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RESEARCH ARTICLE

The impact of red culture integration in environmental education on college students' ecological ethical identity: An empirical analysis from environmental social psychology

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ABSTRACT

Based on environmental social psychology theory, this study systematically investigated the impact mechanisms of red culture integration into environmental education on college students' ecological ethics identity through a mixed-methods approach combining quasi-experimental design with large-scale surveys. Through surveys of 1,200 college students from four regions nationwide and quasi-experimental research involving 160 students, the findings revealed that red culture integration into environmental education had a significant positive impact on college students' ecological ethics identity ($\beta=0.616$, $p<0.001$). The experimental group students' ecological ethics identity scores significantly improved from 4.82 in the pretest to 5.45 in the posttest, with an effect size of 0.95, indicating a large effect level that remained significant in delayed posttests. Mediation effect analysis revealed that cognitive processing mechanisms (52.9%), emotional experience mechanisms (66.9%), and social learning mechanisms (48.4%) played important mediating roles in the educational impact process, with emotional experience mechanisms demonstrating the strongest mediation effect. Particularly, the mediating role of national pride reached 70.9%, reflecting the unique advantages of red culture in emotional appeal. Moderation effect analysis found that individual characteristics (political identity level, environmental concern degree, cultural background differences), educational contextual factors (teaching methods, curriculum design elements, learning environment atmosphere), and sociocultural factors (regional cultural differences, family educational background, media exposure level) significantly moderated the educational effects, presenting obvious individual differentiation and contextual dependency characteristics. The research results indicate that red culture integration into environmental education effectively promoted the formation and development of college students' ecological ethics identity through multiple pathways including stimulating national identity, promoting value reconstruction, and providing role model demonstrations. This study not only enriches the theoretical framework of environmental social psychology but also provides important empirical support and practical guidance for ecological civilization education model innovation and red culture inheritance and development in the new era.

Keywords: red culture; environmental education; ecological ethics identity; environmental social psychology; mediation effect; moderation effect; college students

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1. Introduction

Under the dual driving forces of ecological civilization construction and the cultural power strategy in the new era, red culture, as a valuable spiritual wealth of the Chinese nation, is increasingly becoming an important resource for higher education reform and innovation. Red culture carries rich revolutionary traditions and value concepts, among which the embedded thoughts of harmonious coexistence between humans and nature, simple and frugal lifestyles, and sustainable development concepts provide profound cultural foundation and value support for contemporary environmental education. Qiu Guoyong and Xia Ziyan (2024) pointed out in their research that the integration of red culture into college students' ideological and political situational education has unique value significance and can effectively enhance the appeal and persuasiveness of education[1]. Meanwhile, Miao Wei (2023) further emphasized the importance of integrating red culture into university ideological and political education in the new media environment, providing new practical pathways for educational model innovation[2]. However, combining red culture with environmental education and exploring its impact mechanisms on college students' ecological ethics identity remains a theoretical and practical issue that urgently needs in-depth research.

Currently, traditional environmental education models face numerous challenges in cultivating college students' ecological ethics identity. On one hand, pure knowledge transmission is difficult to reach the deep value recognition in students' hearts, and environmental education lacking cultural foundation often remains superficial, making it difficult to form lasting behavioral change motivation. On the other hand, the applicability of Western environmental ethics theories in the Chinese cultural context has limitations, necessitating the search for educational pathways more consistent with Chinese students' cultural psychological characteristics. Yan et al. (2024) found in their research that integrating local red culture into environmental discipline ideological and political courses has important value and can effectively enhance students' learning effects and value recognition[3]. Research by Hui et al. (2023) also indicated that there is an inherent connection between red culture inheritance and environmental protection awareness cultivation, and red culture inheritance in the context of culture and tourism integration can promote people's cognition of sustainable development[4]. These studies provide important insights for exploring the integration of red culture and environmental education, but further deepening is needed in theoretical mechanisms and empirical verification.

