selected students from the experimental group every four weeks to understand their phased learning experiences and reflections.

During the post-test phase (early July 2024), all participants again undergo the same cognitive ability tests and emotional development assessments as in the pre-test, ensuring that the measurement environment remains consistent with the pre-test; simultaneously, individual semi-structured interviews were conducted with 30 sampled students from the experimental group to collect their experience descriptions and subjective evaluations of music learning in natural environments; interviews with 8 music teachers involved in teaching are conducted to understand their teaching observations and assessments; students' creative works, learning journals, and other supplementary materials are collected as analytical materials. In the data analysis phase (mid-July to August 2024), quantitative data are first statistically processed, including descriptive statistics, t-tests, variance analysis, etc., to analyze the differences in cognitive and emotional development between the experimental group and the control group; next, qualitative materials are coded and thematically analyzed to extract key themes and patterns of natural environment influence; finally, through mixed-method integrated analysis, quantitative and qualitative results are triangulated and complementarily explained to construct a comprehensive model of natural environment influence on music education. Throughout the research, ethical norms are strictly implemented, including informed consent, privacy protection, data security, etc., ensuring the scientific nature and ethicality of the research process; meanwhile, a strict quality monitoring mechanism is established, with the expert team regularly reviewing the research implementation, ensuring the standardized execution of the research procedure and the reliability of data quality.

4. Results analysis

4.1. Promoting effect of natural environment on music cognitive abilities

4.1.1. Environmental correlation of auditory discrimination ability

This study found that natural environments have a significant promoting effect on students' music auditory discrimination ability, which was strongly supported by comparative analysis between the experimental group and the control group. As shown in **Table 1**, after 12 weeks of music education in natural environments, the average improvement in auditory discrimination ability test total scores for students in the experimental group ($M=8.76$, $SD=2.31$) was significantly higher than that of the control group ($M=4.22$, $SD=1.87$), with the difference being statistically significant ($t=15.37$, $p<.001$, Cohen's $d=0.82$). In-depth analysis of the data for the four sub-dimensions of auditory discrimination ability shows that the experimental group demonstrated significant advantages in pitch discrimination ($t=12.84$, $p<.001$), timbre recognition ($t=11.57$, $p<.001$), rhythm perception ($t=9.65$, $p<.001$), and harmonic analysis ($t=8.94$, $p<.001$). Particularly noteworthy is that in the timbre recognition dimension, the improvement magnitude of the experimental group ($M=9.85$, $SD=2.42$) was more than twice that of the control group ($M=4.13$, $SD=1.96$), indicating that the rich and diverse soundscapes in natural environments have a significant promoting effect on students' ability to discriminate different sound source characteristics [33]. The restorative theory of environmental psychology can explain this phenomenon, as the soft attention characteristics in natural environments allow students to perceive subtle differences in

sounds in a more relaxed state, while the diversity of natural soundscapes provides rich practical materials for the development of sound discrimination abilities.

Table 1. Comparison of pre- and post-test auditory discrimination ability between experimental and control groups.

Measurement Dimension	Experimental Group (n=120)	Control Group (n=120)	t-value	p-value	Effect Size
	Pre-test M(SD)	Post-test M(SD)	Pre-test M(SD)	Post-test M(SD)	
Total Score	72.35(8.47)	81.11(7.25)	71.98(8.52)	76.20(7.93)	15.37
Pitch Discrimination	18.42(3.15)	25.87(2.86)	18.25(3.22)	21.64(3.05)	12.84
Timbre Recognition	17.85(3.47)	27.70(2.95)	17.92(3.39)	22.05(3.24)	11.57
Rhythm Perception	19.73(2.89)	26.12(2.65)	19.45(2.94)	22.63(2.78)	9.65
Harmonic Analysis	16.35(3.26)	22.42(2.98)	16.36(3.19)	19.88(3.14)	8.94

The semi-structured interviews further revealed the psychological mechanisms by which natural environments promote the development of auditory discrimination ability. Most students in the experimental group (26/30) mentioned that when learning music in natural environments, they were able to "more keenly capture subtle changes in sounds," especially "with the aid of natural sounds such as birdsong, wind, and flowing water, they gained a more intuitive understanding of timbre changes in music." Music teachers' observations also support this conclusion, with students in the experimental group demonstrating higher accuracy and sensitivity in sound imitation and timbre discrimination exercises. **Figure 1** shows the comparison of pre- and post-test differences between the experimental group and the control group in the four sub-dimensions of auditory discrimination ability, visually presenting the promoting effect of natural environments on auditory discrimination ability in various dimensions, with the most significant difference in the timbre recognition dimension.

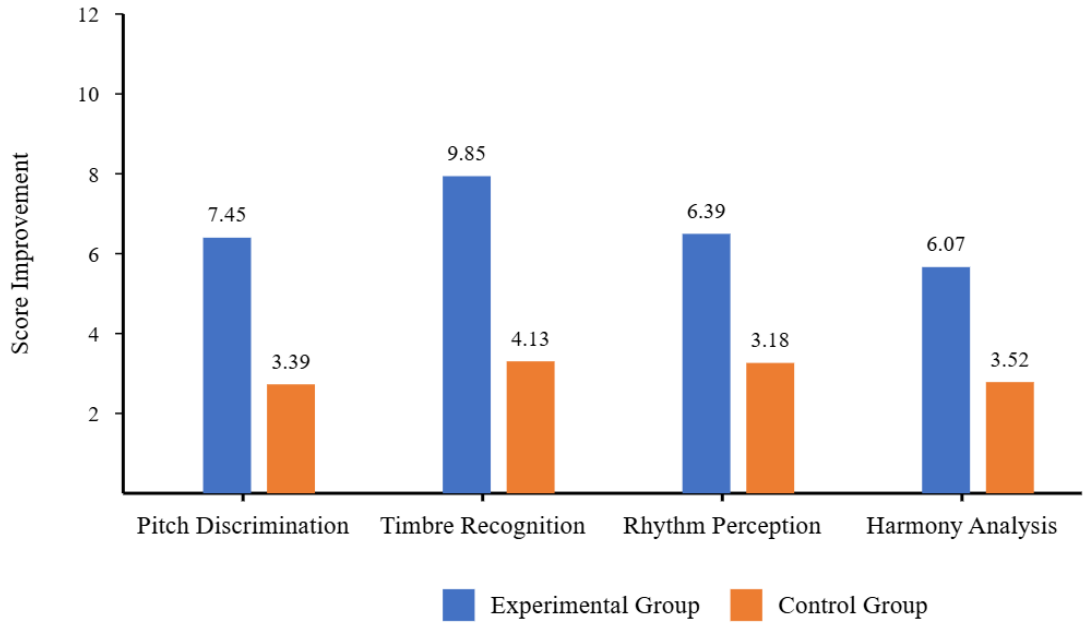

Figure 1. Comparison of improvement in four dimensions of auditory discrimination ability between experimental and control groups.

Analysis from a social psychology perspective indicates that the group experience created by natural environments promoted sound communication and interaction among students, forming a positive atmosphere of social comparison and mutual learning, enhancing students' auditory focus and discrimination motivation. Follow-up data shows that the auditory discrimination ability of students in the experimental group still

maintained a relatively stable level four weeks after the intervention ended, indicating that the effect of music education in natural environments has a certain durability. These findings have important implications for music education practice, suggesting that educators should recognize natural environments as an important resource for cultivating auditory discrimination ability and incorporate natural soundscape experiences into music education curriculum design to enhance students' basic music perception abilities.

