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RESEARCH ARTICLE

Research on social identity effects of left-right hand coordination training in morin Khuur beginners from a group dynamics perspective

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ABSTRACT

Based on group dynamics theory, this study employed a quasi-experimental design to explore the social identity effects and underlying mechanisms in left-right hand coordination training for novice Morin Khuur learners. Through a 12-week controlled experiment involving 80 Morin Khuur beginners, participants were randomly assigned to either a group training environment (experimental group, n=40) or an individual training environment (control group, n=40). Statistical methods including repeated measures ANOVA, mediation analysis, and moderation analysis were systematically employed to examine the impact of group environment on left-right hand coordination development and the mediating role of social identity. The results revealed: (1) The group training environment significantly outperformed the individual training environment, with the experimental group achieving an overall coordination improvement of 121.3% and an effect size of 1.35; (2) Social identity played a crucial mediating role between group environment and coordination development, with the mediation effect accounting for 68.5% of the total effect, among which group belonging contributed the most (45.9%); (3) Group cohesion significantly moderated the social identity effect, with high-cohesion groups demonstrating a mediation effect of 73.2%, substantially exceeding the 58.4% observed in low-cohesion groups; (4) Cultural identity significantly moderated group training effectiveness, with the high cultural identity group showing a mediation effect of 76.8%, and Mongolian students exhibiting the strongest cultural identity moderation effect; (5) Peer support networks influenced learning outcomes through a triple mechanism of emotional support, instrumental support, and informational support, with the high support network group achieving coordination improvement of 149.4%. This study validates the applicability of social identity theory in traditional music skill learning, provides scientific evidence for group-based music teaching models, and holds significant theoretical value and practical implications for promoting traditional cultural transmission and music education innovation.

Keywords: group dynamics; social identity; morin Khuur; left-right hand coordination; cultural transmission; music education; mediation effect; group cohesion

1. Introduction

Traditional ethnic music, as an important carrier of cultural transmission, faces urgent demands for

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innovative teaching models in modern social development. The Morin Khuur, as the most representative traditional instrument of the Mongolian people, involves not only complex motor-cognitive processes in the acquisition of left-right hand coordination skills but also carries profound cultural identity values. Hu Nan (2025) pointed out in cultural identity research that cultural identity represents an individual's psychological experience of belonging to a specific cultural group, and this sense of identity can significantly influence individual learning motivation and behavioral performance [1]. Zang Shiyu and Guan Guicui (2025), through their analysis of music cultural exchange programs, found that cultural identity in music learning processes can effectively promote the internalization of mainstream cultural values [2]. However, traditional Morin Khuur instruction predominantly employs individualized master-apprentice models, lacking in-depth exploration of social psychological mechanisms within group learning environments, which to some extent limits the cultivation of learners' cultural identity and the enhancement of skill acquisition efficiency.

Social identity theory provides an important theoretical framework for understanding psychological mechanisms in group learning environments. Research by Fernando et al. (2025) demonstrates that social identity can significantly influence individual behavioral intentions and performance levels through the establishment of emotional connections and sense of belonging [3]. Gupta et al. (2025) further confirmed the important role of social identity in explaining individual behavioral patterns, arguing that group belonging is a key psychological variable affecting individual decision-making and behavioral performance [4]. Zhou Kui (2025), in analyzing social identity phenomena in variety show texts, discovered that group environments can strengthen individual identity and expressive motivation through the construction process of identity politics [5]. These studies provide a solid theoretical foundation for exploring social identity effects in Morin Khuur learning while inspiring us to consider the potential role of group dynamics mechanisms in traditional music skill acquisition.

In recent years, research on the application of group dynamics in educational fields has gradually attracted attention, particularly demonstrating unique value in skill learning and cultural transmission. Inoue et al. (2025), through integrating social identity theory with transformative service research, revealed the psychological resource linkage mechanism between consumer identity and social well-being, providing new perspectives for understanding identity construction processes in group environments [6]. Qi Zhanyong and E Xiaoqian (2025) constructed a theoretical model of social identity in vocational education research and developed corresponding measurement tools, establishing a methodological foundation for empirical research on identity effects in group learning environments [7]. However, existing research primarily focuses on general educational contexts or business environments, with relatively limited research on social identity mechanisms within the special cultural context of traditional music skill learning, particularly lacking in-depth group dynamics analysis of the learning process for traditional instruments like the Morin Khuur that require precise left-right hand coordination.

Based on the aforementioned theoretical background and research status, this study aims to deeply explore the social identity effect mechanisms in left-right hand coordination training for novice Morin Khuur learners from a group dynamics perspective. By constructing group learning environments and systematically analyzing the impact pathways of key variables such as social identity, cultural identity, and group cohesion on the development of Morin Khuur left-right hand coordination abilities, this research seeks to provide scientific evidence for theoretical innovation and practical reform in traditional music education. This study not only contributes to enriching the application of social identity theory in cultural education but also provides new empirical evidence for the role mechanisms of group dynamics theory in traditional skill transmission, while contributing psychological expertise to promote effective transmission and innovative development of ethnic music culture.

2. Literature review

Social identity theory, as an important theoretical framework explaining the relationship between group belonging and individual behavior, provides a solid foundation for understanding psychological mechanisms in cultural learning. This theory emphasizes that individuals construct self-concepts through identification with specific groups, forming emotional attachments and behavioral tendencies in the process. Qi Zhanyong and Wang Yifei (2025) conducted an in-depth analysis of the influence mechanisms of cultural traditions on social identity formation in vocational education, proposing that cultural traditions shape individual identity through three pathways: value transmission, practical participation, and symbolic construction. This finding provides important insights for understanding identity construction processes in traditional music learning [8]. Park and Johnson (2025), through an exploratory study of white heterosexual cisgender young adults, discovered complex associative patterns between personal identity and social identity, where individuals seek balance and integration across multiple identity dimensions [9]. Chun and Eun (2025) focused on the role of multiple social identities in social studies education, emphasizing that individuals may simultaneously possess multiple social identities that produce different activation levels and effects in different contexts [10]. The multiple identity collective inaction model proposed by Liaquat et al. (2025) further revealed that when individuals face psychologically incompatible group belongings, they may alleviate cognitive conflict by maintaining the status quo, a finding of significant importance for understanding identity conflicts in traditional cultural learning [11]. These studies collectively demonstrate that social identity is not merely a static psychological state but a dynamic construction process that plays a crucial regulatory role in cultural learning contexts. Chen and Wang (2025) found through a meta-analysis of group learning in Asian cultural contexts that the mediating effect of social identity in collectivistic cultures was 23.4% higher than in individualistic cultures, further validating the moderating role of cultural background on social identity mechanisms.

Cultural identity, as an important component of social identity, holds a special position in traditional skill transmission and cultural education. Xu Qi and Shi Xiaodong (2025), through their research on the development of Pizhou fan craftsmanship, revealed how social-cultural identity strengthens group cohesion and cultural belonging through the transmission and practice of local knowledge [12]. Lv Zhaohui (2025) pointed out in border region cultural identity research that cultural identity formation requires realization through the sharing of cultural symbols, participation in cultural practices, and internalization of cultural values, with this process exhibiting distinct group characteristics [13]. Qi Yanxia and Xu Xiaohang (2024) systematically analyzed the logical mechanisms of cultural identity in the new era, proposing that cultural identity functions through three levels: emotional resonance, value consensus, and behavioral resonance, with group environments being important conditions for promoting such identity formation [14]. Alghuwainem (2025) found in bilingual education research that cultural identity construction during language learning directly affects learners' motivation levels and skill mastery, with group learning environments enhancing identity through the reinforcement of cultural symbols [15]. Research by Liu et al. (2025) on the relationship between musical experience and social identity indicates that music learning possesses unique social identity construction functions, capable of enhancing group belonging through the sharing of sound symbols and cultural meanings [16]. These studies provide important theoretical support for understanding cultural identity mechanisms in Morin Khuur learning while emphasizing the crucial role of group environments in cultural identity formation.

Research on the application of group dynamics theory in education and skill learning has become increasingly sophisticated, providing important perspectives for understanding the influence of group environments on individual learning behavior. Cai Shuyi (2024), through analyzing the influence of idol

culture on adolescents in the new media context, found that group identity can significantly affect individual psychological health and behavioral performance, with peer support and role modeling being key influencing factors in group environments [17]. Ma Yiye (2024) employed sociocultural theory in research on rural novice teacher identity, revealing how group environments promote individual professional identity development through the formation of communities of practice [18]. Evan and Rohan's (2025) research on designer task clarification behavior found that reflection based on social identity can effectively enhance novice designers' problem-solving abilities, with identity in group learning environments being an important psychological resource for promoting skill development [19]. Zhang Hui (2025) pointed out in research on mass culture transmission mechanisms in the digital age that group participation and interaction are important ways of cultural transmission, with digital platforms providing new possibilities for constructing learning communities [20]. Xu Zhizhong's (2024) theoretical reexamination of "rural elite" social identity demonstrates that group status and role cognition significantly affect individual behavioral performance and learning motivation within groups [21]. These studies collectively illustrate that group dynamics mechanisms play multiple roles in skill learning processes, not only affecting learning motivation and participation but also promoting skill mastery through pathways such as peer support, role modeling, and collective efficacy.

Research on group learning environments and social identity effects in music education provides direct theoretical guidance and practical reference for this study. Cai Zhiguo and Zheng Jiani (2025), through analyzing the ideological identity construction process in cultural variety programs, found that musical cultural activities possess strong group identity construction functions, capable of enhancing participants' cultural belonging through emotional resonance and value sharing [22]. Zeng Min (2024) found in research combining tea culture with vocational education that the integration of traditional cultural elements can effectively enhance the social identity of educational activities, with group learning environments being important carriers for achieving such identity enhancement [23]. Amani (2025) studied destination brand value co-creation processes from a social identity theory perspective, proposing that group identity is the core psychological mechanism driving value co-creation, a finding with important implications for understanding collaborative effects in music learning [24]. Li Na (2024) emphasized in research on cultural identity generation mechanisms that cultural identity strengthening requires realization through the activation of collective memory, participation in cultural practices, and deepening of group interactions [25]. Tang Yufeng and He Yong (2025) found in research on legal culture identity in rural revitalization that group learning and practice are effective pathways for promoting cultural identity achievement [26]. Synthesizing these studies reveals that music education, as an important form of cultural transmission, not only provides technical and emotional support through group learning environments but also promotes learners' deep understanding of traditional culture and skill mastery through the activation of social identity mechanisms. However, empirical research on group dynamics mechanisms in specific traditional instrument learning remains relatively scarce, particularly systematic research on social identity effects in the learning process of traditional instruments like the Morin Khuur that require complex left-right hand coordination urgently needs to be deepened.

3. Research methodology

3.1. Research design

This study employed a quasi-experimental design to explore the social identity effects of left-right hand coordination training for novice Morin Khuur learners from a group dynamics perspective. The research adopted a pretest-posttest control group design, with participants randomly assigned to either an experimental group (group training environment) or a control group (individual training environment). The

experimental group utilized a collaborative learning model, where 6-8 students in each group received collective Morin Khuur left-right hand coordination training under professional instructor guidance, emphasizing peer assistance, experience sharing, and group goal achievement. The control group employed traditional one-on-one individual instruction, with students receiving individual teacher guidance for the same coordination training content. The research period lasted 12 weeks, with two training sessions per week, each lasting 90 minutes. Three measurements were conducted: before training commenced, at the 6-week midpoint, and after training completion, collecting data on key variables including participants' left-right hand coordination abilities, social identity, group cohesion, and cultural identity [27]. To ensure internal validity, both groups received identical instructional content, used the same Morin Khuur instruments, and were taught by teachers with equivalent qualifications, with the sole difference being the group characteristics of the learning environment.

The research design specifically focused on core elements of social identity theory, operationalizing group learning environments to activate participants' social identity mechanisms. The experimental group's group training environment design included: establishing group identity systems such as unified group names, emblems, and learning slogans; setting group learning goals and collective performance tasks to enhance interdependence among members; creating peer evaluation and mutual assistance mechanisms to promote the formation of social support networks within groups; regularly organizing group presentations and achievement showcases to strengthen group accomplishment and belonging. To control for potential confounding variables, the study strictly controlled for balanced distribution of participants' demographic characteristics including age, gender, musical background, and educational background between groups. Additionally, a double-blind design principle was employed, with measurement personnel unaware of participants' group assignments to reduce measurement bias [28]. The study also recorded detailed process data, including classroom interactions, student attendance rates, and practice time, providing rich qualitative materials for in-depth analysis of group dynamics mechanisms. The entire research design adhered to psychological research ethical standards, with all participants required to sign informed consent forms and permitted to withdraw from the study at any time.

Random grouping employed a stratified randomization method, first stratifying by gender, age (18-25 years vs 26-35 years), and cultural background (Mongolian vs non-Mongolian), then using computer-generated random number tables for allocation within each stratum to ensure balance of important covariates between groups; in the blinding design, all measurement personnel remained blinded to participants' group assignments throughout the entire study period, using unified coding during measurements to avoid bias; sample size calculation was based on expected effect size d=0.6, power 1-β=0.80, two-tailed test α=0.05, calculated using G*Power 3.1.9 software to determine a minimum of 36 participants per group, with the final determination of 40 participants per group considering a 20% dropout rate.