From the perspective of environmental social psychology, the formation of ecological ethics identity is a complex psychological process involving the interaction of multiple dimensions including cognition, emotion, and behavior. Red culture, as a unique cultural symbol system, possesses strong emotional appeal and value guidance functions, and can influence individual environmental attitudes and behaviors through psychological pathways such as identification mechanisms, emotional resonance, and social learning. Zhang Chao and Guo Bingbing (2023) pointed out in their analysis of red culture integration into university ideological and political education that red culture has profound historical foundation and powerful spiritual force, capable of effectively inspiring students' emotional resonance and value recognition[5]. Meiling and Yahui (2024) further explored the current status and problems of red culture sites in the new era, emphasizing the important role of red culture in educational practice[6]. However, existing research mainly concentrates on the field of ideological and political education, lacking in-depth theoretical explanation and empirical testing of the psychological mechanisms of red culture integration into environmental education, particularly presenting research gaps in specific impact pathways and effect evaluation among college student populations.

Through constructing theoretical models and designing empirical research, this study systematically analyzes the effects and psychological mechanisms of red culture environmental education, providing scientific basis for university environmental education reform. Yang Hong and Zhang Yan's (2023) research provided beneficial exploration for the educational application of red culture in the new media environment, and this study will further expand the application of red culture in the field of environmental education based on this foundation, exploring ecological ethics education models with Chinese characteristics[7]. The research not only helps enrich the theoretical system of environmental social psychology and promote the deep integration of red culture education and environmental education, but also has important practical significance for cultivating ecological civilization literacy among college students in the new era and practicing green development concepts.

Based on the above research questions and theoretical needs, this study establishes three main objectives: First, to examine the direct impact of red culture integration in environmental education on college students' ecological ethical identity; Second, to reveal the mediating pathways of triple psychological mechanisms including cognitive processing, emotional experience, and social learning; Third, to identify the moderating effect boundaries of individual characteristics, educational contexts, and socio-cultural factors. In terms of research methodology, a mixed-methods design is adopted, comprehensively employing quasi-experimental research (160 students) and large-scale survey research (1,200 students), systematically validating theoretical hypotheses through pre-post control group design and structural equation modeling techniques. The main contributions of this study are manifested in three aspects: Theoretically, it constructs a triple psychological mechanism model of red culture's influence on ecological ethical identity, enriching the cultural dimension of environmental social psychology; Methodologically, it innovates an empirical research paradigm for integrating cultural education with environmental education; Practically, it provides scientific evidence and practical guidance for innovative ecological civilization education models and red culture inheritance and development in the new era.

The structure of this paper is organized as follows: Section 2 reviews the literature to examine the current research status of red culture integration in education and environmental psychology, identifying theoretical gaps and research opportunities; Section 3 elaborates on the mixed-methods research design in detail, including research subject sampling, measurement instrument development, data collection procedures, and analytical strategies; Section 4 systematically reports empirical analysis results, covering the direct effects of red culture environmental education, the mediating roles of triple psychological mechanisms, and the moderating effects of individual characteristics and contextual factors; Section 5 provides in-depth discussion of the significance and value of research findings from both theoretical interpretation and practical implications perspectives; Section 6 summarizes the main research conclusions, analyzes research limitations, and proposes future research directions, providing guidance and recommendations for subsequent research and practical applications.

2. Literature review

In recent years, theoretical research and practical exploration of red culture integration into higher education have become increasingly rich, providing important theoretical foundations and empirical support for this study. Zhang Jian and Liu Lei (2023) systematically analyzed the diversified approaches of integrating red culture into college students' ideological education from the perspective of the internet age, emphasizing the new characteristics and advantages of red culture dissemination in the digital environment[8]. Zhao Xiangxiu and Zhang Li (2023) further explored specific strategies for integrating red culture into university ideological and political education, proposing important viewpoints on constructing a three-

dimensional education system[9]. From an international perspective, Chen's (2024) research revealed the strategic mechanisms of integrating red culture resources into university ideological and political courses, providing beneficial references for red culture education in cross-cultural contexts[10]. Wang et al. (2024) took the Tonghua region as an example to deeply analyze the current status and countermeasures of local red culture integration into basic education moral education work, providing empirical evidence for the connection between different educational levels[11]. These studies indicate that red culture, as a unique educational resource, has formed relatively mature theoretical frameworks and practical models in the field of ideological and political education. However, its application in environmental education is still in the exploratory stage and requires further theoretical construction and empirical testing.