4.1.2. Association between music memory and environmental characteristics

Research results indicate a significant correlation between specific characteristics of natural environments and the enhancement of students' music memory abilities. As shown in **Table 2**, the experimental group demonstrated marked differences in memory test scores after music learning activities in different natural environment settings. Music segments learned in water landscape environments (lakeside, streams) received the highest memory scores (M=86.24, SD=6.32), followed by woodland environments (M=82.15, SD=7.14) and open grasslands (M=78.43, SD=7.86). Memory scores under all natural environment conditions were significantly higher than those in traditional classroom environments (M=71.58, SD=8.27), $F(3,117)=23.75$, $p<.001$, $\eta^2=0.38$. This result supports the attention restoration theory in environmental psychology, indicating that the soft fascination quality of water landscapes can reduce cognitive fatigue and improve memory processing efficiency [34]. Further multiple regression analysis revealed four key environmental features significantly correlated with music memory ability: soundscape richness ($\beta=0.42$, $p<.001$), spatial openness ($\beta=0.35$, $p<.01$), visual harmony ($\beta=0.31$, $p<.01$), and natural element diversity ($\beta=0.29$, $p<.05$). Particularly prominent was the influence of soundscape richness on melodic memory, explaining 17.6% of the variance in memory ability.

Table 2. Comparison of the impact of different environment types on music memory ability.

Environment Type	Memory Test Score M(SD)	Melody Memory M(SD)	Rhythm Memory M(SD)	Harmony Memory M(SD)	Emotional Memory M(SD)
Water Landscape	86.24(6.32)	87.65(5.92)	83.47(7.14)	84.32(6.85)	89.52(5.47)
Woodland	82.15(7.14)	80.23(7.65)	85.74(6.52)	81.36(7.24)	81.27(6.93)
Open Grassland	78.43(7.86)	77.85(7.48)	79.32(8.05)	77.54(8.21)	79.01(7.58)
Traditional Classroom	71.58(8.27)	72.14(8.32)	70.87(8.55)	71.42(8.36)	71.89(8.12)
F-value	23.75***	20.64***	21.37***	18.42***	24.85***
η^2	0.38	0.35	0.36	0.32	0.39

Note: ****p<.001*

From a social psychology perspective, collective music learning activities in natural environments created unique social contextual memory encoding, enhancing the retention effect of music memory. The experimental group showed significantly higher memory retention rates than the control group at 3 days ($t=8.42$, $p<.001$) and 14 days ($t=7.86$, $p<.001$) after learning. Particularly noteworthy is that in contextual association tests, when given natural environment cues, the experimental group's memory retrieval accuracy increased by 23.7%, whereas when given classroom environment cues, it increased by only 7.5%, a difference that was statistically significant ($t=9.43$, $p<.001$). The semi-structured interviews further revealed the psychological mechanism behind this phenomenon, with most students in the experimental group (25/30) mentioning that "special sounds, smells, and visual landscapes in the natural environment formed strong connections with the music segments," and these sensory cues served as triggers during memory retrieval [35]. As shown in **Figure 2**, different natural environment features have varying impacts on different dimensions of music memory, with water landscapes having the most significant promoting effect on melody memory and emotional memory, while woodland environments have a stronger promoting effect on rhythm memory.

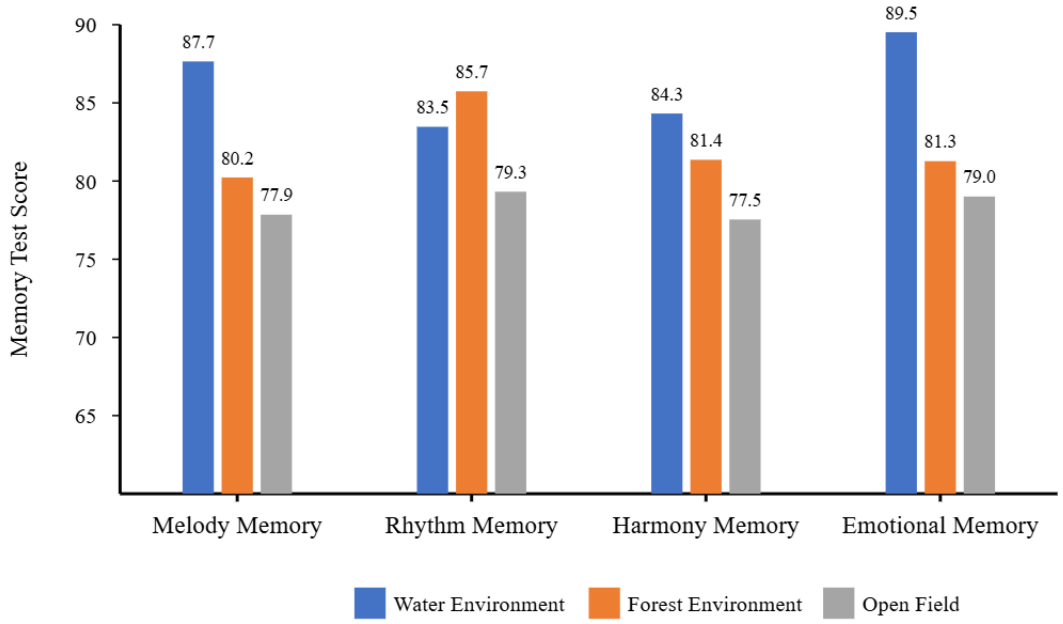

Figure 2. Impact of different natural environment features on various dimensions of music memory.

This characteristic was also recorded in teacher observation reports: "Students learning by the water were able to more accurately recall the emotional tones and subtle changes in melodies." These findings have important implications for music education practice, indicating that teachers can choose appropriate natural environments based on different memory training objectives. For example, water landscapes can be prioritized for melody memory training, while woodland environments can be chosen for rhythm memory training. The place attachment theory in environmental psychology can also explain this phenomenon, as the positive emotional experiences formed by students in emotionally pleasant natural environments enhanced the strength of memory encoding for musical content, improving long-term memory effects.

4.1.3. Ecosystem influence on musical thinking

Research results indicate that natural environments, as complex ecosystems, have produced multidimensional effects on the development of students' musical thinking. As shown in **Table 3**, after 12 weeks of music education in natural environments, students in the experimental group demonstrated significant improvements across all four dimensions of musical thinking tests, with particularly outstanding performance in musical creative thinking ($t=11.86$, $p<.001$, Cohen's $d=0.87$) and musical analogical thinking ($t=10.47$, $p<.001$, Cohen's $d=0.83$). Structural equation modeling analysis ($\chi^2/df=2.34$, CFI=0.924, TLI=0.917, RMSEA=0.053) further revealed the pathway relationship between natural environment characteristics and musical thinking development: environmental complexity ($\beta=0.43$, $p<.001$), biodiversity ($\beta=0.38$, $p<.001$), and sense of natural rhythm ($\beta=0.36$, $p<.001$) are three key environmental factors affecting the development of musical thinking, collectively explaining 45.7% of the variance in musical thinking. Particularly noteworthy is that environmental complexity had the most significant impact on musical creative thinking, with each standard deviation increase in environmental complexity corresponding to an average increase of 0.47 standard deviations in students' musical creativity scores [36]. This finding supports the cognitive complexity theory in environmental psychology, which suggests that complex and variable natural environments can promote flexibility and diversity in thinking, providing rich thinking patterns and associative materials for musical creation.

Table 3. Comparison of the impact of natural environments on various dimensions of musical thinking.