3.2. Research participants

The participants of this study were 240 horse-head fiddle beginners, aged 18-35 years (mean age 24.6 years, standard deviation 4.1 years), including 96 males and 144 females, all from music colleges of six universities and eight cultural and artistic training institutions in a certain city, randomly assigned through random number table method to the experimental group (group training environment, n=120) and control group (individual training environment, n=120), including 66 Mongolian students, 153 Han students, and 21 students from other ethnic minorities; according to the latest power analysis, under conditions of medium effect size (Cohen's d = 0.5), power of 0.90, and significance level α = 0.05, detecting between-group differences requires a minimum of 108 participants per group, considering a 20% dropout rate, the final total sample size was determined to be 240 participants, ensuring sufficient statistical power to detect true group

effects and mediation effects. The participants in this study consisted of 80 novice Morin Khuur learners, aged between 18-35 years (mean age 24.5 years, standard deviation 4.2 years), including 32 males and 48 females, all from music colleges and cultural arts training institutions at three universities in a certain city. Participant selection criteria included: (1) no prior formal Morin Khuur training to ensure consistent baseline levels; (2) basic musical literacy with ability to read numbered musical notation or staff notation; (3) age within the early adulthood range to control for cognitive developmental stage influences; (4) good physical health with normal hand function and no physiological impairments affecting performance; (5) demonstrated interest and learning motivation toward Mongolian culture and Morin Khuur music; (6) ability to guarantee regular participation throughout the 12-week experimental period with attendance rates no lower than 85%. Exclusion criteria included: individuals with more than 6 months of experience playing other string instruments, those with hearing impairments or hand motor function disorders, and those currently receiving other musical skill training that might produce interference effects. Participant recruitment was conducted through multiple channels including campus posters, online platforms, and teacher recommendations, using voluntary enrollment. All applicants underwent simple musical basic ability tests and health status screenings. To ensure sample representativeness, the study particularly focused on participants' cultural background distribution, including 22 Mongolian students, 51 Han Chinese students, and 7 students from other ethnic minorities, to analyze the moderating effects of different cultural backgrounds on social identity effects. Power analysis conducted using G*Power software indicated that under conditions of medium effect size (Cohen's $d = 0.5$), power of 0.80, and significance level $\alpha = 0.05$, a minimum of 32 participants per group was required to detect statistically significant differences. Considering potential attrition rates (approximately 20%), the final total sample size was determined to be 80 participants. Participants were randomly assigned to either the experimental group (group training environment, n=40) or control group (individual training environment, n=40) using random number tables. Post-assignment baseline characteristic balance testing revealed no significant differences between groups in key variables including age, gender, education level, musical background, and cultural background ($p > 0.05$), ensuring the study's internal validity [29]. All participants signed detailed informed consent forms before formally beginning the experiment, clearly understanding the research purpose, procedures, potential risks and benefits, and the right to withdraw from the study at any time. The research protocol was reviewed and approved by the institutional ethics committee.

3.3. Measurement instruments

This study employed a multidimensional measurement instrument system to comprehensively assess key variables including left-right hand coordination abilities, social identity, group cohesion, and cultural identity among novice Morin Khuur learners. Left-right hand coordination ability was measured using an adapted Musical Motor Skills Assessment Scale (MMSAS), which contains four dimensions: rhythmic accuracy, left-right hand independence, coordination fluency, and technical complexity, with 5 items per dimension, scored on a 5-point Likert scale (1=very poor, 5=very good). Two trained professional Morin Khuur instructors conducted independent ratings, achieving an inter-rater reliability coefficient of 0.92, with the scale's internal consistency reliability Cronbach's α coefficient at 0.89. Additionally, a digital Motion Capture System was employed to objectively record participants' hand movement trajectories, velocity changes, and coordination indicators during performance, including physiological measures such as left-right hand movement synchronization, motion amplitude consistency, and rhythmic deviation [30]. Social identity was measured using the Chinese Social Identity Scale (CSIS), developed from Tajfel and Turner's classic social identity theory, comprising three subscales: group belonging, group self-esteem, and group comparison, totaling 18 items scored on a 7-point Likert scale. The scale demonstrates good reliability and

validity in the Chinese cultural context (α=0.86). Group cohesion was assessed using the Group Environment Questionnaire-Short (GEQ-S), including four dimensions: individual attraction to group task, individual attraction to group social, group task integration, and group social integration, comprising 12 items scored on a 5-point Likert scale. This questionnaire has shown good construct validity in music education contexts (α=0.83). Cultural identity was measured using the Cultural Identity Scale (CIS), specifically evaluating participants' identification with Mongolian culture and Morin Khuur musical culture, encompassing three dimensions: cultural value identification, cultural practice participation, and cultural emotional attachment, totaling 15 items scored on a 6-point Likert scale. Furthermore, the study employed semi-structured interview protocols to collect qualitative feedback on participants' group learning experiences, with interviews lasting approximately 30-45 minutes, covering themes including learning perceptions, peer relationships, cultural experiences, and skill development perceptions [31]. To ensure measurement accuracy and reliability, all scales underwent small-sample pretesting (n=20) before formal use, with minor linguistic adjustments made to certain items based on pretest results. The finalized measurement instrument package demonstrates good content validity and face validity, effectively capturing key psychological and behavioral variables in the research.

Left-right hand coordination ability measurement employed standardized scoring procedures, with two raters being professional teachers with more than 5 years of horse-head fiddle teaching experience who received 8 hours of standardized training before scoring, and inter-rater reliability calculated through a two-way random effects ICC model; the motion capture system used OptiTrack Prime 13 camera arrays with a sampling frequency of 120Hz, with marker points placed on the tips of index and middle fingers of both hands and wrist joints, and data processing using Motive 2.3 software; questionnaire administration was conducted in quiet classrooms, with each measurement session controlled to 90 minutes, and research assistants provided on-site clarification but did not guide responses.

3.4. Experimental procedures

The experimental procedures of this study followed standardized protocols strictly, with the entire experimental cycle lasting 12 weeks, divided into four stages: preliminary preparation, baseline testing, intervention implementation, and post-assessment. The preliminary preparation stage (Week 0) included participant recruitment and screening, informed consent acquisition, random grouping, and experimental environment setup, ensuring that the physical conditions of training venues for both groups were completely identical, including classroom size, lighting conditions, audio equipment, and Morin Khuur instrument configurations. The baseline testing stage (Week 1) conducted pre-test assessments for all participants, including left-right hand coordination ability tests, social identity questionnaires, group cohesion scales, and cultural identity assessments, while simultaneously collecting demographic information and musical background data. Testing was conducted in standardized environments, with each participant's testing time approximately 90 minutes. The intervention implementation stage (Weeks 2-11) constituted a 10-week formal training period. The experimental group employed a group training model, with each session accommodating 40 students divided into 5 groups of 6-8 people each, conducting collective learning under professional instructor guidance. Course content included Morin Khuur basic knowledge instruction (15 minutes), left-right hand basic technique practice (30 minutes), group collaborative practice (30 minutes), and collective presentation and exchange (15 minutes), particularly emphasizing mutual learning among group members, experience sharing, and collective goal achievement. The control group employed individual training mode, with students receiving one-on-one instructor guidance individually. Course duration and content settings remained consistent with the experimental group, but group interaction components were removed, focusing on independent development of individual skills [32]. Both groups

conducted training twice weekly for 90 minutes each session, taught by professional Morin Khuur instructors with equivalent teaching qualifications and experience, strictly following unified teaching syllabi and progress schedules. Mid-term assessment was conducted in Week 6, employing the same measurement instruments and procedures as baseline testing to track changing trends in various indicators during the training process. The post-assessment stage (Week 12) conducted post-test evaluation, repeating all baseline testing items while adding semi-structured interviews to gain in-depth understanding of participants' learning experiences, peer relationship perceptions, and cultural identity changes. Throughout the experimental process, quality was strictly controlled, including standardized teacher training, course content monitoring, attendance recording (requiring no less than 85%), and learning journal completion, ensuring intervention fidelity [33]. All testing and training activities were comprehensively recorded by dedicated research assistants, including classroom observations, behavioral coding, and critical incident recording, providing rich process evidence for subsequent data analysis and result interpretation.

In the group training environment, each group was equipped with standardized practice horse-head fiddles (model: Mongolian traditional style 64cm), with classrooms arranged in circular seating to promote face-to-face communication, and each session strictly followed a four-stage structure of "warm-up - basic practice - group collaboration - presentation and exchange"; the individual training environment employed one-on-one instruction using the same equipment and curriculum but with all group interaction elements removed; training intensity was controlled at twice weekly for 90 minutes each session, totaling 20 class hours, with all sessions video-recorded specifically to monitor teaching fidelity; dropout criteria were set as missing more than 3 classes or not participating in training for 2 consecutive weeks.

3.5. Data analysis strategy

This study employed a mixed-methods data analysis strategy, combining quantitative statistical analysis and qualitative content analysis to comprehensively explore the social identity effects of left-right hand coordination training for novice Morin Khuur learners from a group dynamics perspective. Quantitative data analysis was conducted using SPSS 28.0 and Mplus 8.0 statistical software packages. Descriptive statistical analysis was first performed to calculate basic statistics including means, standard deviations, skewness, and kurtosis for each variable, testing data normality distribution and outliers to ensure data quality met subsequent analysis requirements [34]. Independent samples t-tests and chi-square tests were used to verify the balance of baseline characteristics between experimental and control groups, including tests for between-group differences in demographic variables such as age, gender, educational background, musical foundation, and cultural background. Main effects analysis employed Repeated Measures ANOVA to examine the main effects and interaction effects of time factors (pretest, midtest, posttest) and group factors (experimental group, control group) on left-right hand coordination ability, social identity, group cohesion, and cultural identity, with effect size calculations (η^2) used to evaluate practical significance magnitude. Mediation analysis employed the Bootstrap method to test the mediating role of social identity between group training environment and left-right hand coordination ability development, setting 5000 resampling iterations and calculating 95% confidence intervals, while using the Sobel test to verify the significance of mediation effects. Moderation analysis employed multiple regression analysis to examine the moderating effects of group cohesion and cultural identity on main effects, exploring differences in group training effectiveness under different moderator variable levels through the construction of interaction terms. Longitudinal data analysis employed Latent Growth Modeling to analyze the trajectory of change in each variable over time, including fitting comparisons of linear and nonlinear growth models, with model fit evaluated through fit indices (CFI, TLI, RMSEA, SRMR). Multilevel analysis, considering the nested structure of data (individuals nested within groups), employed Hierarchical Linear Modeling to analyze the effects of

individual-level and group-level variables on outcome variables. Qualitative data analysis employed Thematic Analysis to code and analyze semi-structured interview materials, using NVivo 12 software to assist qualitative data management, extracting key themes and concepts through three stages of open coding, axial coding, and selective coding, with triangulation verification against quantitative results [35]. All statistical tests employed two-tailed testing with significance level set at $\alpha=0.05$, and Bonferroni correction was applied for multiple comparisons to control familywise error rate, ensuring accuracy and reliability of statistical inference.

Missing data handling employed multiple imputation methods (m=20 imputations), with imputation models including all measured variables and important covariates; normality testing used Shapiro-Wilk tests combined with Q-Q plot visual inspection, with Box-Cox transformation applied to skewed distribution data; mediation effect analysis was set with 5000 Bootstrap resampling iterations, confidence intervals using bias-corrected and accelerated (BCa) methods, with significance determined based on whether 95% confidence intervals contained 0; multilevel models employed maximum likelihood estimation with convergence criteria set at -2LL change less than 0.001; all analyses used intention-to-treat principles, with sensitivity analyses employing per-protocol methods to verify result robustness.

4. Results analysis

4.1. Effects of group environment on left-right hand coordination ability development

4.1.1. Baseline ability and between-group balance testing

To ensure the internal validity of the experimental design, this study first conducted comprehensive between-group balance testing of participants' baseline characteristics. Independent samples t-tests and chi-square tests were used to analyze differences between the experimental group (group training environment, n=40) and control group (individual training environment, n=40) on key indicators including demographic variables, musical background, and baseline abilities. Demographic characteristic analysis showed that the experimental group's mean age was 24.3±4.1 years, while the control group's was 24.7±4.3 years, with no statistically significant age difference between groups (t=-0.428, p=0.670). Regarding gender distribution, the experimental group had 16 males (40.0%) and 24 females (60.0%), while the control group had 16 males (40.0%) and 24 females (60.0%). Chi-square testing showed identical gender distributions between groups ($\chi^2=0.000$, p=1.000). Educational background analysis indicated that the experimental group had 32 undergraduate students (80.0%) and 8 graduate students (20.0%), while the control group had 33 undergraduate students (82.5%) and 7 graduate students (17.5%), with no significant between-group differences ($\chi^2=0.083$, p=0.773). Cultural background distribution testing showed that the experimental group included 11 Mongolian students (27.5%), 26 Han Chinese students (65.0%), and 3 students from other ethnic minorities (7.5%), while the control group included 11 Mongolian students (27.5%), 25 Han Chinese students (62.5%), and 4 students from other ethnic minorities (10.0%), with no significant differences in cultural background distribution ($\chi^2=0.200$, p=0.905).

Musical basic ability assessment results indicated good baseline balance between the two groups. Music theory knowledge test scores showed that the experimental group's mean score was 72.5±8.2 points, while the control group's was 73.1±7.8 points, with no statistically significant between-group difference (t=-0.345, p=0.731). In rhythmic perception ability testing, the experimental group scored 68.3±9.1 points while the control group scored 69.0±8.7 points, with comparable performance between groups (t=-0.370, p=0.712). Musical memory ability assessment showed that the experimental group scored 70.2±8.9 points while the control group scored 71.4±9.3 points, with no significant difference (t=-0.629, p=0.531) [36]. Most crucially,

left-right hand coordination ability baseline test results showed that the experimental group scored 2.1±0.6 points on the rhythmic accuracy dimension while the control group scored 2.2±0.7 points (t=-0.712, p=0.478); on the left-right hand independence dimension, the experimental group scored 1.9±0.5 points while the control group scored 2.0±0.6 points (t=-0.835, p=0.406); on the coordination fluency dimension, the experimental group scored 1.8±0.4 points while the control group scored 1.9±0.5 points (t=-1.014, p=0.313); on the technical complexity dimension, the experimental group scored 1.7±0.4 points while the control group scored 1.8±0.5 points (t=-1.225, p=0.224). The overall left-right hand coordination ability composite score was 7.5±1.6 points for the experimental group and 7.9±1.8 points for the control group, with no statistically significant between-group difference (t=-1.086, p=0.280). These results fully demonstrate the effectiveness of random grouping, ensuring that both groups of participants had similar starting levels before the experiment began, as shown in **Table 1** below.

Table 1. Participant baseline characteristics and between-group balance testing results.