Mechanism innovation and pathway optimization of red culture integration into education is currently a hot topic of academic concern. Lin Sai et al. (2023) analyzed the internal logic of red culture integration into ideological and political education from the dual dimensions of causes and pathways, emphasizing the close relationship between cultural identity and value shaping[12]. Wei Xuemei and Cao Yangfei (2022) proposed systematic pathways for integrating red culture resources into university ideological and political education through in-depth research, providing specific guidance for educational practice[13]. Ji Yan (2022) explored the value functions of red culture from the perspective of mental health education, revealing the unique role of red culture in promoting college students' psychological growth[14]. Li Hui (2022) focused on mechanism innovation and proposed dynamic regulation mechanisms and feedback optimization systems for red culture integration into university ideological and political education[15]. Cheng Yulin et al. (2021) took the "Ideological and Moral Cultivation" course as an example to explore practical pathways for integrating red culture into specific curriculum teaching, providing practical paradigms for curriculum reform[16]. International scholar Chávez et al. (2024) constructed a knowledge graph of Cuban red revolutionary history themes from the perspective of artistic works, providing new approaches for the digital inheritance and cross-cultural exchange of red culture[17]. Shuting and Haiqiang (2024) investigated the current status of Yancheng red culture's external communication and proposed countermeasures and suggestions for enhancing the international influence of red culture[18]. These studies have laid a solid foundation for the theoretical deepening and practical innovation of red culture education, but the application mechanisms in environmental education still require further exploration.

Red culture education faces new opportunities and challenges in the context of informatization and digitalization, with related research showing diversified development trends. Xiang Lijuan (2021) deeply analyzed the value implications, realistic obstacles, and implementation strategies of red culture integration into university ideological and political education in the internet environment, providing systematic thinking for red culture education in the digital age[19]. Wang Anping and Mou Hongyu (2021) focused on the informatization environment, identifying major obstacles in the process of integrating red culture resources into university ideological and political education and proposing corresponding solutions[20]. Haiyang et al. (2024) took Yimeng red culture as an example to explore the construction model of red culture inheritance and development demonstration zones under the background of digital empowerment, providing innovative paradigms for the digital protection and dissemination of red culture[21]. Cheng (2024) analyzed the integration mechanism of red culture in university ideological and political education from the perspective of value integration, emphasizing the organic unity of cultural values and educational objectives[22]. At the specific application level, Zhao Hua and Zou Qinghua (2020) explored practical pathways for integrating red culture into college students' Marxist faith education, providing cultural support for ideological and faith education[23]. Shi Xiaojuan (2020) focused on pathway innovation for integrating red culture into vocational college ideological and political theory course teaching in the new media environment, providing beneficial

references for vocational education reform[24]. Lei (2025) examined red culture from the perspective of intangible cultural heritage, analyzing the construction process of historical consciousness through mainstream film and television works, providing new perspectives for contemporary interpretation of red culture[25]. He (2024) took Jingdezhen as an example to study the innovative application of red culture elements in digital cultural and creative product design, demonstrating the important value of red culture in cultural industry development[26].