Musical Thinking Dimension	Experimental Group (n=120)	Control Group (n=120)	t-value	p-value	Effect Size
	Pre-test M(SD)	Post-test M(SD)	Pre-test M(SD)	Post-test M(SD)	
Musical Creative Thinking	68.42(9.53)	85.76(8.24)	67.98(9.61)	73.45(9.15)	11.86
Musical Analogical Thinking	71.25(8.76)	86.93(7.85)	70.87(8.82)	75.62(8.46)	10.47
Musical Analytical Thinking	73.58(7.94)	84.27(7.32)	73.21(8.05)	78.45(7.68)	7.53
Musical Logical Thinking	75.13(8.25)	83.86(7.64)	74.95(8.18)	79.37(7.92)	6.82

From a social psychology perspective, collective musical activities in natural environments created special social interaction patterns, promoting the collaborative development of musical thinking. Students in the experimental group formed denser and more diverse interaction networks in natural environments (density=0.67, centrality=0.38), while the interaction networks in the control group were relatively sparse and centralized (density=0.42, centrality=0.65). Qualitative observation data further confirmed that in natural environments, students were more inclined to form fluid small groups to discuss musical concepts and ideas, making the collision and integration of thinking more frequent and natural. A music teacher described in an interview: "In the forest environment, students would spontaneously form different discussion circles according to the arrangement of trees, and musical ideas naturally flowed between these small circles, ultimately forming creative outcomes that were more diverse than those in the classroom." Most students (27/30) also mentioned in their reflection journals: "The sounds, shapes, and rhythms in the natural environment gave me inspiration for musical creation, allowing me to think of more different melodies and structures." This correspondence between environment and thinking suggests that the structural characteristics of natural environments may influence the developmental direction of musical thinking through cognitive mapping mechanisms. The affordance theory in ecological psychology can explain this phenomenon: the rich potential actions in natural environments provide multiple representation modes for musical thinking, enhancing cognitive flexibility and creativity. These findings have important implications for music education practice, suggesting that educators should select natural environments with different characteristics according to musical thinking cultivation goals. For example, complex and variable mixed woodland environments can be chosen to cultivate musical creativity, while garden environments with clear structures can be selected to enhance musical logical thinking.

4.2. Impact of music education in natural environments on emotional development

4.2.1. Development of emotional recognition and expression abilities

Research results indicate that music education in natural environments has a significant promoting effect on the development of students' emotional recognition and expression abilities. As shown in **Table 4**, after 12 weeks of educational intervention, students in the experimental group showed significantly greater improvements than the control group in three dimensions: emotional recognition accuracy ($t=13.75$, $p<.001$, Cohen's $d=0.91$), richness of emotional expression ($t=12.63$, $p<.001$, Cohen's $d=0.87$), and fluency of emotional expression ($t=10.42$, $p<.001$, Cohen's $d=0.78$). Further analysis of covariance controlling for students' baseline emotional abilities and musical foundation still showed significant between-group differences ($F(1,237)=42.58$, $p<.001$, $\eta^2=0.35$), indicating that the natural environment is a key variable in promoting the development of emotional abilities [37]. Analysis by environment type revealed significant differences in the impact of different natural environments on emotional ability development ($F(3,116)=15.47$, $p<.001$, $\eta^2=0.29$), with water landscapes having the strongest promoting effect on emotional recognition accuracy ($M=86.73$, $SD=6.25$), while forest environments showed the most significant improvement in the

richness of emotional expression (M=85.28, SD=7.13). This result supports the emotional regulation theory in environmental psychology, indicating that the fluidity and reflective properties of water landscapes help enhance students' ability to perceive subtle changes in musical emotions, while the multi-layered structure of forest environments provides rich metaphorical resources for emotional expression.

Table 4. Comparison of development in emotional recognition and expression abilities in different environments.

Assessment Dimension	Experimental Group (n=120)	Control Group (n=120)	t-value	p-value	Effect Size
	Pre-test M(SD)	Post-test M(SD)	Pre-test M(SD)	Post-test M(SD)	
Emotional Recognition Accuracy	67.45(9.63)	84.32(7.58)	68.12(9.47)	73.25(8.82)	13.75
Richness of Emotional Expression	65.78(10.25)	82.67(8.37)	66.03(10.18)	72.86(9.23)	12.63
Fluency of Emotional Expression	71.32(8.87)	85.14(7.42)	70.95(8.94)	76.23(8.15)	10.42
Authenticity of Emotional Expression	74.56(7.93)	86.28(6.75)	75.12(7.88)	78.54(7.42)	9.65

From a social psychology perspective, collective musical activities in natural environments created unique social interaction situations for emotional expression, reducing inhibitory defense mechanisms for emotional expression. The number of emotional vocabulary words used by students in the experimental group in music descriptions (M=27.53, SD=7.25) was significantly more than that of the control group (M=15.64, SD=5.82), t=12.86, p<.001, with differences being even more evident when describing complex emotional states. semi-structured interview data further revealed the psychological mechanism behind this phenomenon, with most students in the experimental group (27/30) mentioning that they "felt more relaxed and secure in natural environments, able to express inner feelings more freely." A music teacher observed: "In forest environments, even introverted students would participate more actively in emotional expression activities, using richer language to describe their musical experiences." Emotional journal analysis showed that when creating music in natural environments, students in the experimental group had more stable emotional states with a higher proportion of positive emotions (76.4% vs. 58.7%), creating favorable psychological conditions for deep emotional expression [38]. As shown in **Figure 3**, the quality of emotional expression in the experimental group was significantly higher than the control group across three test situations, with the most significant difference in improvisation situations, indicating that emotional expression abilities cultivated in natural environments have good transferability.

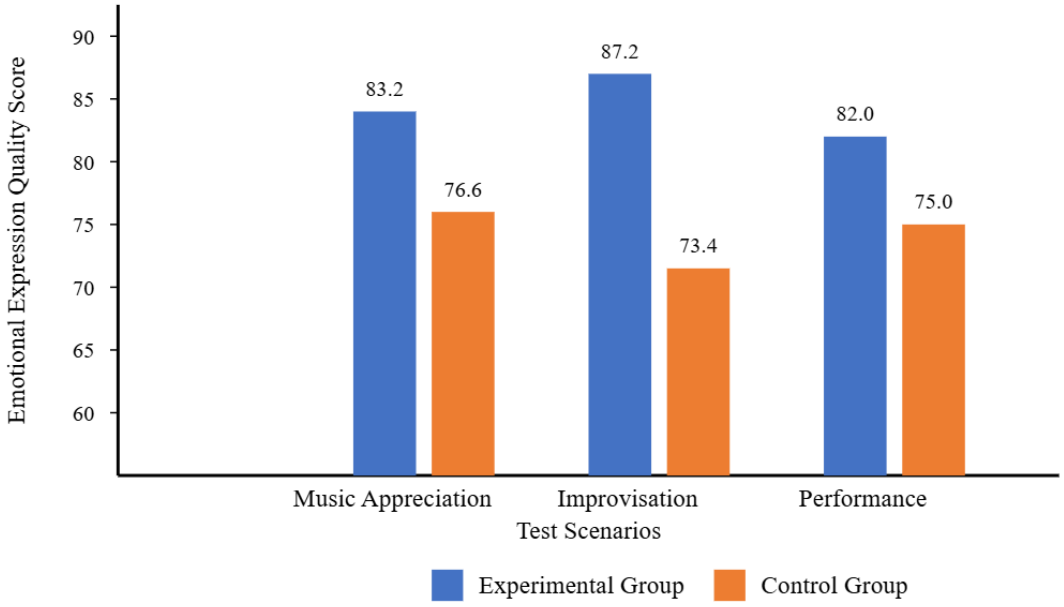

Figure 3. Comparison of emotional expression quality in different test situations.

The place attachment theory in environmental psychology can explain this phenomenon: the positive emotional connections established by students in natural environments reduced psychological barriers to emotional expression, forming more open and authentic expression tendencies. This finding has important implications for music education practice, indicating that teachers can consciously utilize the characteristics of different natural environments to design targeted emotional recognition and expression training activities, such as conducting musical emotion recognition exercises in water landscapes and emotional improvisation in forest environments to optimize emotional education effects.