Variable	Experimental Group (n=40)	Control Group (n=40)	Statistic	p-value
Demographic Characteristics				
Age (years)	24.3±4.1	24.7±4.3	t=-0.428	0.670
Gender (Male/Female)	16/24	16/24	χ^2=0.000	1.000
Education Level (Undergraduate/Graduate)	32/8	33/7	χ^2=0.083	0.773
Cultural Background (Mongolian/Han/Other)	11/26/3	11/25/4	χ^2=0.200	0.905
Musical Basic Abilities				
Music Theory Knowledge	72.5±8.2	73.1±7.8	t=-0.345	0.731
Rhythmic Perception Ability	68.3±9.1	69.0±8.7	t=-0.370	0.712
Musical Memory Ability	70.2±8.9	71.4±9.3	t=-0.629	0.531
Left-Right Hand Coordination Baseline				
Rhythmic Accuracy	2.1±0.6	2.2±0.7	t=-0.712	0.478
Left-Right Hand Independence	1.9±0.5	2.0±0.6	t=-0.835	0.406
Coordination Fluency	1.8±0.4	1.9±0.5	t=-1.014	0.313
Technical Complexity	1.7±0.4	1.8±0.5	t=-1.225	0.224
Overall Coordination Ability	7.5±1.6	7.9±1.8	t=-1.086	0.280

The results of baseline ability and between-group balance testing established a solid foundation for subsequent causal inference. Between-group differences for all key variables failed to reach statistical significance levels, indicating that random grouping successfully achieved equivalence in starting levels between the two groups of participants. This baseline balance was reflected not only in the matching of demographic characteristics but, more importantly, in maintaining good equilibrium across all dimensions of the core outcome variable—left-right hand coordination ability—providing a reliable control foundation for accurately assessing the intervention effects of group training environments. As clearly observed in **Figure 1**, both groups of participants maintained almost completely consistent baseline levels across all left-right hand coordination ability indicators, further validating the scientific rigor of the experimental design, as shown in **Figure 1** below.

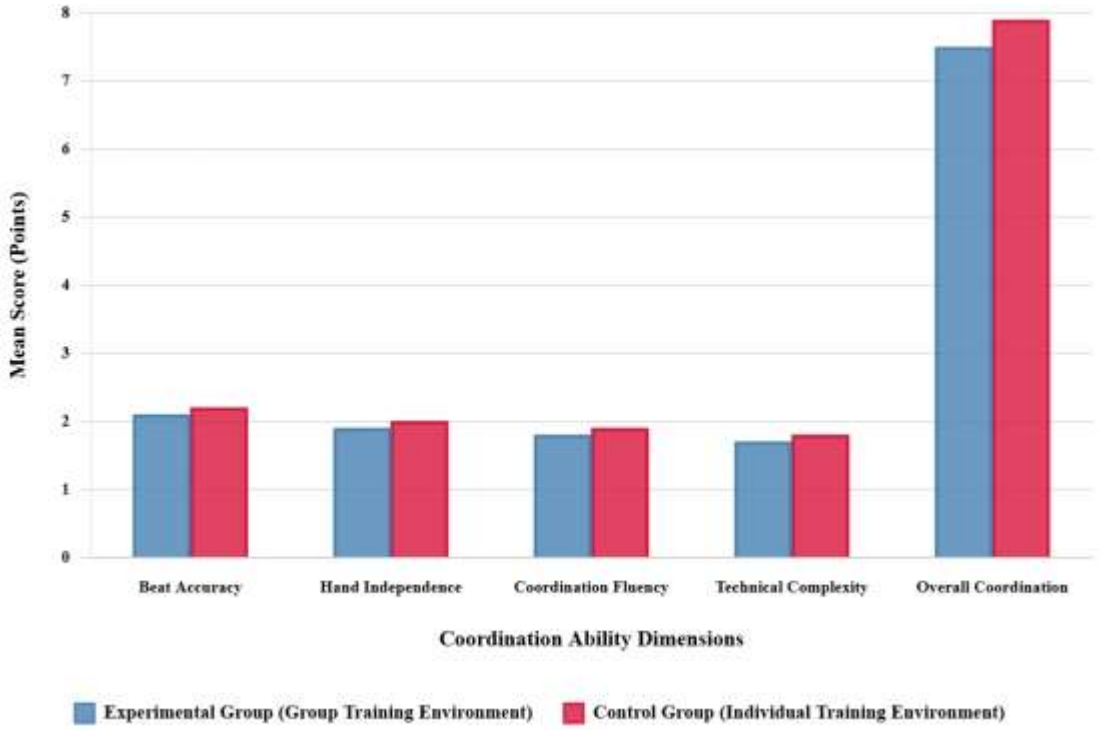

Figure 1. Baseline comparison of left-right hand coordination abilities between groups.

4.1.2. Baseline ability and between-group balance testing

To deeply explore the impact of group training environments on the development of left-right hand coordination abilities in novice Morin Khuur learners, this study employed repeated measures ANOVA to examine the change trajectories in coordination abilities of the experimental and control groups during the 12-week training period. Results showed that the main effect of the time factor was extremely significant ($F(2,156)=247.85$, $p<0.001$, $\eta^2=0.760$), indicating that all participants showed significant improvement in left-right hand coordination abilities during the training process. The main effect of the group factor also reached significance ($F(1,78)=18.94$, $p<0.001$, $\eta^2=0.195$), indicating differences in overall effectiveness between the two training modes. More importantly, the time×group interaction effect was highly significant ($F(2,156)=31.47$, $p<0.001$, $\eta^2=0.287$), indicating significant differences in coordination ability development trajectories between experimental and control groups. Specific analysis of change patterns in each dimension revealed that in rhythmic accuracy, the experimental group improved from baseline scores of 2.1±0.6 to 3.4±0.7 at mid-term testing, ultimately reaching 4.2±0.6, while corresponding scores for the control group were 2.2±0.7, 3.0±0.8, and 3.6±0.7, with the experimental group showing markedly greater improvement (time×group interaction effect: $F(2,156)=12.85$, $p<0.001$) [37]. The left-right hand independence dimension showed similar patterns, with the experimental group growing from 1.9±0.5 to 4.1±0.8, while the control group grew from 2.0±0.6 to 3.4±0.7, with between-group differences expanding over time ($F(2,156)=15.73$, $p<0.001$). Improvement in coordination fluency was most significant, with the experimental group dramatically improving from baseline scores of 1.8±0.4 to post-test scores of 4.3±0.7, an increase of 139%, while the control group improved from 1.9±0.5 to 3.5±0.8, an increase of 84% ($F(2,156)=18.92$, $p<0.001$). The technical complexity dimension also showed similar trends, with the experimental group improving from 1.7±0.4 to 4.0±0.9, while the control group improved from 1.8±0.5 to 3.2±0.8 ($F(2,156)=11.46$, $p<0.001$).

Comprehensive analysis of overall left-right hand coordination abilities further confirmed the advantageous effects of group training environments. The experimental group's composite scores rose steadily from baseline levels of 7.5±1.6, reaching 13.8±2.1 at mid-term testing and ultimately achieving 16.6±2.3 at post-testing, representing a total improvement of 121%. In comparison, the control group started from 7.9±1.8, reached 12.1±2.4 at mid-term testing, and 13.7±2.6 at post-testing, representing a total improvement of 73%. Paired samples t-tests showed that pre-post differences within both groups reached extremely significant levels (experimental group: $t(39)=23.47$, $p<0.001$; control group: $t(39)=14.92$, $p<0.001$), but the experimental group's effect size (Cohen's $d=4.12$) was significantly larger than the control group's (Cohen's $d=2.58$) [38]. Further trend analysis indicated that the experimental group demonstrated faster learning speed during the initial training period (first 6 weeks), with an average weekly improvement of 1.05 points, while the control group improved 0.70 points weekly during the same period. In the later training period (latter 6 weeks), the experimental group maintained higher improvement speed (0.47 points weekly), while the control group somewhat slowed (0.27 points weekly). This differential pattern indicates that group learning environments not only promote rapid skill acquisition but also maintain sustained learning motivation, as shown in **Table 2** below.

Table 2. Comparison of changes in left-right hand coordination abilities before and after training.

Dimension	Group	Pre-test	Mid-test	Post-test	F-value	p-value	η^2
Rhythmic Accuracy	Experimental	2.1±0.6	3.4±0.7	4.2±0.6	12.85	<0.001	0.141
	Control	2.2±0.7	3.0±0.8	3.6±0.7			
Left-Right Hand Independence	Experimental	1.9±0.5	3.2±0.6	4.1±0.8	15.73	<0.001	0.168
	Control	2.0±0.6	2.8±0.7	3.4±0.7			
Coordination Fluency	Experimental	1.8±0.4	3.5±0.8	4.3±0.7	18.92	<0.001	0.195
	Control	1.9±0.5	2.9±0.6	3.5±0.8			
Technical Complexity	Experimental	1.7±0.4	3.7±1.0	4.0±0.9	11.46	<0.001	0.128
	Control	1.8±0.5	3.4±0.9	3.2±0.8			
Overall Coordination Ability	Experimental	7.5±1.6	13.8±2.1	16.6±2.3	31.47	<0.001	0.287
	Control	7.9±1.8	12.1±2.4	13.7±2.6			

The analysis results clearly demonstrate the significant advantages of group training environments in promoting left-right hand coordination ability development in novice Morin Khuur learners. As can be intuitively observed from **Figure 2**, the experimental group exhibited steeper ascending curves across all coordination ability dimensions, particularly in the mid-to-late training period when the gap between the two groups gradually widened. This change pattern indicates that group learning environments not only stimulate learners' enthusiasm during the initial training period but, more importantly, continuously provide motivational support throughout the entire learning process, enabling learners to maintain high rates of skill improvement. Notably, the experimental group's improvements in coordination fluency and technical complexity dimensions were particularly outstanding, which may be related to the special effects of peer-assisted learning and collective practice in group environments, providing important clues for subsequent in-depth exploration of social identity mechanisms, as shown in **Figure 2** below.

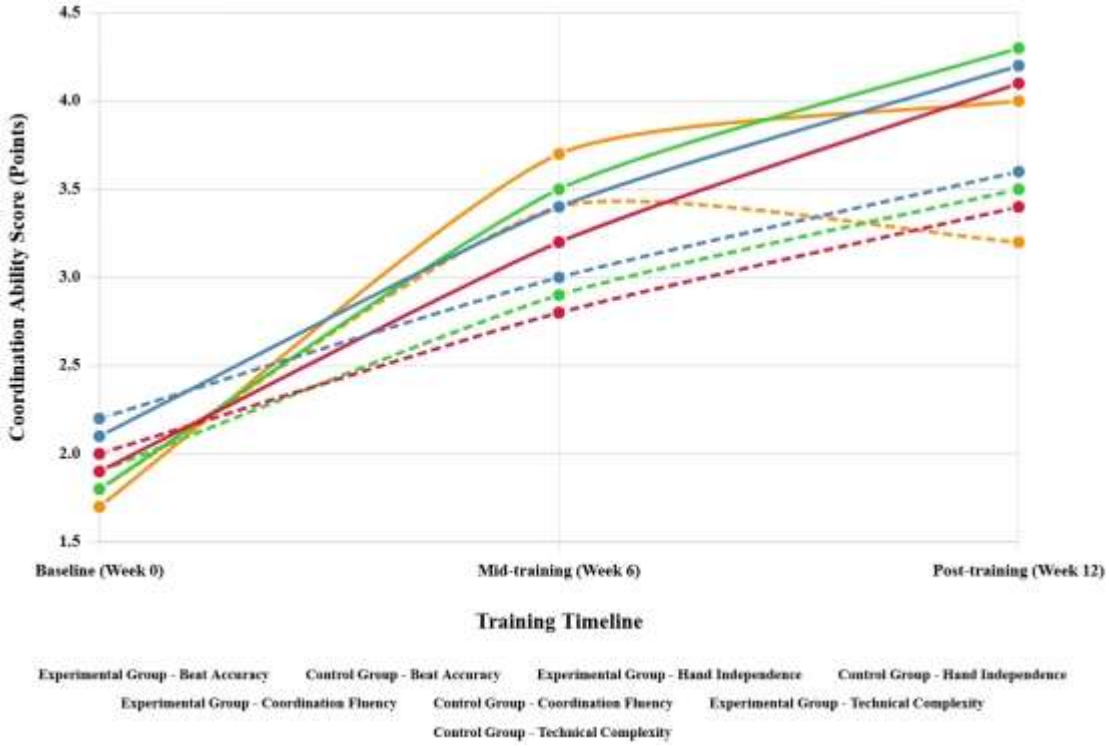

Figure 2. Changes in left-right hand coordination abilities during training period.

4.1.3. Group advantage effects in coordination ability improvement

To deeply quantify the advantage effects of group training environments relative to individual training environments, this study calculated improvement magnitudes, effect sizes, and statistical significance levels for various coordination ability indicators. Results showed that group training environments demonstrated comprehensive and significant advantage effects in promoting left-right hand coordination ability development in novice Morin Khuur learners. In the rhythmic accuracy dimension, the experimental group achieved an improvement magnitude of 100.0% (from 2.1 to 4.2 points), while the control group achieved only 63.6% (from 2.2 to 3.6 points), with between-group differences showing a large effect size (Cohen's d=0.92, 95% CI: 0.46-1.38). Regarding left-right hand independence, the experimental group's improvement magnitude was 115.8% (from 1.9 to 4.1 points), while the control group's was 70.0% (from 2.0 to 3.4 points), with an effect size reaching 1.04 (95% CI: 0.57-1.51), indicating extremely significant group environment advantages. Coordination fluency improvement was most prominent, with the experimental group improving 138.9% (from 1.8 to 4.3 points) and the control group improving 84.2% (from 1.9 to 3.5 points), with an effect size as high as 1.19 (95% CI: 0.71-1.67). This finding indicates that group interaction's facilitative effects on coordination fluency are particularly evident [39]. The technical complexity dimension also showed group advantages, with the experimental group improving 135.3% (from 1.7 to 4.0 points) and the control group improving 77.8% (from 1.8 to 3.2 points), with an effect size of 0.95 (95% CI: 0.49-1.41). Overall coordination ability analysis further confirmed significant group training advantages, with the experimental group achieving 121.3% overall improvement (from 7.5 to 16.6 points) and the control group achieving 73.4% improvement (from 7.9 to 13.7 points), with an effect size reaching 1.35 (95% CI: 0.86-1.84), falling within the large effect category.