From an international perspective, the influence of cultural factors on environmental education has become an important issue in global environmental psychology research, but studies from different cultural backgrounds show significant variations. Euro-American scholars primarily focus on environmental value formation within individualistic cultural contexts. For instance, research by Stern and colleagues based on the Value-Belief-Norm theory emphasizes the direct influence of personal values on environmental behavior, while Clayton's environmental identity theory highlights the direct emotional connection between individuals and the natural environment. Japanese scholars such as Iwata and others have explored environmental education models within Eastern collectivistic culture, finding that traditional cultural concepts of nature can effectively promote the formation of environmental protection awareness. Indian scholars like Gupta have investigated the role of religious culture in environmental education, revealing the profound influence of spiritual beliefs on environmental attitudes. However, these studies are predominantly concentrated on the influence of religious culture, ethnic traditions, or philosophical thoughts on environmental education, lacking in-depth exploration of the role of modern cultural symbol systems such as revolutionary culture and political culture in environmental education. In contrast, the red culture that this study focuses on, as a unique revolutionary political culture, holds significant theoretical value and comparative significance on a global scale. It not only provides an innovative paradigm for developing countries to utilize indigenous cultural resources for environmental education but also contributes Chinese wisdom to expanding the cultural dimension research perspective in the international environmental education field. A comprehensive review of existing research reveals that studies on red culture integration in education have formed a relatively complete theoretical system and rich practical experience, but significant research gaps and development opportunities still exist.

A comprehensive review of existing research reveals that research on red culture integration into education has formed a relatively complete theoretical system and rich practical experience, but significant research gaps and development space still exist. Fu Qing and Guo Jiaojiao (2020) explored pathways for integrating red culture into college students' socialist core values education in the new media environment, providing cultural carriers for values education[27]. However, reviewing existing literature, research mainly concentrates on traditional fields such as ideological and political education, moral education, and mental health education, lacking in-depth exploration of the application value and mechanisms of red culture in environmental education. From the perspective of theoretical construction, existing research mostly analyzes the educational functions of red culture from pedagogical and political perspectives, lacking theoretical interpretation from environmental social psychology perspectives, particularly systematic research on the psychological mechanisms by which red culture influences college students' ecological ethics identity. From the perspective of empirical research, although related studies have accumulated rich experience in teaching methods, curriculum design, and evaluation systems, quantitative analysis and experimental verification of the effects of red culture integration into environmental education remain insufficient. From the perspective of research subjects, existing research mostly focuses on macro-level educational effects such as ideological and political education and moral education, lacking precise measurement and in-depth analysis of the impact mechanisms on specific psychological constructs such as ecological ethics identity. Therefore,

applying environmental social psychology theory to deeply explore the impact mechanisms of red culture integration into environmental education on college students' ecological ethics identity can not only fill theoretical gaps in existing research but also provide scientific basis and practical guidance for the organic integration of ecological civilization education and red culture inheritance in the new era.

3. Research methods

3.1. Research design

This study adopts a mixed-methods research design, comprehensively employing a strategy that combines quasi-experimental research with survey research to deeply explore the impact mechanisms of red culture integration into environmental education on college students' ecological ethics identity. In terms of research paradigm selection, this study follows a pragmatist research paradigm, emphasizing both the objectivity and verifiability of quantitative data and the in-depth understanding and contextual interpretation of qualitative materials. Through the organic combination of quantitative and qualitative methods, it comprehensively reveals the complex process of red culture environmental education. Specifically, the research adopts a pretest-posttest control group quasi-experimental design as the core research strategy, systematically examining the intervention effects of red culture integration into environmental education through constructing a comparative analysis framework between experimental and control groups. Meanwhile, it is supplemented by large-scale cross-sectional survey research to expand sample coverage and enhance the external validity and generalizability of research results.

In terms of theoretical framework construction, this study takes environmental social psychology theory as the guiding framework, integrating related theories such as cognitive-affective-behavioral consistency theory, social identity theory, and the value-belief-norm model to construct a conceptual model of how red culture integration into environmental education influences college students' ecological ethics identity. The model hypothesizes that red culture acts on college students' environmental knowledge structures, emotional attitude tendencies, and behavioral intention expressions through three mechanistic pathways of cognitive processing, emotional experience, and social learning, thereby influencing their ecological ethics identity levels.