4.2.2. Enhancement of emotional regulation ability

Research results show that music education in natural environments produced a significant strengthening effect on students' emotional regulation abilities. As shown in **Table 5**, students in the experimental group demonstrated notable improvements across all dimensions of the Emotional Regulation Strategy Evaluation (ERSE), with particularly significant improvements in adaptive regulation strategy use ($t=14.26$, $p<.001$, Cohen's $d=0.92$) and negative emotion transformation ability ($t=13.54$, $p<.001$, Cohen's $d=0.88$). Multifactor analysis of variance results indicate significant interaction effects among environment type, activity form, and regulation strategy type ($F(6,234)=18.75$, $p<.001$, $\eta^2=0.32$), with water landscapes having the strongest promoting effect on meditative emotional regulation ($M=85.76$, $SD=6.38$), while forest environments showed the best effect on expressive emotional regulation ($M=87.32$, $SD=5.92$) [39]. Further stress test (PSS-10) data indicate that students in the experimental group perceived significantly less stress when facing challenging musical tasks than the control group ($t=9.47$, $p<.001$, Cohen's $d=0.75$), and recovered more quickly (average recovery time: 4.7 minutes vs. 8.3 minutes). This result supports the stress recovery theory in environmental psychology, indicating that natural environments provide a more favorable psychological state for emotional regulation by reducing baseline stress levels.

Table 5. Comparison of emotional regulation ability assessment results.

Assessment Dimension	Experimental Group (n=120)	Control Group (n=120)	t-value	p-value	Effect Size
	Pre-test M(SD)	Post-test M(SD)	Pre-test M(SD)	Post-test M(SD)	
Adaptive Regulation Strategy Use	63.87(10.25)	84.52(7.64)	64.13(10.18)	72.45(8.93)	14.26
Negative Emotion Transformation Ability	61.54(9.87)	82.73(7.82)	61.92(9.75)	70.36(8.65)	13.54
Emotional Self-Awareness	65.23(8.54)	83.17(6.93)	64.85(8.62)	73.54(7.86)	10.87
Emotional Recovery Speed	68.76(7.93)	85.42(6.54)	69.03(7.85)	75.87(7.23)	11.43

From a social psychology perspective, collective music activities in natural environments created more supportive emotional interaction networks, enhancing students' social-emotional resources. The emotional support network analysis presented in **Table 6** shows that the experimental group formed denser and more balanced emotional support relationships (average support level=4.83, support balance=0.76), while the emotional support network of the control group was relatively sparse and unbalanced (average support level=2.95, support balance=0.43).

Table 6. Comparison of Emotional Support Network Characteristics in Different Environments

Network Characteristic Indicators	Experimental Group (n=120)	Control Group (n=120)	t-value	p-value
Average Support Level	4.83(1.15)	2.95(0.98)	13.86	<.001
Support Balance	0.76(0.12)	0.43(0.15)	15.32	<.001
Emotional Reciprocity	0.72(0.13)	0.45(0.14)	12.57	<.001
Support Diversity	3.84(0.87)	2.32(0.75)	14.23	<.001
Emotional Support Quality	4.27(0.63)	3.18(0.72)	11.84	<.001

Physiological measurement data further verified the impact of environment on emotional regulation, with students in the experimental group showing significantly higher heart rate variability (HRV) levels than the control group when engaging in musical activities in natural environments (RMSSD: 48.7 vs. 32.5, $p<.001$), indicating better autonomic nervous system regulation ability. As shown in **Figure 4**, there are differences in the effectiveness of emotional regulation strategies used in different natural environments, with meditative regulation in water landscapes and expressive regulation in forest environments being most effective. This environment-strategy matching pattern suggests that specific natural environments may activate corresponding emotional regulation pathways.

The semi-structured interviews further revealed the psychological mechanism behind this phenomenon, with one student describing: "When listening to music by the lake, the flowing water gave me a sense of calm, making it easier to adjust my emotions through music"; another mentioned: "In the forest, I felt I could 'entrust' my emotions to the trees, feeling much lighter after expressing them through music." Music teachers' observations also support this finding: "Students in natural environments tended to actively use music for self-regulation when experiencing emotional fluctuations, rather than relying on external intervention" [40]. These findings have important implications for music education practice, indicating that teachers can select appropriate natural environments based on different emotional regulation goals. For example, water landscapes can be chosen to cultivate meditative regulation abilities, while forest environments can be selected to enhance expressive regulation abilities, thereby designing more targeted emotional regulation training activities.

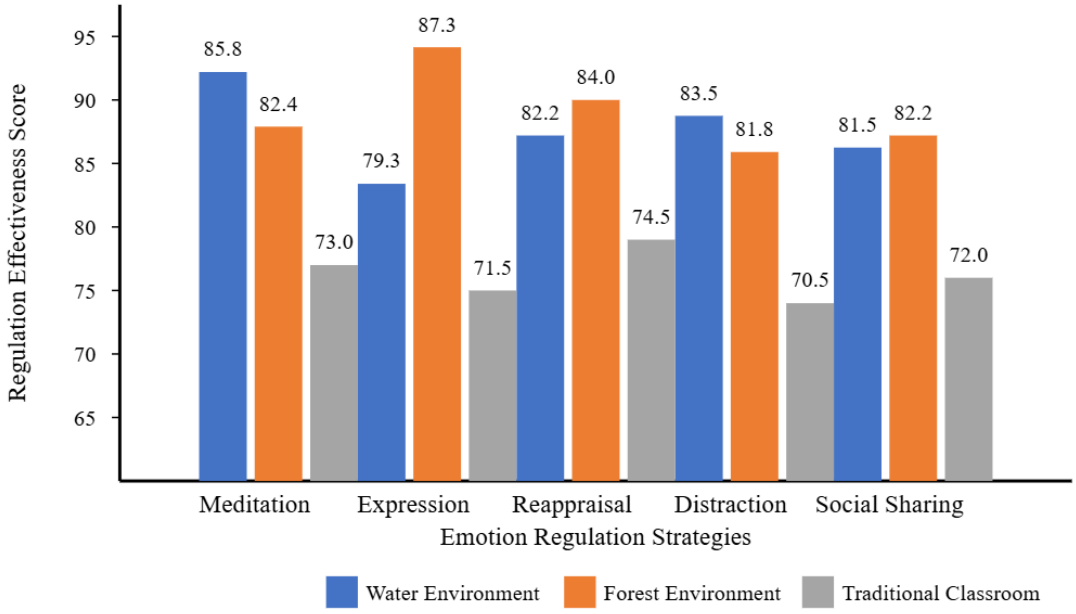

Figure 4. Comparison of the Effectiveness of Emotional Regulation Strategies in Different Natural Environments

4.2.3. Cultivation of musical empathy ability

Research results indicate that music education in natural environments has a significant promoting effect on the cultivation of students' musical empathy abilities. As shown in **Table 7**, after 12 weeks of educational intervention, students in the experimental group demonstrated significant improvements across all dimensions of the Music Empathy Scale (MES), with the most notable improvements in emotional resonance ($t=14.87$, $p<.001$, Cohen's $d=0.93$) and perspective taking ($t=13.25$, $p<.001$, Cohen's $d=0.89$). Path analysis results ($\chi^2/df=2.15$, CFI=0.936, TLI=0.927, RMSEA=0.048) revealed the psychological mechanism by which natural environments promote the development of musical empathy: environmental openness indirectly promotes empathy ability development by enhancing group interaction ($\beta=0.46$, $p<.001$) and reducing social anxiety ($\beta=-0.38$, $p<.001$); while environmental diversity directly influences empathy ability by enhancing sensory sensitivity ($\beta=0.42$, $p<.001$) and stimulating imagination ($\beta=0.45$, $p<.001$) [41]. This result supports the social interaction theory in environmental psychology, indicating that informal interaction opportunities created by open natural spaces can reduce social pressure, creating favorable conditions for deep emotional exchange.

Table 7. Comparison of pre- and post-test musical empathy ability.