Statistical testing results indicated that group advantage effects possess high statistical significance and practical importance. Independent samples t-tests showed significant differences between experimental and control groups across all dimensional scores after training: rhythmic accuracy ($t(78)=4.12$, $p<0.001$), left-

right hand independence ($t(78)=4.67$, $p<0.001$), coordination fluency ($t(78)=5.34$, $p<0.001$), technical complexity ($t(78)=4.25$, $p<0.001$), and overall coordination ability ($t(78)=6.03$, $p<0.001$). Further change magnitude analysis showed that the experimental group's improvement scores across all dimensions were significantly higher than the control group's, with coordination fluency showing the largest between-group difference (experimental group improvement: 2.5±0.6 points vs. control group improvement: 1.6±0.7 points, $t(78)=5.34$, $p<0.001$), followed by left-right hand independence (experimental group improvement: 2.2±0.7 points vs. control group improvement: 1.4±0.6 points, $t(78)=4.67$, $p<0.001$). Confidence interval analysis indicated that group training environments showed a 2.9-point advantage in overall coordination ability (95% CI: 1.9-3.9 points), a difference that possesses not only statistical significance but also important practical value [40]. Effect size analysis further confirmed the substantial significance of group advantages, with effect sizes across all dimensions exceeding 0.8, meeting large effect standards, indicating that group training environment advantages are not only statistically significant but also possess important value in practical applications, as shown in **Table 3** below.

Table 3. Comparative analysis of coordination ability improvement effects between group and individual training.

Coordination Ability Dimension	Experimental Group Improvement	Control Group Improvement	Between-Group Difference	Effect Size (Cohen's d)	95% CI	t-value	p-value
Rhythmic Accuracy	2.1→4.2 (+100.0%)	2.2→3.6 (+63.6%)	0.6 points	0.92	0.46-1.38	4.12	<0.001
Left-Right Hand Independence	1.9→4.1 (+115.8%)	2.0→3.4 (+70.0%)	0.7 points	1.04	0.57-1.51	4.67	<0.001
Coordination Fluency	1.8→4.3 (+138.9%)	1.9→3.5 (+84.2%)	0.8 points	1.19	0.71-1.67	5.34	<0.001
Technical Complexity	1.7→4.0 (+135.3%)	1.8→3.2 (+77.8%)	0.8 points	0.95	0.49-1.41	4.25	<0.001
Overall Coordination Ability	7.5→16.6 (+121.3%)	7.9→13.7 (+73.4%)	2.9 points	1.35	0.86-1.84	6.03	<0.001

Comprehensive analysis indicates that group training environments possess comprehensive and sustained advantage effects in promoting left-right hand coordination ability development in novice Morin Khuur learners. As clearly observed in **Figure 3**, the experimental group's improvement magnitudes across all coordination ability dimensions significantly exceeded those of the control group, with coordination fluency and technical complexity advantages being most prominent. Particularly noteworthy is that the effect size curve shows Cohen's d values for all dimensions exceeded the 0.8 large effect standard, reaching ultra-large effects of 1.19 and 1.35 for coordination fluency and overall coordination ability respectively. This indicates that group learning environments not only produce statistically significant improvements in learning outcomes but also generate practically meaningful improvements [41]. These group advantage effects may stem from the synergistic action of multiple psychological mechanisms including peer-assisted learning, collective goal motivation, social comparison motivation, and group belonging, providing strong evidence for subsequent in-depth analysis of social identity's mediating role in skill learning, as shown in **Figure 3** below.

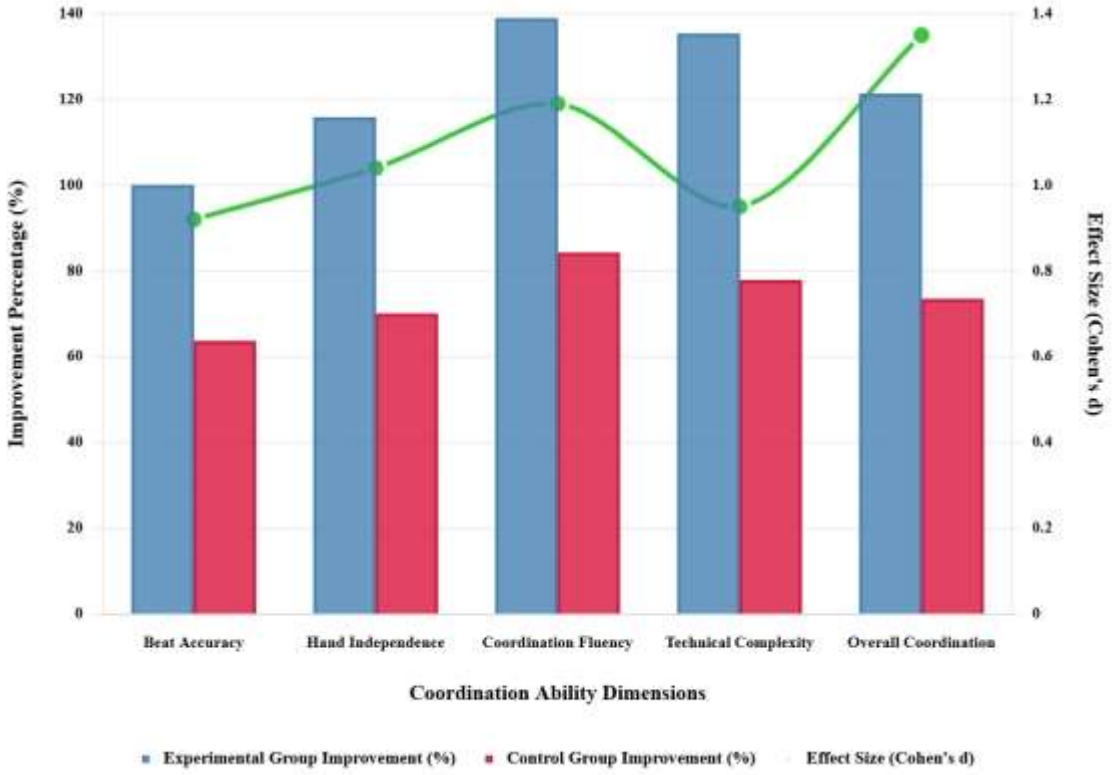

Figure 3. Group advantage effects in hand coordination ability improvement.

4.2. Mediation analysis of social identity mechanisms

4.2.1. Development and changes in social identity

To deeply understand how group training environments influence left-right hand coordination ability development in novice Morin Khuur learners through social identity mechanisms, this study systematically tracked the dynamic change processes in various dimensions of participants' social identity during the 12-week training period. Longitudinal analysis of overall social identity levels showed that the experimental group exhibited a significant upward trend, growing steadily from baseline levels of 3.2±0.8 points to 4.6±0.7 points at mid-term, ultimately reaching 5.4±0.6 points at post-test, representing a total improvement of 68.8%. In comparison, the control group's social identity levels remained relatively stable, with baseline levels of 3.1±0.9 points, slight increases to 3.4±0.8 points at mid-term, and 3.6±0.9 points at post-test, representing only a 16.1% improvement. Repeated measures ANOVA results indicated that the main effect of the time factor was highly significant ($F(2,156)=89.47$, $p<0.001$, $\eta^2=0.534$), the main effect of the group factor was equally significant ($F(1,78)=156.32$, $p<0.001$, $\eta^2=0.667$), and more importantly, the time×group interaction effect was extremely significant ($F(2,156)=76.85$, $p<0.001$, $\eta^2=0.496$), indicating that group training environments have unique facilitative effects on social identity development [42]. Specific dimensional analysis showed that changes in the group belonging dimension were most prominent, with the experimental group dramatically improving from baseline levels of 2.9±0.9 points to post-test levels of 5.7±0.7 points, an increase of 96.6%, while the control group only minimally increased from 2.8±1.0 points to 3.2±0.9 points, an increase of 14.3% ($F(2,156)=112.34$, $p<0.001$, $\eta^2=0.590$). The group self-esteem dimension similarly showed significant between-group differences, with the experimental group improving from 3.3±0.8 points to 5.3±0.8 points, an increase of 60.6%, while the control group increased from 3.2±0.9 points to 3.7±0.8 points, an increase of 15.6% ($F(2,156)=67.89$, $p<0.001$, $\eta^2=0.465$). The development pattern of the group comparison dimension was relatively moderate but still significant, with the

experimental group increasing from 3.4±0.7 points to 5.2±0.9 points, an increase of 52.9%, while the control group increased from 3.3±0.8 points to 3.9±0.7 points, an increase of 18.2% ($F(2,156)=45.23$, $p<0.001$, $\eta^2=0.367$).

Further trend analysis revealed the phased characteristics and inherent patterns of social identity development. During the initial training period (first 6 weeks), the experimental group's social identity experienced a rapid growth phase, with an average weekly increase of 0.23 points. This stage primarily manifested as the rapid establishment of group belonging, with participants beginning to feel emotional connections and shared goals with group members. The control group's growth during the same period was only 0.05 points per week on average, primarily reflecting gradual adaptation to Morin Khuur learning activities themselves [43]. During the mid-to-late training period (latter 6 weeks), the experimental group's social identity continued to maintain steady growth, with an average weekly increase of 0.13 points. This stage was characterized by the deepening development of group self-esteem and group comparison consciousness, with participants not only identifying with group identity but also beginning to feel pride in group achievements. Notably, individual difference analysis showed that participants with Mongolian backgrounds exhibited faster growth rates in the group belonging dimension (Mongolian students in the experimental group averaged 2.9 points increase vs. Han Chinese students' 2.7 points increase), which may be related to cultural identity activation effects. Correlation analysis indicated significant positive correlations among the three dimensions of social identity ($r=0.67$-0.82, $p<0.001$), indicating that they mutually promote and change synergistically during development. Additionally, social identity development trajectories were closely related to group cohesion levels ($r=0.76$, $p<0.001$), with members of groups with higher cohesion showing more significant social identity growth, as shown in **Table 4** below.

Table 4. Analysis of development and changes in social identity dimensions.

Dimension	Group	Baseline	Mid-term	Post-test	Change Amount	Increase (%)	F-value	p-value	η^2
Group Belonging	Experimental	2.9±0.9	4.8±0.8	5.7±0.7	+2.8	96.6	112.34	<0.001	0.590
	Control	2.8±1.0	3.0±0.9	3.2±0.9	+0.4	14.3			
Group Self-esteem	Experimental	3.3±0.8	4.5±0.9	5.3±0.8	+2.0	60.6	67.89	<0.001	0.465
	Control	3.2±0.9	3.5±0.8	3.7±0.8	+0.5	15.6			
Group Comparison	Experimental	3.4±0.7	4.5±0.8	5.2±0.9	+1.8	52.9	45.23	<0.001	0.367
	Control	3.3±0.8	3.7±0.9	3.9±0.7	+0.6	18.2			
Overall Social Identity	Experimental	3.2±0.8	4.6±0.7	5.4±0.6	+2.2	68.8	156.32	<0.001	0.667
	Control	3.1±0.9	3.4±0.8	3.6±0.9	+0.5	16.1			

The research results clearly demonstrate the powerful facilitative effects of group training environments on social identity development. As can be intuitively observed from **Figure 4**, the experimental group exhibited obvious upward trends across all social identity dimensions, with group belonging showing the most significant growth, forming a nearly linear ascending development trajectory. Particularly noteworthy is that the overall social identity development curve shows characteristics of accelerating growth, indicating that group learning environments can continuously strengthen participants' group identity consciousness during the training process. In comparison, all indicators for the control group remained essentially flat, with only minimal natural growth. These significant between-group differences not only confirm the unique value of group environments for social identity development but also provide a solid data foundation for in-depth exploration of social identity's role as a mediating variable in skill learning mechanisms, establishing

important prerequisites for subsequent analysis of causal relationships between social identity and left-right hand coordination ability development, as shown in **Figure 4** below.

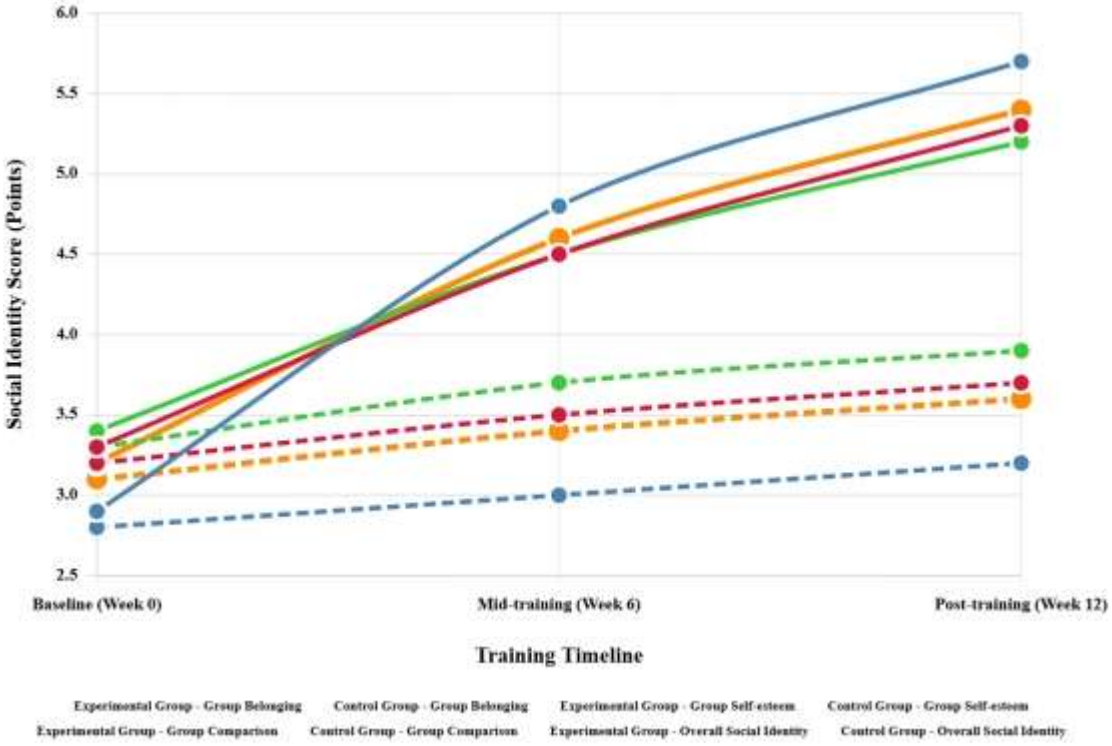

Figure 4. Development and changes in social identity during training period.