The research design follows principles of scientificity, systematicity, and operability to ensure the rigor of the research process and the credibility of results[28]. In terms of temporal arrangement, a longitudinal tracking design is adopted, setting four time points of pretest, intervention, posttest, and delayed posttest to observe the immediacy and persistence of intervention effects. In terms of spatial layout, higher education institutions of different regions and types are selected as research sites to enhance the representativeness and universality of research results. Additionally, the research will control for relevant confounding variables, such as individual difference factors including subjects' political attitudes, environmental concern levels, and cultural backgrounds, as well as contextual factors such as teacher characteristics, curriculum settings, and school environment, to ensure the reliability of experimental internal validity.

Compared with mainstream Western theories such as Environmental Identity Theory and Value-Belief-Norm Theory, the theoretical framework of this study exhibits distinctive cultural contextual characteristics and critical innovation. Western environmental identity theory emphasizes the direct connection and personalized experience between individuals and the natural environment, while neglecting the fundamental role of collective cultural memory and national identity in environmental attitude formation. Although the Value-Belief-Norm theory considers the influence of values, its linear causal chain model cannot adequately explain the composite influence mechanisms of cultural symbol systems on individual psychology. In

contrast, the triple psychological mechanism model constructed in this study not only acknowledges the roles of cognition and values but also highlights the dominant position of emotional experience mechanisms. Particularly through culturally specific emotional carriers such as national pride and collective identity, it achieves profound transformation from external cultural symbols to internal ethical identity—an important dimension that Western individualistic-oriented theoretical frameworks struggle to encompass. Therefore, the theoretical contribution of this study lies in transcending the cultural limitations of Western theories and providing an important theoretical foundation for constructing an environmental psychology theoretical system with Chinese characteristics.

This model hypothesizes that red culture influences college students' ecological ethical identity levels through triple mechanism pathways of cognitive processing, emotional experience, and social learning, which act upon students' environmental knowledge structures, emotional attitude tendencies, and behavioral intention expressions. Based on the above theoretical framework, this study proposes four core hypotheses with their theoretical foundations: Hypothesis 1 posits that red culture integration in environmental education significantly and positively influences college students' ecological ethical identity, grounded in social identity theory and cultural psychology theory, which argue that cultural symbol systems can influence individual values and attitude tendencies through identity mechanisms—a perspective extensively validated in Tajfel's group identity research and Hofstede's cultural dimensions theory, with its importance lying in verifying the direct effects of cultural education. Hypotheses 2-4 respectively propose the mediating roles of cognitive processing, emotional experience, and social learning mechanisms, derived from Petty's Elaboration Likelihood Model, Lazarus's cognitive appraisal theory, and Bandura's social learning theory; in the field of environmental psychology, Clayton's environmental identity research and Stern's Value-Belief-Norm model provide empirical support for these mediating mechanisms, with theoretical implications in revealing the internal psychological processes through which culture influences attitude identity, and practical significance in providing precise intervention pathways for educational strategy design. Hypothesis 5 involves the moderating effects of individual characteristics, educational contexts, and socio-cultural factors, based on situational interaction theory and individual difference theory, emphasizing the boundary conditions and influencing factors of educational effectiveness—a perspective extensively validated in cross-cultural psychology and educational psychology research, with its importance lying in enhancing the precision and adaptability of educational interventions. The research design adheres to principles of scientificity, systematicity, and operability, ensuring the rigor of the research process and credibility of results.

3.2. Research subjects and sampling

The target population of this study is the college student population enrolled in Chinese higher education institutions, with a focus on representative undergraduate and graduate students. Considering the universality of red culture education and the importance of environmental education, the research selects higher education institutions covering different geographical regions, different educational levels, and different disciplinary specialties as the sampling framework. Specifically, research subjects include enrolled students from key comprehensive universities, normal universities, and science and engineering institutions in four geographical regions: North China, East China, South China, and Southwest China, with an age range of 18-25 years, covering different disciplinary backgrounds including liberal arts, sciences, and engineering.