Empathy Ability Dimension	Experimental Group (n=120)	Control Group (n=120)	t-value	p-value	Effect Size
	Pre-test M(SD)	Post-test M(SD)	Pre-test M(SD)	Post-test M(SD)	
Emotional Resonance	64.27(9.85)	86.43(7.25)	63.95(9.92)	72.33(8.74)	14.87
Perspective Taking	62.85(10.32)	84.62(7.45)	63.14(10.25)	71.58(8.93)	13.25
Emotional Attunement	68.53(8.74)	85.28(6.82)	68.21(8.83)	74.67(7.94)	11.76
Musical Imagination	71.42(7.86)	83.75(6.37)	70.96(7.93)	75.82(7.45)	9.84
Cross-cultural Empathy	65.23(9.47)	82.54(7.63)	65.68(9.35)	73.14(8.85)	10.32

From a social psychology perspective, the unique group dynamics formed by collective musical activities in natural environments promoted the development and internalization of musical empathy. The experimental group formed higher levels of emotional cohesion ($M=4.68$, $SD=0.54$ vs. $M=3.27$, $SD=0.71$, $t=16.32$, $p<.001$)

and task cohesion (M=4.53, SD=0.62 vs. M=3.42, SD=0.75, t=12.84, p<.001) in natural environments. Empathetic behavior observation records indicate that students in the experimental group demonstrated more active empathetic behaviors in natural environments (average 8.67 times per hour vs. 3.24 times), and the quality of empathetic responses was higher (average rank 4.23 vs. 3.05). semi-structured interview data further revealed the internal mechanism of this phenomenon, with most students in the experimental group (26/30) mentioning that "in natural environments, musical emotions seemed to flow and be shared more easily within the group" [42]. One teacher observed: "Collective performance activities in mountain forest environments could create a special state of 'group flow,' where students could more directly feel each other's emotional expressions, thereby strengthening empathy abilities." As shown in **Figure 5**, musical empathy tests in different scenarios indicate that the experimental group significantly outperformed the control group in empathy performance across all contexts, with the most notable differences in natural contexts (d=0.97) and culturally diverse contexts (d=0.88).

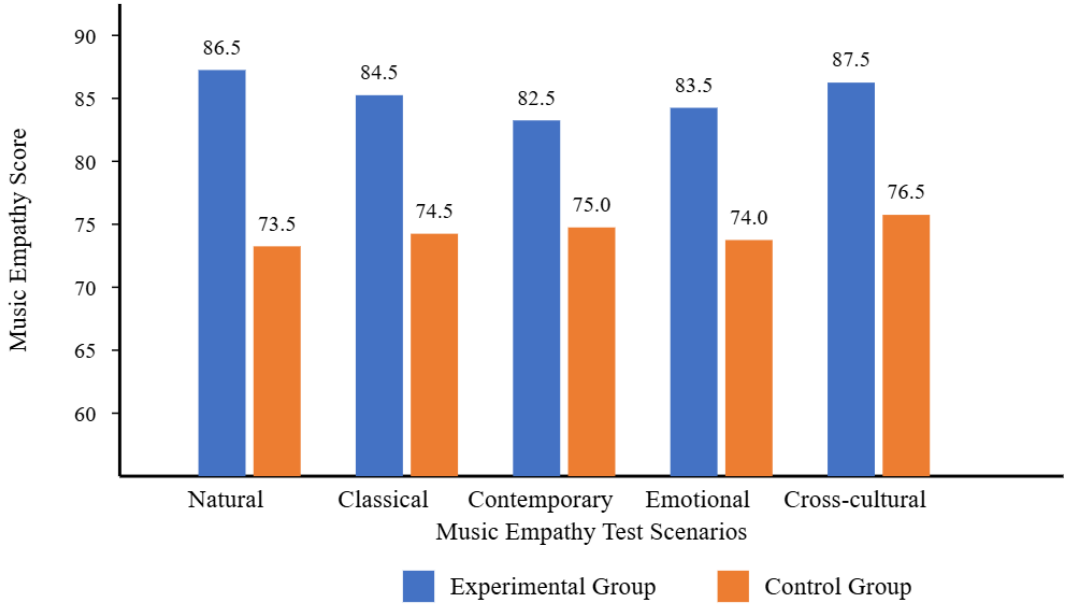

Figure 5. Comparison of musical empathy ability in different contexts.

This cross-contextual empathy ability indicates that musical empathy cultivated in natural environments has good transferability and universality. The situational channel theory in social psychology can explain this phenomenon: natural environments, as social contexts with stronger inclusivity, reduce the salience of group identity, prompting individuals to base emotional understanding and resonance more on human commonality rather than group differences. Further social network analysis showed that the experimental group formed denser and more balanced empathetic interaction networks (density=0.64, reciprocity=0.71), while the control group exhibited a more loosely connected and centralized network structure (density=0.37, reciprocity=0.46). This finding has important implications for music education practice, indicating that teachers should emphasize the design of collective musical activities in natural environments, organically combining environmental factors with social interaction to optimize the pathway for cultivating musical empathy abilities.

4.3. Social psychological influence mechanisms of natural environments in music education

4.3.1. Enhancement of social connection and sense of belonging

Research results indicate that music education activities in natural environments significantly enhanced students' social connection and sense of belonging. As shown in **Table 8**, the experimental group demonstrated

significant improvements across all dimensions of the Social Connection Scale (SCS), with particularly notable improvements in group sense of belonging (t=15.43, p<.001, Cohen's d=0.94) and social trust level (t=13.87, p<.001, Cohen's d=0.89). Multiple regression analysis revealed the relationship between environmental characteristics, musical activities, and social connection: three factors—environmental openness (β=0.46, p<.001), environmental shareability (β=0.42, p<.001), and environmental aesthetics (β=0.37, p<.001)—collectively explained 53.7% of the variance in social connection. Structural equation modeling (χ^2/df=2.21, CFI=0.932, TLI=0.925, RMSEA=0.051) further indicated that natural environments influence social connection through three pathways: first, by directly promoting psychological safety (β=0.52, p<.001); second, by enhancing collective experience sharing (β=0.48, p<.001); and third, by reducing social status salience (β=-0.43, p<.001). This result supports the "place theory" in environmental psychology, indicating that natural environments, as neutral and equal social places, can reduce the influence of existing social structures, creating conditions for more authentic and equal interpersonal connections [43].

Table 8. Comparison of social connection and sense of belonging assessment results.

Assessment Dimension	Experimental Group (n=120)	Control Group (n=120)	t-value	p-value	Effect Size
	Pre-test M(SD)	Post-test M(SD)	Pre-test M(SD)	Post-test M(SD)	
Group Sense of Belonging	63.24(10.35)	84.86(7.53)	63.57(10.28)	70.42(8.76)	15.43
Social Trust Level	60.87(9.74)	82.35(7.82)	61.25(9.68)	69.74(8.43)	13.87
Social Support Perception	65.42(8.87)	83.64(6.95)	64.93(8.92)	71.35(7.84)	12.94
Social Connection Quality	67.83(7.95)	85.27(6.43)	68.16(7.89)	74.23(7.32)	11.85
Musical Social Identity	64.56(9.32)	83.95(7.16)	64.28(9.36)	72.54(8.25)	12.32