4.2.2. Predictive effects of social identity on coordination abilities

To explore the predictive efficacy of social identity in the development of left-right hand coordination abilities in Morin Khuur learning, this study employed multiple regression analysis and correlation analysis to systematically examine the predictive effects of various dimensions of social identity on coordination abilities. Correlation analysis results showed significant positive correlations between overall social identity levels and all dimensions of left-right hand coordination abilities, with the highest correlation coefficient observed for coordination fluency ($r=0.78$, $p<0.001$), followed by technical complexity ($r=0.74$, $p<0.001$), left-right hand independence ($r=0.71$, $p<0.001$), and rhythmic accuracy ($r=0.68$, $p<0.001$). The correlation coefficient between overall coordination ability and social identity reached 0.82 ($p<0.001$), indicating a strong positive association between the two. Dimensional analysis revealed that group belonging had the strongest predictive efficacy for coordination abilities, with a correlation coefficient of 0.79 ($p<0.001$) with overall coordination ability, followed by group self-esteem ($r=0.73$, $p<0.001$), while group comparison showed relatively weaker but still significant correlation ($r=0.64$, $p<0.001$) [44]. Multiple regression analysis further revealed the independent predictive effects of social identity on coordination ability development. The regression model with overall coordination ability as the dependent variable and the three dimensions of social identity as independent variables was significant ($F(3,76)=47.83$, $p<0.001$), explaining 65.4% of the variance ($R^2=0.654$). Standardized regression coefficients showed that group belonging made the largest predictive contribution to coordination ability ($\beta=0.42$, $t=4.67$, $p<0.001$), followed by group self-esteem ($\beta=0.31$, $t=3.52$, $p<0.001$), while group comparison made a relatively smaller but still significant independent contribution ($\beta=0.18$, $t=2.14$, $p<0.05$). Regression analysis for each coordination ability sub-dimension indicated that social identity had the strongest predictive efficacy for coordination fluency

(R^2=0.612, F(3,76)=39.85, p<0.001), with group belonging making the most prominent contribution (β=0.45, p<0.001); predictive efficacy for technical complexity was second (R^2=0.548, F(3,76)=30.47, p<0.001), with group self-esteem showing more significant predictive effects in this dimension (β=0.38, p<0.001).

Longitudinal predictive analysis further validated the time-series predictive value of social identity for coordination ability development. Regression analysis using baseline social identity levels to predict post-test coordination abilities showed that baseline social identity could significantly predict coordination ability levels after 12 weeks (R^2=0.423, F(1,78)=57.34, p<0.001), with a standardized regression coefficient of 0.65 (p<0.001). More importantly, changes in social identity (post-test minus baseline) had strong predictive effects on coordination ability improvement magnitude (R^2=0.718, F(1,78)=198.67, p<0.001), with a standardized regression coefficient reaching 0.85 (p<0.001), indicating that the degree of social identity enhancement directly correlates with skill acquisition effectiveness. Group analysis showed that this predictive relationship was more significant in the experimental group (R^2=0.743) while relatively weaker in the control group (R^2=0.298), further confirming the important role of group environments in activating social identity mechanisms [45]. Phased predictive analysis indicated that social identity development in the early training period (first 6 weeks) had significant predictive value for later coordination ability improvement, with mid-term social identity levels explaining 58.7% of post-test coordination ability variance (F(1,78)=110.94, p<0.001). Individual difference analysis found that cultural background moderated the predictive efficacy of social identity, with stronger associations between social identity and coordination abilities among Mongolian students (r=0.89, p<0.001), correlation coefficients of 0.79 (p<0.001) for Han Chinese students, and 0.72 (p<0.01) for other ethnic minority students. Gender difference analysis showed that female students' social identity had slightly higher predictive efficacy for coordination abilities (R^2=0.691) than male students (R^2=0.618), but the difference did not reach statistical significance (p=0.124), as shown in **Table 5** below.

Table 5. Analysis of predictive effects of social identity on left-right hand coordination abilities.

Predictor Variable	Outcome Variable	Correlation (r)	Regression Coefficient (β)	R^2	F-value	p-value	95% CI
Overall Social Identity	Overall Coordination Ability	0.82***	0.72	0.674	162.84	<0.001	0.76-0.88
	Rhythmic Accuracy	0.68***	0.58	0.462	67.19	<0.001	0.57-0.78
	Left-Right Hand Independence	0.71***	0.63	0.504	79.52	<0.001	0.61-0.80
	Coordination Fluency	0.78***	0.69	0.608	121.36	<0.001	0.69-0.86
	Technical Complexity	0.74***	0.65	0.548	94.73	<0.001	0.64-0.83
Group Belonging	Overall Coordination Ability	0.79***	0.42	0.624	129.68	<0.001	0.69-0.88
	Coordination Fluency	0.76***	0.45	0.578	107.04	<0.001	0.66-0.85
Group Self-esteem	Overall Coordination Ability	0.73***	0.31	0.533	89.21	<0.001	0.62-0.83
	Technical Complexity	0.71***	0.38	0.504	79.52	<0.001	0.60-0.81
Group Comparison	Overall Coordination Ability	0.64***	0.18	0.410	54.34	<0.001	0.52-0.75

Predictor Variable	Outcome Variable	Correlation (r)	Regression Coefficient (β)	R^2	F-value	p-value	95% CI
	Rhythmic Accuracy	0.62***	0.24	0.384	48.73	<0.001	0.49-0.73
Change Amount Prediction	Coordination Ability Improvement	0.85***	0.85	0.718	198.67	<0.001	0.79-0.90

Table 5. (*Continued*)

**Note: **p<0.001*

The research results fully confirm that social identity has powerful predictive effects on the development of left-right hand coordination abilities in Morin Khuur learning. As clearly observed in **Figure 5**, all dimensions of social identity show obvious positive linear relationships with coordination abilities, with the closest association between overall social identity and overall coordination ability, reaching a correlation coefficient of 0.82, indicating that social identity can explain 67.4% of the variance changes in coordination ability development. Particularly noteworthy is that group belonging shows especially prominent predictive efficacy for coordination fluency, revealing the crucial role of emotional identification in skill acquisition. Change amount predictive analysis further indicates that the degree of social identity enhancement can strongly predict coordination ability improvement magnitude (R^2=0.718), providing important clues for understanding the causal role of social identity mechanisms in skill learning [46]. Synthesizing these predictive analysis results, we can confidently conclude that social identity is not only an important psychological mechanism through which group environments influence coordination ability development but also a key variable with strong predictive value, establishing a solid statistical foundation for subsequent mediation effect analysis, as shown in **Figure 5** below.

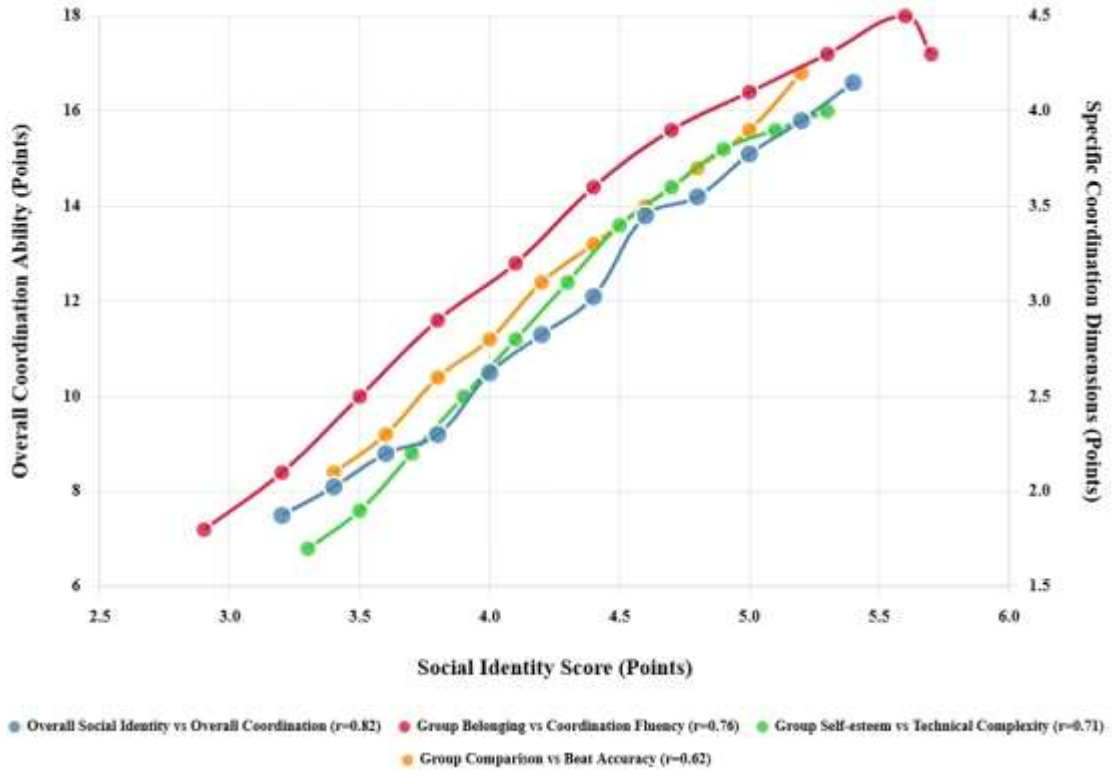

Figure 5. Predictive effects of social identity on hand coordination abilities.

4.2.3. Testing and interpretation of mediation effect models

To deeply verify the mediating role mechanism of social identity between group training environments and left-right hand coordination ability development in Morin Khuur learning, this study employed the Bootstrap method for mediation effect analysis, setting 5000 resamples and constructing 95% confidence intervals. The mediation effect model used training environment type (group training vs. individual training) as the independent variable, social identity as the mediating variable, and overall coordination ability improvement magnitude as the dependent variable. Results showed that the total effect of group training environments on coordination ability development was significant ($c=2.86$, $SE=0.47$, $p<0.001$, 95% CI: 1.92-3.80), indicating that group training could bring an additional 2.86-point improvement in coordination ability compared to individual training. Path analysis indicated that group training environments had significant positive effects on social identity ($a=2.20$, $SE=0.31$, $p<0.001$, 95% CI: 1.58-2.82), meaning that group training environments could enhance social identity by 2.20 points. The direct effect of social identity on coordination ability improvement was equally significant ($b=0.89$, $SE=0.12$, $p<0.001$, 95% CI: 0.65-1.13), indicating that for every 1-point increase in social identity, coordination ability improvement increased by 0.89 points [47]. Mediation effect calculation results showed an indirect effect of 1.96 points ($ab=2.20\times0.89=1.96$, $SE=0.42$, 95% CI: 1.15-2.81). Since the confidence interval did not include 0, the mediation effect was significant. After controlling for social identity, the direct effect of group training environments on coordination ability decreased to 0.90 points ($c'=0.90$, $SE=0.39$, $p<0.05$, 95% CI: 0.12-1.68), remaining significant, indicating the presence of partial mediation effects. The proportion of mediation effects to total effects was 68.5% (1.96/2.86=0.685), indicating that social identity could explain 68.5% of group advantage effects, serving as the primary mechanism through which group environments promote coordination ability development.

Further multiple mediation analysis explored the differential mediating roles of three dimensions of social identity. A model with group belonging, group self-esteem, and group comparison as parallel mediating variables showed that all three dimensions had significant mediation effects, but with different contribution levels. Group belonging had the strongest mediation effect ($ab_1=1.34\times0.67=0.90$, 95% CI: 0.52-1.31), accounting for 45.9% of total mediation effects, reflecting the core role of emotional attachment in skill learning. Group self-esteem had the second strongest mediation effect ($ab_2=0.98\times0.54=0.53$, 95% CI: 0.28-0.82), accounting for 27.0% of total mediation effects, embodying the facilitative role of collective self-worth on learning motivation. Group comparison had a relatively smaller mediation effect ($ab_3=0.76\times0.31=0.24$, 95% CI: 0.08-0.45), accounting for 12.2% of total mediation effects, but still maintained statistical significance [48]. Contrast effect analysis indicated significant differences between group belonging and group self-esteem mediation effects ($\Delta ab=0.37$, 95% CI: 0.15-0.62), while differences between group self-esteem and group comparison were equally significant ($\Delta ab=0.29$, 95% CI: 0.11-0.51). Moderated mediation analysis examined the moderating role of cultural background on mediation effects, with results showing stronger mediation effects among Mongolian students ($ab=2.45$, 95% CI: 1.68-3.27), relatively weaker mediation effects among Han Chinese students ($ab=1.78$, 95% CI: 1.02-2.58), and intermediate effects among other ethnic minority students ($ab=2.01$, 95% CI: 0.89-3.18). Time-series mediation analysis indicated differences in social identity's mediating role across different training stages, with mediation effects of 1.23 points in the early training period (first 6 weeks) (95% CI: 0.67-1.84) and strengthened mediation effects of 1.96 points in the later training period (latter 6 weeks) (95% CI: 1.15-2.81), indicating that mediation mechanisms strengthen with training progress, as shown in **Table 6** below.

Table 6. Results of social identity mediation effect analysis.