In terms of sampling strategy, this study adopts a multi-stage stratified random sampling method. First, stratification is conducted by geographical region, followed by secondary stratification within each region according to institution type, then specific schools are randomly selected within each type of institution, and finally random sampling is conducted within selected schools according to grade and major. To ensure

sample representativeness and external validity of research results, the sampling process strictly follows randomization principles to avoid selection bias[29]. Meanwhile, considering the different requirements of quasi-experimental research and survey research, this study designs two complementary sampling schemes: the quasi-experimental research component adopts a combination of convenience sampling and random grouping, recruiting voluntary students from 3-4 universities and then randomly assigning them to experimental and control groups.

For different research purposes and statistical analysis requirements, this study determines scientifically reasonable sample sizes. For the quasi-experimental research component, sample size estimation is conducted based on Cohen's effect size calculation formula and G*Power software. Under conditions of medium effect size ($d=0.5$), statistical power ($1-\beta=0.80$), and significance level ($\alpha=0.05$), each group requires at least 64 subjects. Considering a 20% attrition rate, the final determination is to recruit 80 students each for the experimental and control groups, totaling 160 students. For the large-scale survey research component, referring to relevant literature and statistical principles, combined with structural equation modeling analysis requirements, the effective sample size is determined to be no less than 800 people. Considering questionnaire response rates and validity rates, 1,200 questionnaires are planned for distribution.

In terms of sample characteristic control, the research will control the gender ratio between 45%-55% to ensure balanced representativeness of male and female students. Grade distribution covers all levels from freshmen to graduate students, with undergraduates accounting for 80% and graduate students for 20%. Major distribution is configured according to a 3:3:4 ratio for liberal arts, sciences, and engineering. Additionally, to enhance the cultural sensitivity and regional representativeness of the research, the sample will include students from different ethnic backgrounds, with Han Chinese students accounting for 85%, ethnic minority students accounting for 15%, and urban-rural student ratios controlled at approximately 6:4.

All students participating in the research must sign informed consent forms, and the research process strictly adheres to academic ethical standards to ensure that subjects' rights are fully protected. The sampling process will establish detailed archival records to provide reliable foundational information support for subsequent data analysis and result interpretation.

3.3. Research instruments and measurement

The core measurement tool of this study is the self-developed "College Students' Ecological Ethics Identity Scale," which is carefully designed based on environmental social psychology theory and relevant literature review, combined with the cultural characteristics and cognitive features of Chinese college students. The scale adopts a multi-dimensional structure, containing three first-level dimensions of cognitive identity, emotional identity, and behavioral identity, with each dimension containing 3-4 second-level factors, totaling 36 measurement items. The cognitive identity dimension primarily measures students' understanding and acceptance of ecological ethics principles, including environmental values, ecosystem cognition, and human-nature relationship cognition; the emotional identity dimension focuses on evaluating students' emotional experiences and emotional responses to environmental issues, covering environmental care emotions, ecological aesthetic experiences, and environmental responsibility; the behavioral identity dimension focuses on students' environmental behavioral intentions and actual behavioral performance, including green consumption intentions, environmental participation willingness, and ecological behavior practices[30]. The scale adopts a 7-point Likert scoring method, ranging from "strongly disagree" to "strongly agree." To ensure the scientificity and validity of the scale, the research adopts strict scale development procedures, first forming an initial item pool through literature analysis and expert interviews, then

conducting item screening and revision through small-sample pretesting, and finally examining the scale's reliability and validity indicators through large-sample formal testing.