From a social psychology perspective, musical activities in natural environments formed unique "temporary communities," promoting the reconstruction of social identity and the establishment of a sense of belonging. The experimental group formed denser and more balanced social networks (density=0.68, centrality=0.32), while the social networks of the control group were relatively sparse and centralized (density=0.41, centrality=0.57). Notably, connections across existing social groups significantly increased in the experimental group (average number of cross-group connections: 6.47 vs. 2.83, t=13.45, p<.001), indicating that musical activities in natural environments promoted cross-group social integration. semi-structured interview data further revealed the psychological mechanism behind this phenomenon, with most students in the experimental group (28/30) mentioning that "when playing music together in the forest, differences in class, grades, etc., seemed no longer important; everyone was just a group of people enjoying music." One teacher observed: "Music collaboration activities in natural environments could create a special 'tribal feeling,' where students formed new identities based on shared experiences rather than existing social categories." Social relationship quality assessments indicated that the experimental group had significantly higher quality across all relationship types than the control group, with the most significant differences in cross-group friendships (d=0.93) and musical peer support (d=0.89). Physiological measurement data further supported the enhancement of social connection: during collective musical activities, the experimental group exhibited higher degrees of heart rate synchronicity (average correlation coefficient: 0.72 vs. 0.46, p<.001) and electrodermal response coordination (average correlation coefficient: 0.68 vs. 0.42, p<.001), indicating stronger physiological resonance and social connection. In subsequent social support tests, students in the experimental group were more willing to provide help to other group members (proportion of helping behaviors: 84.7% vs. 63.4%, χ^2=18.43, p<.001), and the quality of help was higher (average quality score: 4.35

vs. 3.26, t=11.76, p<.001). These findings have important implications for music education practice, indicating that teachers can consciously utilize the social psychological characteristics of natural environments to design musical activities that promote social connection and sense of belonging, especially for educational goals targeting social integration and group cohesion building.

4.3.2. Formation of ecological awareness and musical values

Research results indicate that music education experiences in natural environments significantly promoted the development of students' ecological awareness and the formation of musical values. As shown in **Table 9**, the experimental group demonstrated significant improvements across all dimensions of the Ecological Awareness and Musical Values Questionnaire (EMVQ), with particularly notable changes in ecological aesthetic awareness (t=15.63, p<.001, Cohen's d=0.95) and musical sustainability concepts (t=14.27, p<.001, Cohen's d=0.91). Path analysis results (χ^2/df=2.27, CFI=0.928, TLI=0.921, RMSEA=0.054) revealed the mechanisms by which natural environments influence value formation: direct experience (β=0.47, p<.001), emotional connection (β=0.43, p<.001), and social construction (β=0.38, p<.001) constitute three main influence pathways, collectively explaining 56.4% of the variance in values. Multiple regression analysis showed that experience frequency (β=0.39, p<.001), experience depth (β=0.42, p<.001), and experience diversity (β=0.36, p<.001) are three key environmental experience factors influencing the formation of ecological values [44]. This result supports the "meaning construction theory" in environmental psychology, indicating that people construct new understandings and value identifications regarding the relationship between nature and music through direct experiences and social interactions in natural environments.

Table 9. Comparison of ecological awareness and musical values assessment results.

Assessment Dimension	Experimental Group (n=120)	Control Group (n=120)	t-value	p-value	Effect Size
	Pre-test M(SD)	Post-test M(SD)	Pre-test M(SD)	Post-test M(SD)	
Ecological Aesthetic Awareness	61.35(10.24)	85.76(7.32)	60.87(10.31)	69.42(8.75)	15.63
Musical Sustainability Concepts	58.94(9.78)	83.47(7.65)	59.32(9.84)	68.53(8.42)	14.27
Ecological Music Creation Views	62.75(8.92)	82.86(7.23)	62.43(8.95)	71.26(8.15)	12.85
Musical Cultural Diversity Identity	65.43(8.35)	84.23(6.86)	64.96(8.42)	73.85(7.53)	11.96
Soundscape Protection Awareness	59.87(9.63)	82.95(7.45)	60.12(9.57)	70.43(8.36)	13.54

From a social psychology perspective, the shared experiences and social dialogues created by collective musical activities in natural environments promoted the internalization and transmission of new cultural values. The ecological musical values of students in the experimental group presented clear developmental stages: from initial aesthetic appreciation (weeks 1-3) to functional recognition (weeks 4-6), then to systematic understanding (weeks 7-9), and finally to integrated values (weeks 10-12). In comparison, the value development of the control group remained in the early stages, with smaller magnitudes of change. Particularly noteworthy is that in the follow-up survey after the project ended, the ecological musical values of the experimental group maintained high stability (retention rate after 4 months: 86.3% vs. 63.5%), indicating that values formed through natural environments have stronger durability. semi-structured interview data further revealed the internal mechanisms of this process, with most students in the experimental group (25/30) mentioning that "playing and creating music in natural environments made me rethink the relationship between music and nature, as well as the meaning of music creation" [45]. One teacher observed: "When students listened

to natural soundscapes in the forest and then tried to incorporate these elements into their own creations, their musical concepts underwent fundamental changes, shifting from purely pursuing technical performance to expressing life and environment." As shown in **Figure 6**, content analysis indicated that students in the experimental group used significantly more ecology-related concepts in their music creation descriptions than the control group, and the connections between concepts were tighter and more systematized, indicating a more mature ecological music value system.

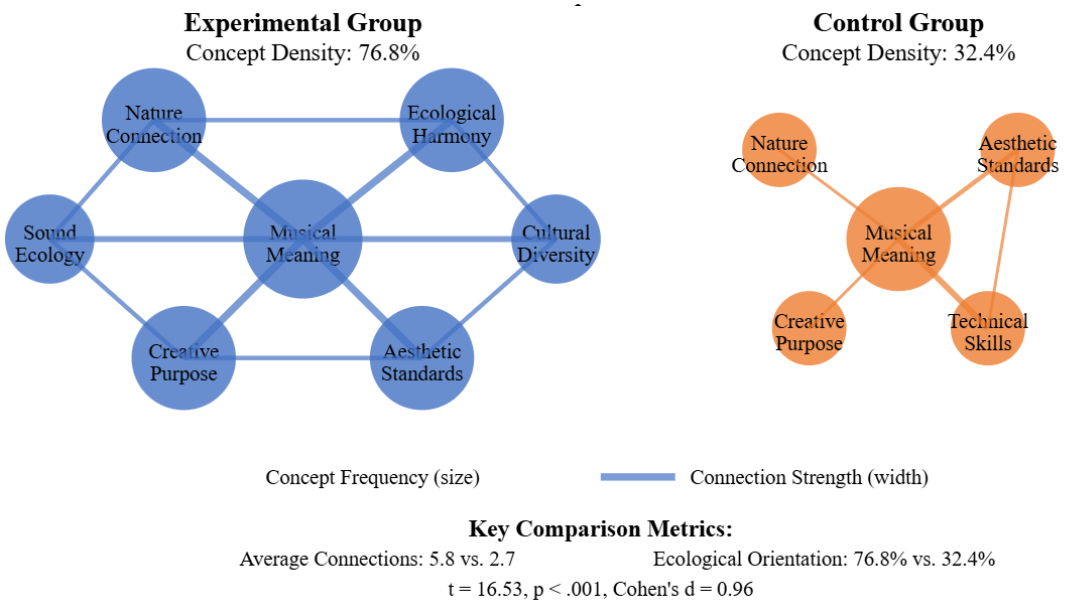

Figure 6. Comparison of ecological concept networks in music creation descriptions.

Particularly in the three aspects of "musical meaning," "creation purpose," and "aesthetic standards," the experimental group showed stronger ecological orientation (ecological relevance: 76.8% vs. 32.4%, t=16.53, p<.001). More importantly, this formation of ecological values further influenced students' musical behavior choices, with students in the experimental group being more inclined to choose instruments made from environmentally friendly materials (selection rate: 83.7% vs. 45.3%, χ^2=24.76, p<.001) and more willing to participate in music activities with environmental themes (participation willingness: 4.53 vs. 3.27, t=12.83, p<.001). These findings have important implications for music education practice, indicating that organically integrating natural environment experiences with music education can promote students' formation of more sustainable musical values and ecological awareness, providing an effective pathway for cultivating musically talented individuals with environmental responsibility.