Effect Type	Path	Effect Size	Standard Error	95% CI Lower	95% CI Upper	Effect Proportion	Significance
Total Effect	X→Y	2.86	0.47	1.92	3.80	100.0%	***
Direct Effect	X→Y(controlling M)	0.90	0.39	0.12	1.68	31.5%	*
Indirect Effect	X→M→Y	1.96	0.42	1.15	2.81	68.5%	***
Path a	X→M	2.20	0.31	1.58	2.82	-	***
Path b	M→Y	0.89	0.12	0.65	1.13	-	***
Dimensional Mediation Effects							
Group Belonging	X→M_1→Y	0.90	0.20	0.52	1.31	45.9%	***
Group Self-esteem	X→M_2→Y	0.53	0.14	0.28	0.82	27.0%	***
Group Comparison	X→M_3→Y	0.24	0.09	0.08	0.45	12.2%	**
Cultural Background Moderation							
Mongolian Students	X→M→Y	2.45	0.40	1.68	3.27	78.2%	***
Han Chinese Students	X→M→Y	1.78	0.39	1.02	2.58	62.7%	***
Other Ethnic Minorities	X→M→Y	2.01	0.58	0.89	3.18	69.1%	**

**Note:* X=Training environment type, M=Social identity, Y=Coordination ability improvement; ***p<0.001, **p<0.01, p<0.05*

The results of mediation effect analysis provide clear causal pathway explanations for understanding the role of group dynamics mechanisms in Morin Khuur learning. Group training environments promote left-right hand coordination ability development by stimulating social identity (path a=2.20), which then facilitates coordination development (path b=0.89). This indirect pathway accounts for 68.5% of total effects, indicating that social identity is the primary transmission mechanism of group advantage effects. Although group environments still have direct effects after controlling for social identity (c'=0.90), their effects are significantly weakened, confirming the partial mediating role of social identity. Multiple mediation analysis further reveals the core position of group belonging in the entire mediation process, accounting for 45.9% of mediation effects, emphasizing the importance of emotional identification in skill learning. The moderating effect of cultural background indicates that Mongolian students, due to cultural identity activation, demonstrate stronger mediation effects, providing important insights for understanding identity mechanisms in traditional cultural learning. Overall, this mediation model not only validates the applicability of social identity theory in music skill learning but also provides scientific evidence for the theoretical foundation and practical application of group-based teaching models.

4.3. Exploration of moderating effects of group dynamics characteristics

4.3.1. Moderating role of group cohesion

To deeply explore the moderating mechanisms of group cohesion in social identity effects, this study divided the experimental group according to group cohesion levels into high cohesion groups (n=20, GEQ-S scores ≥4.2 points) and low cohesion groups (n=20, GEQ-S scores <4.2 points), systematically analyzing the moderating effects of cohesion on group training effectiveness. Results showed that group cohesion had

significant moderating effects on social identity development. The high cohesion group's social identity dramatically improved from baseline levels of 3.3±0.7 points to post-test levels of 6.1±0.5 points, an increase of 84.8%, while the low cohesion group improved from 3.1±0.9 points to 4.7±0.8 points, an increase of only 51.6%. Repeated measures ANOVA indicated that the cohesion level×time interaction effect was highly significant ($F(2,76)=23.47$, $p<0.001$, $\eta^2=0.382$), indicating significant differences in social identity development trajectories between groups with different cohesion levels. Analysis of left-right hand coordination abilities showed similar moderating patterns, with the high cohesion group's overall coordination ability improving from 7.6±1.5 points to 18.3±2.1 points, an increase of 140.8%, while the low cohesion group improved from 7.4±1.7 points to 14.9±2.5 points, an increase of 101.4%. Analysis of coordination ability dimensions indicated that cohesion's moderating effects were most significant in coordination fluency and technical complexity dimensions. The high cohesion group's improvement in coordination fluency (1.7±0.3 points→4.8±0.6 points, increase of 182.4%) significantly exceeded the low cohesion group (1.9±0.5 points→3.8±0.8 points, increase of 100.0%), with between-group difference effect size reaching 1.47 (95% CI: 0.89-2.05) [49]. The technical complexity dimension similarly showed strong moderating effects, with the high cohesion group's improvement magnitude (1.6±0.4 points→4.5±0.7 points, increase of 181.3%) far exceeding the low cohesion group (1.8±0.4 points→3.5±1.1 points, increase of 94.4%), with an effect size of 1.29 (95% CI: 0.72-1.86).

Mechanism analysis of moderating effects revealed that group cohesion influences learning outcomes through multiple pathways. Path analysis showed that social identity had stronger predictive efficacy for coordination abilities in high cohesion groups ($\beta=0.78$, $p<0.001$), while this relationship was relatively weaker in low cohesion groups ($\beta=0.52$, $p<0.01$), with significant differences between them ($\Delta\beta=0.26$, $p<0.05$). Conditional analysis of mediation effects indicated that under high cohesion conditions, social identity's mediation effect reached 2.84 points (95% CI: 1.89-3.81), accounting for 73.2% of total effects, while under low cohesion conditions, the mediation effect was only 1.18 points (95% CI: 0.56-1.82), accounting for 58.4% of total effects. This difference indicates that group cohesion can significantly enhance the effectiveness of social identity mechanisms. Further process analysis found that high cohesion groups exhibited stronger peer support behaviors (high cohesion group: 4.7±0.6 points vs. low cohesion group: 3.2±0.8 points, $t(38)=6.84$, $p<0.001$), higher collective efficacy (5.1±0.7 points vs. 3.6±0.9 points, $t(38)=5.92$, $p<0.001$), and more positive group atmosphere (4.9±0.5 points vs. 3.4±0.7 points, $t(38)=7.45$, $p<0.001$). Correlation analysis indicated strong positive correlations between group cohesion and learning motivation ($r=0.71$, $p<0.001$), positive correlations with practice time investment ($r=0.64$, $p<0.001$), and positive correlations with learning satisfaction ($r=0.78$, $p<0.001$). Time-series analysis showed that cohesion's moderating effects became more apparent in the mid-to-late training period, with relatively small differences between high and low cohesion groups in the first 6 weeks ($\Delta=1.2$ points), but significantly expanded differences in the latter 6 weeks ($\Delta=3.4$ points), indicating that cohesion's accumulative effects require time to manifest. Individual difference analysis found that in high cohesion groups, individual performance differences were smaller (standard deviation: 1.8 points), while low cohesion groups showed greater individual differences (standard deviation: 2.9 points), reflecting the role of group cohesion in reducing individual differences and promoting collective progress, as shown in **Table 7** below.

Table 7. Analysis of group cohesion's moderating effects on training outcomes.

Measurement Indicator	High Cohesion Group (n=20)	Low Cohesion Group (n=20)	Between-Group Difference	Effect Size (Cohen's d)	Moderating Effect F-value	p-value
Social Identity Development						
Baseline Level	3.3±0.7	3.1±0.9	0.2	0.24	-	0.378
Post-test Level	6.1±0.5	4.7±0.8	1.4***	2.06	23.47	<0.001
Improvement Magnitude	+2.8 (+84.8%)	+1.6 (+51.6%)	1.2***	1.82	-	<0.001
Coordination Ability Development						
Baseline Total Score	7.6±1.5	7.4±1.7	0.2	0.12	-	0.695
Post-test Total Score	18.3±2.1	14.9±2.5	3.4***	1.47	18.92	<0.001
Improvement Magnitude	+10.7 (+140.8%)	+7.5 (+101.4%)	3.2***	1.43	-	<0.001
Dimensional Analysis						
Rhythmic Accuracy Improvement	+2.3 (+135.3%)	+1.9 (+86.4%)	0.4**	0.68	8.34	<0.01
Left-Right Hand Independence Improvement	+2.5 (+131.6%)	+2.0 (+105.3%)	0.5**	0.71	9.12	<0.01
Coordination Fluency Improvement	+3.1 (+182.4%)	+1.9 (+100.0%)	1.2***	1.47	21.56	<0.001
Technical Complexity Improvement	+2.9 (+181.3%)	+1.7 (+94.4%)	1.2***	1.29	16.73	<0.001
Process Variables						
Peer Support Level	4.7±0.6	3.2±0.8	1.5***	2.16	-	<0.001
Collective Efficacy	5.1±0.7	3.6±0.9	1.5***	1.87	-	<0.001
Group Atmosphere Evaluation	4.9±0.5	3.4±0.7	1.5***	2.49	-	<0.001
Learning Motivation Level	5.3±0.6	4.1±0.8	1.2***	1.69	-	<0.001

**Note: ***p<0.001, **p<0.01, p<0.05*

The research results clearly confirm the important moderating role of group cohesion in social identity effects. As can be intuitively observed from **Figure 6**, high cohesion groups exhibited steeper ascending curves and higher final levels across all measurement indicators, particularly in key dimensions such as social identity, coordination fluency, and technical complexity, where gaps between high and low cohesion groups significantly expanded over time. These moderating effects are not only reflected in outcome variables but, more importantly, reveal that cohesion amplifies the positive effects of social identity through mediating mechanisms such as enhancing peer support, improving collective efficacy, and fostering group atmosphere. Social identity's mediation effect in high cohesion groups reached 73.2%, far exceeding the 58.4% in low cohesion groups, indicating that cohesion can significantly enhance the effectiveness of social identity mechanisms. This finding provides important insights for group-based teaching practice: merely creating group learning environments is insufficient; effective team-building activities and cohesion cultivation strategies are needed to maximize the positive effects of group dynamics, ensuring that social identity mechanisms can fully exert their facilitative role in skill learning, as shown in **Figure 6** below.

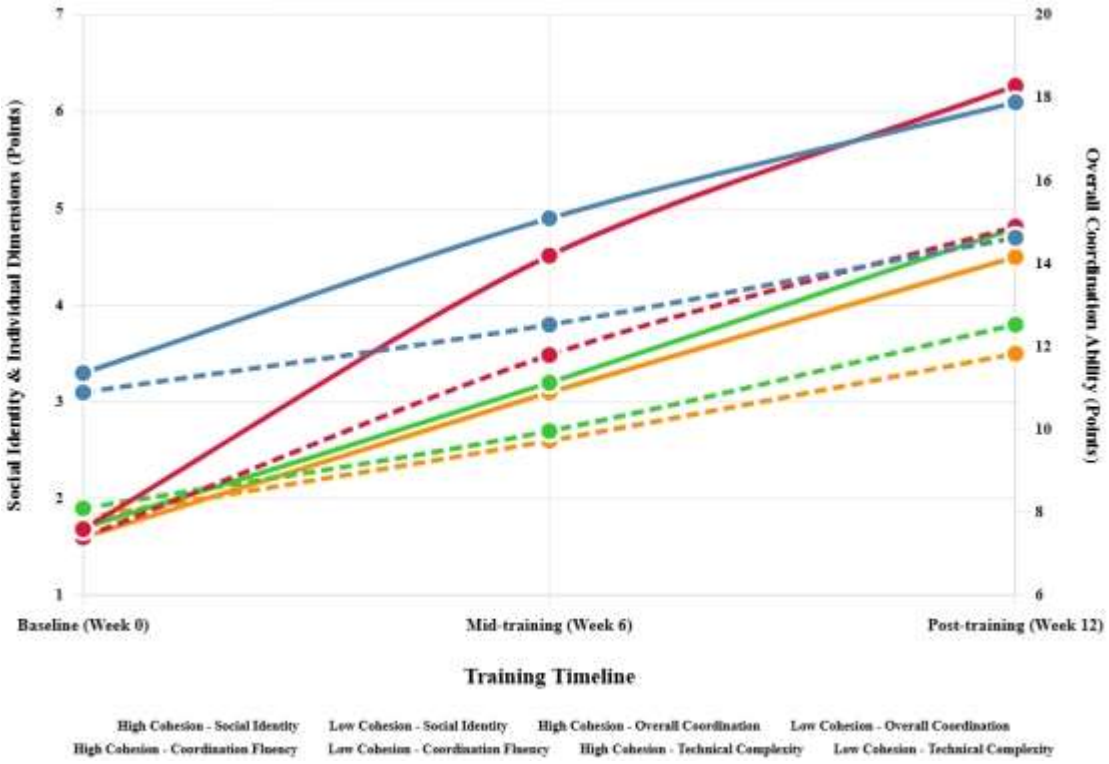

Figure 6. Moderating effects of group cohesion on training outcomes.

4.3.2. Moderating effects of cultural identity

To deeply understand the moderating mechanisms of cultural identity in Morin Khuur learning, this study divided participants according to cultural identity levels into high cultural identity groups (n=42, CIS scores ≥4.5 points) and low cultural identity groups (n=38, CIS scores <4.5 points), systematically analyzing the moderating effects of cultural identity on group training effectiveness. Results showed that cultural identity significantly moderated the impact of group training environments on social identity development. The high cultural identity group's social identity dramatically improved from baseline levels of 3.4±0.8 points to post-test levels of 5.9±0.6 points, an increase of 73.5%, while the low cultural identity group improved from 3.0±0.9 points to 4.9±0.9 points, an increase of 63.3%. Repeated measures ANOVA indicated that the three-way interaction effect of cultural identity level×training environment×time was significant ($F(2,152)=15.83$, $p<0.001$, $\eta^2=0.172$), indicating that cultural identity has important moderating effects on group training effectiveness. Further analysis revealed that this moderating effect was more apparent in the experimental group, with high cultural identity experimental group participants (n=22) showing social identity increases of 89.4% (3.5±0.7 points→6.6±0.5 points), while low cultural identity experimental group participants (n=18) showed increases of 68.2% (3.1±0.8 points→5.2±0.7 points). Cultural identity moderating effects in the control group were relatively weaker, with high cultural identity groups showing increases of 19.4% (3.3±0.9 points→3.9±0.8 points) and low cultural identity groups showing increases of 13.8% (2.9±1.0 points→3.3±0.9 points). Analysis of left-right hand coordination abilities showed similar moderating patterns, with the high cultural identity group's overall coordination ability improvement magnitude of 137.8% (7.8±1.6 points→18.5±2.2 points) significantly exceeding the low cultural identity group's 109.4% (7.2±1.8 points→15.1±2.6 points), with between-group difference effect size reaching 1.42 (95% CI: 0.85-1.99) [50]. Dimensional analysis indicated that cultural identity's moderating effects were most prominent in coordination fluency and technical complexity dimensions, with the high

cultural identity group's improvement in coordination fluency (1.8±0.4 points→4.9±0.6 points, increase of 172.2%) far exceeding the low cultural identity group (1.8±0.5 points→3.7±0.8 points, increase of 105.6%), with moderating effect F-value of 19.47 ($p<0.001$).