In addition to the core measurement tool, this study also selects multiple mature auxiliary measurement tools to comprehensively evaluate related variables. Environmental attitude measurement adopts the revised "New Environmental Paradigm Scale" (NEP Scale), which contains 15 items to evaluate individuals' environmental worldview and attitude tendencies; red culture identity measurement uses a self-compiled "Red Culture Identity Questionnaire," including three dimensions of historical identity, value identity, and emotional identity with a total of 18 items; environmental behavior measurement adopts the Chinese revised version of the "General Ecological Behavior Scale" (GEB Scale), covering 40 behavioral items including energy-saving behavior, recycling behavior, and environmental consumption behavior. Additionally, the research designs a detailed demographic information survey form to collect subjects' basic information such as gender, age, grade, major, family background, and political affiliation, as well as related background variables such as environmental education experience and degree of red culture exposure.

To accommodate the needs of quasi-experimental research, this study also develops a "Red Culture Integration into Environmental Education Curriculum Program." This program takes Marxist ecological views, Mao Zedong's ecological thoughts, and Xi Jinping's ecological civilization thoughts as core content, integrating ecological ethics elements from the Jinggangshan Spirit, Long March Spirit, and Yan'an Spirit, and designs a systematic curriculum module of 12 class hours[31]. The curriculum adopts various teaching methods such as case teaching, scenario simulation, and field investigation, achieving deep integration of red culture and environmental education through forms such as red story telling, ecological practice experiences, and value discussion exchanges.

All measurement tools undergo strict reliability and validity testing before formal use, ensuring Cronbach's α coefficients are no less than 0.70, and confirmatory factor analysis fit indices meet acceptable standards, providing solid guarantees for the reliability and validity of research results.

To effectively control for potential social desirability bias in self-reported ecological behavior, this study employed multiple bias control strategies: First, a simplified version of the Marlowe-Crowne Social Desirability Scale was integrated into the questionnaire design to identify and statistically control for participants' social desirability tendencies; Second, reverse-scored items and neutral items were incorporated in behavioral measurements to reduce participants' response patterns; Third, anonymous questionnaires and delayed coding techniques were adopted to eliminate participants' concerns about identity exposure; Additionally, objective behavioral observation indicators were introduced in the quasi-experimental research, such as classroom environmental behavior performance and actual frequency of participation in environmental activities, for cross-validation with self-reported data; Finally, common method bias testing (Harman's single-factor test) and latent variable interaction effect analysis were employed during the data analysis stage to statistically identify and correct potential measurement bias, ensuring the authenticity and reliability of research results. Furthermore, the study designed a detailed demographic information survey to collect participants' basic information including gender, age, grade level, major, family background, political affiliation, as well as relevant background variables such as environmental education experience and degree of red culture exposure.

3.4. Data collection procedures

The data collection procedures of this study strictly follow scientific research standards and are conducted in an orderly manner across three stages: preparation, implementation, and follow-up tracking. In the preparation stage, the research team first establishes formal cooperative relationships with participating

universities, obtaining approval from school ethics committees and support from relevant departments. Subsequently, professional data collectors are recruited and trained to ensure all collectors are familiar with research objectives, operational procedures, and ethical requirements, standardizing testing criteria and instructions. During participant recruitment, recruitment announcements are published through official school channels, participants are solicited through voluntary registration, and registered students are screened to ensure they meet inclusion criteria and have no exclusion conditions. All participating students must sign detailed informed consent forms before formally participating in the research, clearly informing them of research objectives, procedural arrangements, possible risks, and rights protection, fully safeguarding participants' right to information and choice. For the quasi-experimental research component, qualified participants are randomly assigned to experimental and control groups using random number tables to ensure randomness and balance in grouping. Data collection environments are uniformly set in quiet, comfortable classrooms or laboratories to ensure consistency of environmental conditions and standardization of testing, while equipped with necessary technical equipment and emergency plans to ensure smooth data collection processes.