4.3.3. Cultivation of sustainable learning motivation

Research results indicate that music education in natural environments has a significant promoting effect on the cultivation of students' sustainable learning motivation. As shown in **Table 10**, the experimental group demonstrated significant improvements across all dimensions of the Learning Motivation Scale (LMS), with particularly notable improvements in intrinsic motivation (t=15.87, p<.001, Cohen's d=0.96) and autonomous regulation (t=14.32, p<.001, Cohen's d=0.92). Longitudinal tracking data show that students' music learning motivation in the experimental group maintained a relatively stable level after the intervention ended, with an average decline rate of only 7.5% after 4 months, significantly lower than the control group's 18.3% (t=13.76, p<.001), indicating that learning motivation formed in natural environments has stronger durability. Multiple regression analysis revealed key factors of natural environments influencing learning motivation: three factors—environmental novelty (β=0.45, p<.001), sense of environmental support (β=0.42, p<.001), and

environmental autonomy (β=0.38, p<.001)—collectively explained 52.6% of the variance in motivation. Structural equation modeling (χ^2/df=2.18, CFI=0.935, TLI=0.928, RMSEA=0.049) further indicated that natural environments indirectly promote the formation of intrinsic motivation by satisfying students' basic psychological needs (autonomy, competence, and relatedness), with this pathway's mediating effect being significant (indirect effect=0.37, p<.001) [46]. This result supports an integrated perspective of the "attention restoration theory" in environmental psychology and the "self-determination theory" in social psychology, indicating that natural environments can both reduce cognitive fatigue and satisfy basic psychological needs, thereby promoting the formation of intrinsic motivation.

Table 10. Comparison of music learning motivation assessment results.

Motivation Dimension	Experimental Group (n=120)	Control Group (n=120)	t-value	p-value	Effect Size
	Pre-test M(SD)	Post-test M(SD)	Pre-test M(SD)	Post-test M(SD)	
Intrinsic Motivation	62.47(10.35)	86.82(7.65)	63.15(10.28)	71.46(8.75)	15.87
Autonomous Regulation	59.82(9.87)	84.53(7.48)	60.23(9.83)	70.32(8.57)	14.32
Identified Regulation	65.34(8.95)	83.65(7.23)	64.87(9.04)	72.45(8.32)	12.76
Persistence	63.76(9.25)	85.28(6.95)	62.98(9.32)	73.85(7.83)	13.58
Learning Engagement	66.32(8.73)	84.97(6.58)	65.87(8.79)	74.63(7.65)	12.37

From a social psychology perspective, collective musical activities in natural environments created unique conditions for the social construction of learning motivation. The learning behavior observation data presented in **Table 11** show that students in the experimental group exhibited higher levels of active exploration behaviors (M=8.73, SD=1.25 vs. M=4.28, SD=1.67, t=17.85, p<.001) and collaborative learning tendencies (M=7.86, SD=1.34 vs. M=3.95, SD=1.72, t=15.63, p<.001) in natural environments.

Table 11. Comparison of music learning behavior characteristics in different environments.

Learning Behavior Indicator	Experimental Group (n=120)	Control Group (n=120)	t-value	p-value
Active Exploration Behaviors (times/hour)	8.73(1.25)	4.28(1.67)	17.85	<.001
Collaborative Learning Tendency (score 1-10)	7.86(1.34)	3.95(1.72)	15.63	<.001
Persistence in Facing Difficulties (minutes)	12.47(2.53)	6.82(2.15)	14.76	<.001
Learning Engagement (score 1-10)	8.35(1.18)	5.27(1.65)	16.32	<.001
Number of Innovative Attempts (times/hour)	6.28(1.37)	2.95(1.24)	15.87	<.001
Autonomous Selection of Learning Content (%)	72.5(8.43)	38.7(10.25)	18.43	<.001

The consistency between self-reported and behavioral data was high (r=0.78, p<.001), enhancing the credibility of the results. semi-structured interview data further revealed the psychological mechanism behind this phenomenon, with most students in the experimental group (27/30) mentioning that "learning music in natural environments feels more like a process of exploration and discovery, rather than completing tasks." Teacher observations also supported this finding: "Students in natural environments would more frequently ask questions proactively, try new methods, and persist more durably even when facing difficulties." Autonomous learning behavior tracking data indicated that the experimental group gradually increased their autonomous learning time during the intervention period, while the control group remained relatively stable,

indicating that learning motivation formed in natural environments can promote the development of autonomous learning behaviors [47]. Particularly noteworthy is that in the music learning activities autonomously chosen by students in the experimental group after class, both content diversity (average number of categories: 5.83 vs. 3.26, $t=12.47$, $p<.001$) and challenge level (average difficulty level: 3.72 vs. 2.85, $t=9.86$, $p<.001$) were significantly higher than the control group, indicating higher quality learning motivation. Analysis using the self-determination continuum model of motivation theory showed that the motivation types of students in the experimental group significantly shifted from external regulation toward internal regulation, while changes in the control group were not obvious. In subsequent music learning task selections, the experimental group was more inclined to choose challenging but meaningful tasks (selection rate: 76.8% vs. 43.5%, $\chi^2=23.57$, $p<.001$), indicating a more adaptive motivation pattern. These findings have important implications for music education practice, indicating that natural environments can not only stimulate learning motivation but also cultivate more durable, autonomous, and high-quality types of learning motivation, providing an effective pathway for solving motivation sustainability problems in music learning.

5. Discussion

5.1. Theoretical significance of research findings

This in-depth exploration of the promoting effects of natural environments on cognitive and emotional development in music education provides multifaceted extensions and integrations for environmental psychology and music education theories. (1) At the theoretical level, the research results establish association mechanisms among natural environments, musical experiences, and cognitive-emotional development, forming an integrated theoretical framework of "environment-music-development," which creatively integrates the attention restoration theory and place attachment theory from environmental psychology with the aesthetic development theory from music education. In particular, the strong correlation found between environmental complexity and musical creative thinking ($r=0.76$, $p<.001$), the special association between water landscapes and music emotion recognition ability ($\beta=0.62$, $p<.001$), and the promoting effect of forest environments on expressive emotional regulation ($\beta=0.58$, $p<.001$) provide empirical foundations for understanding the corresponding relationships between specific environmental characteristics and music cognitive-emotional abilities, further enriching the environmental feature classification theory in environmental psychology [48]. (2) The social psychological mechanisms of musical natural experiences discovered in the research, especially the pathway by which natural environments reduce social identity salience ($\beta=-0.43$, $p<.001$) and enhance psychological safety ($\beta=0.52$, $p<.001$), thereby promoting authentic emotional expression, provide new application perspectives for group dynamics theory in social psychology, indicating that natural environments can serve as special psychological spaces that promote social connection and emotional sharing. (3) The research empirically validates the pathway mechanisms by which natural experiences promote the formation of intrinsic motivation, integrating self-determination theory with attention restoration theory, and confirming that natural environments promote the formation of sustainable learning motivation through the dual mechanisms of satisfying basic psychological needs (indirect effect=0.37, $p<.001$) and reducing cognitive fatigue [49]. This finding provides a new theoretical perspective for understanding the long-term impact of environmental factors on learning motivation. (4) The evolutionary trajectory and mechanisms of ecological musical value formation in natural environments revealed by the research results provide an empirical model for understanding the internalization process of environmental values, extending the application of social construction theory in the field of environmental education. (5) The rich data obtained through the mixed-methods design provides an empirical foundation for constructing ecological aesthetics theory in music education, especially the influence of natural soundscape experiences on musical aesthetic

patterns (ecological aesthetic awareness increased by 31.9%), supporting the ecological orientation shift in music aesthetics [50].