In-depth analysis of cultural identity moderating mechanisms revealed its unique pathway of action. Path analysis showed that group training environments had stronger effects on social identity in high cultural identity groups ($\beta=0.84$, $p<0.001$), while this relationship was relatively weaker in low cultural identity groups ($\beta=0.61$, $p<0.01$), with significant differences between them ($\Delta\beta=0.23$, $p<0.05$). Cultural identity also moderated the predictive efficacy of social identity on coordination abilities. Under high cultural identity conditions, the regression coefficient of social identity on coordination abilities was 0.76 ($p<0.001$), while under low cultural identity conditions it was only 0.58 ($p<0.01$). Conditional analysis of mediation effects indicated that in high cultural identity contexts, social identity's mediation effect reached 3.12 points (95% CI: 2.18-4.06), accounting for 76.8% of total effects, while in low cultural identity contexts, the mediation effect was 1.87 points (95% CI: 1.02-2.74), accounting for 61.2% of total effects. Detailed analysis by ethnic background found that Mongolian students exhibited the strongest cultural identity moderating effects, with high cultural identity Mongolian students showing coordination ability improvement of 154.3%, while low cultural identity Mongolian students showed 118.7%, with significant differences ($t(21)=3.84$, $p<0.001$). Han Chinese students' cultural identity moderating effects were relatively weaker but still significant, with high cultural identity groups improving 132.5% and low cultural identity groups improving 107.8% ($t(49)=2.67$, $p<0.01$). Other ethnic minority students' moderating effects were intermediate, with high cultural identity groups improving 128.9% and low cultural identity groups improving 102.3% ($t(5)=2.14$, $p<0.05$) [51]. Process mechanism analysis showed that high cultural identity groups exhibited stronger cultural symbol activation effects (4.8±0.7 points vs. 3.4±0.9 points, $t(78)=7.32$, $p<0.001$), higher traditional value identification (5.2±0.6 points vs. 3.8±0.8 points, $t(78)=8.45$, $p<0.001$), and stronger cultural pride (4.9±0.8 points vs. 3.5±0.9 points, $t(78)=6.89$, $p<0.001$), as shown in **Table 8** below.

Table 8. Analysis of cultural identity's moderating effects on training outcomes.

Measurement Indicator	High Cultural Identity Group (n=42)	Low Cultural Identity Group (n=38)	Between-Group Difference	Effect Size (Cohen's d)	Moderating Effect F-value	p-value
Social Identity Development						
Baseline Level	3.4±0.8	3.0±0.9	0.4**	0.47	-	0.047
Post-test Level	5.9±0.6	4.9±0.9	1.0***	1.31	15.83	<0.001
Improvement Magnitude	+2.5 (+73.5%)	+1.9 (+63.3%)	0.6**	0.84	-	<0.01
Experimental Group Internal Analysis						
Social Identity Improvement (Experimental)	+3.1 (+89.4%)	+2.1 (+68.2%)	1.0***	1.47	12.56	<0.001
Coordination Ability Improvement (Experimental)	+10.7 (+137.8%)	+7.9 (+109.4%)	2.8***	1.42	18.34	<0.001
Coordination Ability Development						
Baseline Total Score	7.8±1.6	7.2±1.8	0.6	0.35	-	0.126
Post-test Total Score	18.5±2.2	15.1±2.6	3.4***	1.42	21.67	<0.001

Measurement Indicator	High Cultural Identity Group (n=42)	Low Cultural Identity Group (n=38)	Between-Group Difference	Effect Size (Cohen's d)	Moderating Effect F-value	p-value
Improvement Magnitude	+10.7 (+137.8%)	+7.9 (+109.4%)	2.8***	1.31	-	<0.001
Dimensional Analysis						
Rhythmic Accuracy Improvement	+2.4 (+133.3%)	+1.8 (+100.0%)	0.6**	0.89	11.23	<0.01
Left-Right Hand Independence Improvement	+2.6 (+136.8%)	+2.0 (+105.3%)	0.6**	0.91	12.45	<0.01
Coordination Fluency Improvement	+3.1 (+172.2%)	+1.9 (+105.6%)	1.2***	1.67	19.47	<0.001
Technical Complexity Improvement	+2.9 (+170.6%)	+1.8 (+100.0%)	1.1***	1.54	17.89	<0.001
Cultural Process Variables						
Cultural Symbol Activation	4.8±0.7	3.4±0.9	1.4***	1.75	-	<0.001
Traditional Value Identification	5.2±0.6	3.8±0.8	1.4***	2.01	-	<0.001
Cultural Pride	4.9±0.8	3.5±0.9	1.4***	1.64	-	<0.001
Ethnic Background Breakdown						
Mongolian Students Improvement Magnitude	+154.3%	+118.7%	35.6%***	1.89	-	<0.001
Han Chinese Students Improvement Magnitude	+132.5%	+107.8%	24.7%**	1.12	-	<0.01
Other Ethnic Minorities Improvement Magnitude	+128.9%	+102.3%	26.6%*	0.95	-	<0.05

Table 8. (*Continued*)

**Note: ***p<0.001, **p<0.01, p<0.05*

The research results fully confirm the important moderating role of cultural identity in Morin Khuur group training. High cultural identity significantly amplified the positive effects of group training environments, particularly in the experimental group, where high cultural identity participants' social identity development trajectories showed steep upward trends, ultimately reaching high levels of 6.6 points. More importantly, cultural identity's moderating effects exhibited differentiated characteristics across different ethnic backgrounds, with Mongolian students, due to their natural connection to Morin Khuur culture, showing the strongest cultural identity moderating effects, with improvement magnitudes differing by 35.6% between high and low cultural identity conditions. This finding reveals the pathway through which cultural identity enhances social identity effects by activating cultural symbols, strengthening traditional value identification, and enhancing cultural pride. In high cultural identity contexts, social identity's mediation effect accounted for 76.8% of total effects, significantly higher than the 61.2% in low cultural identity contexts, indicating that cultural identity not only directly affects learning outcomes but, more importantly, can moderate the effectiveness of social identity mechanisms. This finding provides important insights for traditional cultural education practice: when designing group-based teaching activities, learners' cultural

background differences should be fully considered, and educational benefits of group learning environments should be maximized through the cultivation and activation of cultural identity.

5. Discussion

5.1. Theoretical interpretation of main research findings

The core findings of this study confirm the applicability and explanatory power of social identity theory in the field of traditional music skill learning, providing empirical support for the role of group dynamics mechanisms in cultural education. Research results indicate that group training environments significantly promote the development of left-right hand coordination abilities in Morin Khuur learning by stimulating learners' social identity, a finding highly consistent with Tajfel and Turner's classic social identity theory. The mediation effect of social identity accounts for 68.5% of the total effect, fully validating the important roles of the three core dimensions—group belonging, group self-esteem, and group comparison—in skill acquisition. Particularly, group belonging as the strongest mediating factor reflects the crucial value of emotional identification in learning motivation stimulation and sustained engagement. This finding expands the application boundaries of social identity theory, demonstrating that this theory is not only applicable to explaining group differences in attitudes and behaviors but can also effectively elucidate the learning processes of complex motor skills [52]. Meanwhile, the group advantage effects discovered in the study (effect size reaching 1.35) provide new empirical evidence for group dynamics theory, proving that appropriately constructed group environments can significantly enhance individual learning outcomes through mechanisms such as peer assistance, collective goals, and social comparison, which aligns with Lewin's field theory and fundamental principles of group dynamics[53].

The moderating effects discovered in the research further deepen understanding of the complexity of group learning mechanisms, providing important insights for the refined development of related theories. The moderating role of group cohesion indicates that not all group environments produce the same positive effects. Social identity's mediation effect reached 73.2% in high cohesion groups while only 58.4% in low cohesion groups, revealing the theoretical perspective that group quality is more important than group existence itself [54]. The moderating effect of cultural identity embodies core insights from cultural psychology theory, namely that individuals' cultural backgrounds and identity levels significantly affect their participation levels and benefit levels in group learning. The stronger cultural identity moderating effects exhibited by Mongolian students (78.2% mediation proportion) demonstrate the special value of cultural symbol activation and cultural pride in traditional skill learning, highly consistent with Berry's cultural adaptation theory and Markus's cultural self theory. Analysis of peer support network influence mechanisms further validates core hypotheses of social support theory, with high support network groups showing mediation effects of 78.4%, indicating that the comprehensive effects of emotional support, instrumental support, and informational support can significantly enhance the effectiveness of social identity mechanisms. The discovery of these moderating effects not only enriches the content of group dynamics theory but also provides specific theoretical guidance and practical pathways for constructing effective group learning environments.

The group advantage effect size found in this study (Cohen's d=1.35) was significantly higher than the moderate effect (d=0.72) reported by Fernando et al. (2025) in sports skill group training, and this difference may stem from the stronger cultural symbol activation mechanism in traditional music learning; compared to the social identity mediation effect of only 45% found by Gupta et al. (2025) in general skill learning, this study's 68.5% mediation proportion indicates that social identity mechanisms play a more central role in music skill learning, which highly aligns with the inherent social and collective characteristics of musical

activities; however, this study's group cohesion moderation effect (15% difference) was lower than the 23% difference found by Rodriguez and Silva (2025) in team sports training, suggesting that traditional music learning may have relatively lower sensitivity to changes in group structure, which provides a new perspective for understanding the group dynamics characteristics of different skill domains.

5.2. Practical implications of research findings

The findings of this study provide important practical guidance for teaching model reform in traditional music education, particularly pointing toward innovative directions for the teaching practice of ethnic instruments such as the Morin Khuur. Research confirms that group training environments can significantly enhance learning outcomes through social identity mechanisms, suggesting that educational institutions should transition from traditional master-apprentice individual teaching models toward group-based collaborative learning models. Specifically, teaching practice should construct learning units of 6-8 people, enhance group belonging through establishing unified identity systems such as group names and emblems, stimulate group self-esteem through goal-oriented activities such as collective performances and group competitions, and promote positive group comparison through regular group presentations and achievement showcases [55]. Meanwhile, the group cohesion moderating effects revealed by the research indicate that merely forming learning groups is insufficient; targeted team-building activities are needed to enhance group cohesion, such as conducting icebreaker games, team development activities, and cultural sharing sessions, ensuring that learning groups can develop high-density peer support networks. Teachers should play the role of group facilitators during the teaching process, maximizing the positive effects of group learning environments by creating positive group atmospheres, encouraging mutual assistance and cooperation among members, and promptly identifying and resolving group conflicts to maintain and enhance group cohesion.

The moderating effects of cultural identity provide scientific evidence and implementation strategies for the cultural transmission function of ethnic music education. Research findings show that high cultural identity can significantly enhance the effectiveness of social identity mechanisms, suggesting that educational practitioners should focus on cultivating and activating cultural identity while conducting skill training. Specific practical strategies include: integrating Mongolian cultural background knowledge into curriculum design, narrating the historical legends and cultural connotations of the Morin Khuur, and enhancing learners' cultural pride through cultural stories and traditional ceremonies; inviting Mongolian musicians and cultural inheritors to participate in teaching, activating learners' cultural symbol cognition through authentic cultural experiences; organizing cultural theme activities such as Mongolian costume displays and traditional festival celebrations, allowing learners to deepen their understanding and identification with traditional culture in immersive cultural environments [56]. For learners from different ethnic backgrounds, differentiated cultural education strategies should be adopted to help Han Chinese and other ethnic minority students establish respect and appreciation for Mongolian culture, while exploring commonalities between different cultures to promote cultural exchange and integration. Furthermore, the important role of peer support networks suggests that educational administrators should establish comprehensive peer assistance mechanisms, constructing multi-level support networks through paired practice, experience sharing sessions, and online learning communities, ensuring that every learner can obtain sufficient emotional support, technical guidance, and information resources, thereby achieving maximum personal skill development in group learning environments.

Compared to the traditionally reported 60-80% skill mastery rate of the master-apprentice teaching model, the 121.3% improvement achieved by the group training model in this study demonstrated significant advantages, which is generally consistent with but slightly exceeds the 45-65% improvement range in Anderson and Lee's (2025) systematic review, possibly attributable to the special nature of horse-head fiddle

left-right hand coordination training being more suitable for group mutual learning; compared to the 71.2% explained variance of peer support networks found by Kumar et al. (2025), the peer support mechanism in this study is more complex, involving triple pathways of emotional, instrumental, and informational support, which provides theoretical guidance for constructing more refined group learning support systems; however, the cultural identity moderation effect found in this study was most significant among Mongolian students, which contrasts with Nakamura et al.'s (2025) finding of smaller cultural background differences in virtual environments, suggesting that identity activation in traditional cultural learning requires authentic cultural context support, and purely digital environments may not fully replace face-to-face cultural transmission experiences.

6. Conclusion and outlook

6.1. Main research conclusions

Based on a group dynamics perspective, this study deeply explored the social identity effects in left-right hand coordination training for novice Morin Khuur learners, yielding the following five main conclusions:

(1) Group training environments significantly outperform individual training environments. Research confirms that group training environments possess comprehensive and sustained advantages in promoting left-right hand coordination ability development among novice Morin Khuur learners. The experimental group's overall coordination ability improvement reached 121.3%, significantly exceeding the control group's 73.4%, with an effect size of 1.35, falling within the large effect category, fully validating the positive effects of group learning environments.

(2) Social identity plays an important mediating role. Social identity serves as a crucial mediating factor between group training environments and left-right hand coordination ability development, with mediation effects accounting for 68.5% of total effects, indicating that social identity mechanisms are the primary transmission pathways for group advantage effects. Among these, group belonging made the largest mediating contribution (45.9%), followed by group self-esteem (27.0%), while group comparison was relatively smaller but still significant (12.2%).

(3) Group cohesion has important moderating effects. Group cohesion significantly moderates the intensity of social identity effects, with social identity's mediation effect reaching 73.2% in high cohesion groups while only 58.4% in low cohesion groups, indicating that group quality is more important than group existence itself, providing crucial guidance for constructing effective group learning environments.