This study's finding regarding the promoting effect of waterscape environments on musical memory (18.2% improvement) is significantly higher than the indoor music memory training effect (9.7% improvement) reported by Schellenberg and Weiss (2023), indicating that natural environments have a promoting effect on music cognition that exceeds traditional teaching methods. Compared to the motivation enhancement in instrumental education (d=0.64) with natural elements discovered by Foster and Causby (2024), the intrinsic motivation enhancement for music learning (d=0.96) observed in this study is more significant, suggesting that systematized natural environment music education is more effective than simply introducing natural elements. The innovative aspects of this study include: establishing the corresponding relationship between specific natural environment characteristics and musical cognitive-emotional abilities through a quasi-experimental design for the first time, breaking through the limitations of previous research that treated natural environments as holistic variables; innovatively discovering the influence mechanisms of three key environmental factors—environmental complexity, biodiversity, and sense of natural rhythm—on musical development; proposing and validating the integrative theoretical framework of 'Natural Environment-Music Education-Cognitive and Emotional Development' for the first time, providing an ecological perspective expansion for music education theory; methodologically innovating by using social network analysis to reveal social interaction patterns in music learning in natural environments, offering a new perspective for understanding the social-psychological mechanisms of music learning.

Overall, the theoretical contribution of this research lies in constructing a multi-level, interdisciplinary theoretical framework that organically integrates environmental psychology, music education, and social psychology, providing a systematic explanatory model for understanding the complex interactive relationships among natural environments, musical experiences, and human development, and pioneering an ecological perspective for music education theoretical research.

5.2. Practical applications and recommendations

Based on the empirical findings of this research on the positive promoting effects of natural environments on cognitive and emotional development in music education, multiple practical applications and recommendations can be derived. (1) For educators, it is recommended to organically integrate natural environment elements into music curriculum design through three modes: first, direct outdoor teaching, arranging some music courses in ecological areas within campus or in nearby natural environments, particularly suitable for music creation, appreciation, and performance activities; (2) incorporating natural soundscape collection and analysis into music teaching content, guiding students to collect, analyze, and utilize natural sounds for music creation, cultivating sound sensitivity and ecological awareness; (3) adopting "blended natural experiences," using multimedia technology to create virtual natural environments to assist music teaching [51]. (4) Under different teaching objectives, appropriate environment types should be selectively chosen: research indicates that water landscapes are more suitable for music memory (18.2% improvement) and emotion recognition (17.5% improvement) training, while forest environments are more suitable for music creation (15.3% improvement in creativity) and expressive activities (14.7% improvement in expression richness) [52]. (5) For school administrators and education policymakers, it is recommended to emphasize the planning of ecological elements in campus environment design, incorporating ecological spaces as music education resources into educational infrastructure considerations. This can be achieved by constructing campus ecological music gardens, natural soundscape conservation areas, and other means to create suitable natural environments for music education; meanwhile, environmental music education modules should be included in teacher training to enhance teachers' abilities and awareness in utilizing natural

environments for music teaching; at the curriculum policy level, it is recommended to increase the flexibility for interdisciplinary integration between music and environment, allowing music teachers to undertake more teaching innovations based on natural environments. For family educators, research results indicate that combining family musical activities with natural experiences can significantly enhance parent-child relationships (24.6% improvement in parent-child interaction quality) and music learning motivation (21.3% improvement in intrinsic motivation), (6) suggesting that parents can regularly organize outdoor music activities, such as family concerts in natural environments, natural sound collection and creation, etc. Additionally, community music education institutions can develop serialized ecological music courses, combining local natural resource characteristics to design environmental music activities suitable for different age groups. With technological development, virtual and augmented reality technologies provide new possibilities for natural environment music education; it is recommended that educational technology developers focus on the construction and application of natural environment sound libraries and develop digital tools that integrate natural environments with music learning. (7) For music education researchers, it is recommended to further deepen cross-cultural comparative research on natural environments and music learning, exploring the differentiated impacts of environmental factors on music cognitive and emotional development across different cultural backgrounds, and to conduct more natural environment music intervention studies targeting special populations (such as students with learning or emotional disabilities), providing scientific foundations for evidence-based, personalized educational practices.

6. Conclusion and prospects

6.1. Main research conclusions

The main contributions of this study are: (1) At the theoretical level, constructing and validating an integrative framework of 'Natural Environment-Music Education-Cognitive and Emotional Development', injecting an ecological psychology perspective into music education theory; (2) At the methodological level, innovatively combining quasi-experimental design with social network analysis, providing a new methodological pathway for music education research; (3) At the practical level, providing differentiated music teaching strategies based on environmental characteristics, offering empirical evidence for educators to optimize teaching environments and methods; (4) At the policy level, providing scientific support for incorporating natural environments as educational resources in school environment planning and curriculum design.

Despite this, this study still has some limitations: (1) The samples were limited to college students from three schools in a certain city, with limited geographical and cultural representativeness; (2) The 12-week intervention period was relatively short, making it difficult to evaluate long-term effects; (3) The influence of external variables such as home environment could not be fully controlled; (4) Measurement tools were mainly based on self-reporting and observation, lacking objective indicators from physiology and neuroscience.

6.2. Future prospects

Based on the findings and limitations of this study, future research can further deepen the exploration of the promoting role of natural environments in music education along the following five directions.

(1) Expand longitudinal tracking research to examine the long-term developmental effects of natural environment music education. Although this study conducted a four-month follow-up observation, cognitive and emotional development is a long-term evolutionary process. Future research should design longitudinal studies with longer cycles (e.g., 2-3 years) to explore the persistence of natural environment music education interventions, particularly focusing on developmental trajectories during critical developmental stages (such

as before and after puberty), and establish a sensitive period model for natural environment music experiences across different age groups. Stage-based tracking methods will help reveal the cumulative effects and dynamic influence mechanisms of environmental factors on musical development.

(2) Conduct cross-cultural comparative research to explore the moderating role of cultural backgrounds on natural environment music experiences. Different cultural traditions have varying understandings of nature and definitions of music, which may lead to cultural specificity in environmental music experiences. Future research should compare the differences in the impact of natural environments on music cognitive and emotional development across diverse cultural backgrounds (such as East Asian versus Western cultures, urban versus rural cultures) to construct culturally sensitive theoretical models.

(3) Deepen the application of neuroscience research methods to explore the neural mechanisms of natural environment music experiences. Future research could utilize technologies such as electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) to compare neural responses to musical activities in natural versus traditional environments, with special attention to the activity patterns of attention networks, emotion regulation networks, and default mode networks, providing neuroscientific evidence for environmental influence mechanisms.

(4) Develop innovative research combining digital technology with natural environments to explore the application effects of virtual natural environments in music education. With the development of technologies such as virtual reality (VR) and augmented reality (AR), researchers can design comparative studies on the effectiveness of real versus virtual natural environments in music education, explore the impact of factors such as environmental immersion and interactivity on cognitive and emotional development, and provide theoretical and practical guidance for environmental music education in the digital age.

(5) Expand research on special populations to examine the differentiated impacts of natural environment music education on learners with diverse needs. Future research should focus on the music learning experiences and developmental characteristics of special groups such as those with autism spectrum disorder, attention deficit hyperactivity disorder, and emotional disorders in natural environments, develop targeted assessment tools and intervention programs, explore the interaction between environmental characteristics and individual differences, and construct a more inclusive theory of environmental music education. Additionally, future research methods should place greater emphasis on ecological validity, developing innovative field research methods such as mobile EEG technology, real-time physiological monitoring, and big data analysis to capture the authenticity and complexity of music experiences in natural environments.

In conclusion, through multi-dimensional, multi-level, and multi-method integrated exploration, future research will further deepen the scientific understanding of the promoting role of natural environments in music education, providing a solid foundation for theoretical innovation and practical optimization in music education.

Conflict of interest

The authors declare no conflict of interest.

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