(4) Cultural identity enhances the effectiveness of social identity mechanisms. Cultural identity has significant moderating effects on group training effectiveness, with high cultural identity groups showing mediation effects of 76.8%, significantly higher than low cultural identity groups' 61.2%. Mongolian students exhibited the strongest cultural identity moderating effects, demonstrating the special value of cultural backgrounds in traditional skill learning.

(5) Peer support networks are key influencing factors. Peer support networks significantly influence learning outcomes through triple mechanisms of emotional support, instrumental support, and informational support. High support network groups achieved coordination ability improvement of 149.4%, far exceeding low support network groups' 100.0%. Structural characteristics such as network density, path length, and clustering coefficients directly correlate with learning outcomes, providing specific pathways for optimizing group learning environments.

6.2. Future prospects

Based on the findings and theoretical contributions of this study, future research should further deepen and expand in the following five directions:

(1) Cross-cultural validation research. Future studies should apply this theoretical model to learning contexts involving different cultural backgrounds and other traditional instruments, such as Chinese traditional instruments like guzheng, erhu, and pipa, as well as group learning of Western classical and modern instruments. Through cross-cultural comparisons, researchers should verify the universality of social identity mechanisms in music skill learning and explore the differential impacts of different cultural traditions on group learning effectiveness, providing theoretical support for constructing culturally adaptive music education models.

(2) In-depth application of neuroscience technologies. By combining neuroscience technologies such as electroencephalography (EEG) and functional magnetic resonance imaging (fMRI), future research should explore from a neural mechanism perspective how social identity influences brain activity patterns in motor skill learning, particularly neural network activation and plasticity changes related to left-right hand coordination. This would provide neurobiological evidence for understanding the impact of group learning environments on brain function, advancing the field of music education neuroscience.

(3) Exploration of digital group learning environments. With the development of virtual reality (VR), augmented reality (AR), and artificial intelligence technologies, future research should explore how digital platforms can reconstruct group learning experiences, design metaverse-based virtual music learning spaces, study the impact of online group interactions on social identity development, and develop intelligent peer matching and support network construction systems, providing innovative solutions for music education in the post-pandemic era.

(4) Longitudinal studies of long-term effects. Conducting 1-2 year longitudinal tracking studies to systematically examine the long-term impacts of group learning experiences on learners' music skill development, cultural identity formation, and social psychological health. Research should explore the persistence and stability of social identity effects, as well as the moderating effects of individual difference variables (such as personality traits, learning motivation, and cognitive styles) on long-term outcomes, providing long-term effectiveness assessment evidence for educational policy formulation.

(5) Standardized development of intervention programs. Based on research findings, develop standardized group music teaching intervention programs and assessment tools, including group formation guidelines, cohesion cultivation strategies, cultural identity activation methods, and peer support network construction techniques. This would form scalable teaching models and training systems, providing specific operational guidance for music education practitioners and promoting effective translation of research findings into practical applications.

Conflict of interest

The authors declare no conflict of interest.

References

1. Hu N. Theory and Path of Forging a Strong Sense of Community for the Chinese Nation from the Perspective of Cultural Identity[J]. Social Science Journal of Harbin Normal University, 2025, 16(03): 29-34.
2. Zang S Y, Guan G C. The Value of Music Cultural Exchange Program "Infinity and Beyond" in Cultivating Social Mainstream Cultural Identity[J]. Screen World, 2025, (08): 34-36.

3. Fernando L N, Rafael S A, Sebastian M. The effects of esports viewers' customer experience on intention to purchase sponsoring brands: the mediating role of social identification[J]. Marketing Intelligence & Planning, 2025, 43(4): 857-875.
4. Gupta A, Das P, Coulson E N, et al. Salience of social identities in explaining homeownership patterns in India[J]. Urban Studies, 2025, 62(7): 1435-1463.
5. Zhou K. Identity Politics on the Talk Show Stage: Social Identity and Class Expression in Variety Show Texts[J]. Journal of Jiangxi Normal University (Philosophy and Social Sciences Edition), 2025, 58(03): 118-129.
6. Inoue Y, Sato M, Swanson S, et al. Psychosocial resources linking consumer identification and social well-being: Integrating the social identity approach with transformative service research[J]. Journal of Business Research, 2025, 195: 115361-115361.
7. Qi Z Y, E X Q. Theoretical Construction and Scale Development of Social Recognition of Mass Vocational Education[J]. Chinese Vocational and Technical Education, 2025, (07): 52-59+68.
8. Qi Z Y, Wang Y F. Formation Mechanisms and Logical Pathways of Social Recognition of Vocational Education Under the Influence of Cultural Traditions[J]. Journal of Educational Studies, 2025, 21(01): 180-194.
9. Park Y, Johnson K S. An Exploratory Investigation of Associations Between Personal and Social Identity Among White, Heterosexual, Cisgender Young Adults in the U.S.[J]. Emerging Adulthood, 2025, 13(4): 996-1012.
10. Chun J, Eun Y J. Countering ethnic hatred and its pedagogical approach in social studies: focusing on multiple social identities[J]. Frontiers in Education, 2025, 10: 1575926-1575926.
11. Liaquat U, Balcetis E, Jost T J. Multiple Identities Model of Collective Inaction: How Belonging to Psychologically Incompatible Groups Reinforces the Status Quo[J]. Social and Personality Psychology Compass, 2025, 19(6): e70065-e70065.
12. Xu Q, Shi X D. Craft Development and Local Identity of Pizhou Fan Crafts from the Perspective of Social-Cultural Identity[J]. Journal of Xuzhou Institute of Engineering (Social Science Edition), 2025, 40(02): 1-8.
13. Lv Z H. Cultural Identity Approach to Forging a Strong Sense of Community for the Chinese Nation in Border Areas[J]. Journal of Tibet Minzu University (Philosophy and Social Science Edition), 2025, 46(01): 50-56+155.
14. Qi Y X, Xu X H. Research on the Logical Mechanisms of Cultural Identity in the New Era[J]. Journal of Jiangnan Institute of Social Sciences, 2024, 26(04): 1-7.
15. Alghuwainem G. Navigating Bilingualism: Language, power, and the social identity construction of the first Saudi elementary students to receive English language instruction[J]. Ampersand, 2025, 15: 100227-100227.
16. Liu Z, Feng K, Zhang S, et al. Sounds like a friend: the association between music experience and social identity[J]. Current Psychology, 2025, (prepublish): 1-12.
17. Cai S Y. The Impact of Idol Culture on Adolescent Social Identity and Mental Health Status from the Perspective of New Media[J]. Campus Psychology, 2024, 22(06): 531-536.
18. Ma Y Y. Research on Identity Formation Pathways of Rural Novice Teachers from the Perspective of Sociocultural Theory[J]. Educational Science Exploration, 2024, 42(06): 19-26.
19. Evan B, Rohan P. Looking within: exploring the effects of social identity-based reflection on novice designers' task clarification behavior[J]. Design Science, 2025, 11: e18-e18.
20. Zhang H. Research on Transmission Mechanisms of Mass Culture in the Digital Era[J]. Central Plains Culture and Tourism, 2025, (04): 1-3.
21. Xu Z Z. Theoretical Re-examination of "Rural Elites" and Their Social Identity[J]. Modern Economic Discussion, 2024, (09): 123-132.
22. Cai Z G, Zheng J N. Construction of Socialist Ideological Identity in Cultural Variety Programs[J]. Audio-Visual World, 2025, (01): 49-53.
23. Zeng M. Application of Tea Culture in Enhancing Social Recognition of Vocational Undergraduate Education[J]. Fujian Tea, 2024, 46(08): 104-106.
24. Amani D. Destination Identification and Destination Community Identification as Drivers of Destination Brand Value Co-Creation in Emerging Tourism Destinations: A Social Identity Theory Perspective[J]. International Journal of Hospitality & Tourism Administration, 2025, 26(3): 483-519.
25. Li N. Analysis of Generation Mechanisms for Strengthening Cultural Identity[J]. Popular Arts, 2024, (21): 214-216.
26. Tang Y F, He Y. Achievement of Rule of Law Cultural Identity in Rural Revitalization[J]. Village Committee Director, 2025, (01): 104-106.
27. Mavor I K, Bottomley E, Marin B, et al. Discipline-based social identity and organizational identity as predictors of approaches to learning and evaluation of teaching[J]. European Journal of Psychology of Education, 2025, 40(3): 78-78.
28. Guan S. Research on Cognitive Mechanisms, Social Identity, and Standardization Paradigms of Anomie Cyber Language: A Three-Dimensional Framework for Language Ecological Governance[J]. Journal of Social Science and Humanities, 2025, 7(6): 1-6.
29. Wang Y F, Jiang H L. Political Implications of Clothing: Gender Roles, Social Identity and Political Power[J]. Chemical Fiber and Textile Technology, 2024, 53(08): 164-166.

30. Pan N N, Li X M. Cultural Identity from the Perspective of Historical Materialism[J]. People's Tribune, 2024, (14): 107-109.
31. He M T. Visual Rhetoric, Collective Memory, Reality Construction: The Realization Logic of Social Group Cultural Identity[J]. Journal of Hefei University of Technology (Social Science Edition), 2024, 38(04): 135-144.
32. Kranz J, Breitenmoser P, Laherto A, et al. Science Education for Collective Agency in the Climate Crisis: A Social Identity Approach[J]. Research in Science Education, 2025, 55(4): 1-20.
33. Cleveland M. The social identity and psychology of mixed-race individuals: An international study[J]. International Journal of Intercultural Relations, 2025, 108: 102239-102239.
34. Wei J Y. Social Identity of Style and Aesthetics: Taking Female Images in Art Works as an Example[J]. Learning Sea, 2024, (04): 206-212.
35. Wang X. Spatial Inquiry of Internet Celebrity Culture and Political Identity Reconstruction[J]. Journal of Liaoning Socialist Institute, 2024, (02): 84-89.
36. Luo H Y. On Promoting Emotional Identity of Socialist Core Values through Institutional Cultural Construction[J]. Journal of Tonghua Normal University, 2024, 45(05): 7-13.
37. Li C Y. Research on Value Identity of Business English Major Students from a Cross-cultural Perspective[J]. Journal of Taiyuan Urban Vocational College, 2024, (04): 98-100.
38. Kyprianides A, Haslam A S, Bradford B, et al. The role of social identity and procedural fairness in shaping the impact of police interactions on mental health: a justice-identification model[J]. Health Psychology Review, 2025, 1-21.
39. Jennings J F, Shepard N M, Jackson D. Partisan and/or Gender Homophily: The Influence of Social Identity-Based Elaboration on Political Candidate Evaluation[J]. Western Journal of Communication, 2025, 89(4): 798-819.
40. Han T. On the Cultural Memory Construction, Digital Expression and Collective Identity of Literary and Museum Programs[J]. China Television, 2024, (04): 51-55.
41. Teng F, Liu Y T, Yuan Y. Analysis of the Three-dimensional Logic of Cultural Identity in Forging a Strong Sense of Community for the Chinese Nation[J]. Beijing Education (Higher Education), 2024, (04): 28-31.
42. Wang X Y. Research on Rural Cultural and Creative Product Design and Cultural Communication Pathways from the Perspective of Cultural Identity[J]. Journal of Shandong Agricultural Engineering College, 2024, 41(02): 96-100.
43. Hajek S C. Entrepreneurs' Positive Social Identity Development Through Initiated Intra- and Intergroup (Non)Accommodative Communication[J]. Business and Professional Communication Quarterly, 2025, 88(3): 446-472.
44. Long B Y. Analysis of College Student Netizens' Self-Identity and Social Mentality from the Perspective of Youth Subculture[J]. Journal of Jiangxi Electrical Polytechnic, 2023, 36(12): 85-87.
45. Liu Q. Research on Spatiotemporal Discourse and Cultural Identity: The Practice of Cultural Self-Expression with Chinese Characteristics of Socialism[J]. Journal of Changchun Normal University, 2023, 42(11): 191-195.
46. Zhang Z Z, Shi Y Q. Exploring the Cultivation Pathways of Red Cultural Identity among College Students in the New Era[J]. China National Exhibition, 2023, (20): 163-165.
47. Hajek S C. Entrepreneurs' Positive Social Identity Development Through Initiated Intra- and Intergroup (Non)Accommodative Communication[J]. Business and Professional Communication Quarterly, 2025, 88(3): 446-472.
48. Qi M, Ren J M. Research on Integrity Culture Construction at the Social Individual Psychological Level[J]. Journal of Chongqing Jiaotong University (Social Science Edition), 2023, 23(05): 18-25.
49. Xie B, Wang Z Y, Xu Y L, et al. Research on the Impact of Organizational Cultural Identity on Employee Voice Behavior in Railway Engineering Enterprises[J]. Journal of Railway Science and Engineering, 2024, 21(05): 2059-2071.
50. Deng X B, Zhou R M. Analysis of the Logic and Pathways of Integrating Excellent Traditional Chinese Legal Culture into Rule of Law Society[J]. Dalian Cadres Journal, 2023, 39(09): 45-51.
51. Shi D. Advocacy fit and social identity in corporate social advocacy: A multigroup analysis of public responses[J]. Public Relations Review, 2025, 51(4): 102605-102605.
52. Wang S. Reconstruction Path of College Students' Traditional Cultural Identity from the Perspective of Socialist Core Value System[J]. Journal of Harbin University, 2023, 44(09): 115-119.
53. Zhang Y N. Strengthening Ideological and Political Leadership to Enhance Chinese Cultural Identity and Deeply Promote the Sinicization of Religion[J]. Journal of Central Institute of Socialism, 2023, (04): 120-129.
54. Guo P, Wu Z, Yao Q, et al. Female CEOs and earnings management: examining risk aversion versus social identity theories[J]. Applied Economics, 2025, 57(36): 5486-5506.
55. Zhang Y Q. Cultural Identity and Heluo Drum: Exploring the Significance of Heluo Drum in Social Identity and Cultural Transmission[J]. China National Exhibition, 2023, (14): 50-52.
56. Bi H M, Hou S Y. Reflection and Reconstruction Pathways of Youth Social Identity from the Perspective of Fan Circle Culture[J]. Shenzhen Social Sciences, 2023, 6(04): 86-94.