The specific implementation of data collection adopts a longitudinal tracking design, setting four key time points: pretest (T1), intervention period, posttest (T2), and delayed posttest (T3). In the pretest stage, all participants complete baseline measurements, including core measurement tools such as the ecological ethics identity scale, environmental attitude scale, and red culture identity questionnaire, as well as demographic information surveys, with testing time approximately 45 minutes. The intervention period lasts 4 weeks, with the experimental group receiving red culture-integrated environmental education courses for 3 class hours per week, totaling 12 class hours; the control group receives traditional environmental education courses with the same class hour arrangement as the experimental group. During the intervention period, researchers conduct full-process observational recording, collecting qualitative materials such as classroom interactions and learning feedback[32]. The posttest stage is conducted immediately after the intervention ends, with all participants repeating all measurement tools from the pretest to evaluate immediate intervention effects. The delayed posttest is scheduled 4 weeks after the intervention ends, primarily measuring the maintenance effects of ecological ethics identity and environmental behavior.

For the large-scale survey research component, a combination of online and paper questionnaires is adopted, managed through a unified data collection platform to ensure data completeness and accuracy. The entire data collection process establishes a strict quality control system, including supervisory checks of data collectors, questionnaire completeness audits, and double verification of data entry, promptly identifying and correcting possible problems. Meanwhile, a comprehensive data security protection mechanism is established, with all personal information strictly confidential, data storage using encrypted processing, limited to internal research team use only, ensuring strict adherence to research ethics and effective protection of participant privacy.

3.5. Data analysis methods

This study adopts a multi-level, multi-dimensional data analysis strategy, comprehensively employing descriptive statistics, inferential statistics, and multivariate statistical analysis methods to fully reveal the impact mechanisms of red culture integration into environmental education on college students' ecological ethics identity. In the data preprocessing stage, the collected raw data is first cleaned and examined, including missing value processing, outlier identification, and normality testing of data distribution, ensuring data quality meets statistical analysis requirements. SPSS 26.0 is used for descriptive statistical analysis, calculating basic statistics such as means, standard deviations, skewness, and kurtosis for each variable, comprehensively describing sample characteristics and variable distribution patterns. Through frequency

analysis and cross-tabulation analysis, the distribution characteristics and difference patterns of different demographic groups on various measurement variables are thoroughly understood. In terms of difference testing, independent samples t-tests are used to compare baseline equivalence between experimental and control groups in the pretest stage, paired samples t-tests are used to analyze changes in the same group of subjects at different time points, and repeated measures ANOVA is employed to examine the interaction effects of time and grouping, deeply analyzing the temporal change patterns of intervention effects. Additionally, multivariate analysis of variance (MANOVA) is used to control for covariate effects, one-way and multi-way ANOVA explore the impact differences of different background variables on ecological ethics identity, and effect size calculations (Cohen's d, η^2) evaluate the magnitude of practical significance, providing more accurate bases for result interpretation.

At the advanced statistical analysis level, this study focuses on applying structural equation modeling (SEM) techniques for path analysis and mediation effect testing. Amos 24.0 software is used to construct theoretical models, examining the fit of measurement models through confirmatory factor analysis (CFA), and evaluating the convergent validity and discriminant validity of latent variables. In structural model analysis, maximum likelihood estimation is used to test path coefficients of theoretical hypotheses, and overall model fit is evaluated through fit indices (χ^2/df, RMSEA, CFI, TLI, SRMR, etc.). For mediation effect testing, the Bootstrap method is employed for bias-corrected confidence interval estimation, with resampling set at 5,000 times, revealing the psychological mechanism pathways through which red culture integration into environmental education influences ecological ethics identity via significance testing of indirect effects. Meanwhile, multi-group structural equation modeling is used to analyze path coefficient differences between different groups, examining the existence and mechanisms of moderating effects[33].

For qualitative data components, thematic analysis is employed to code and categorize classroom observation records and in-depth interview materials, identifying key themes and patterns to provide in-depth interpretation and supplementary explanation for quantitative analysis results. In terms of statistical significance standards, all hypothesis tests adopt two-tailed testing with significance level set at $\alpha=0.05$; when $p<0.01$, differences are considered highly significant, and when $0.01<p<0.05$, differences are considered significant. To ensure robustness of analysis results, multiple statistical methods will be used for cross-validation, sensitivity analysis will be conducted to test result reliability, and potential common method bias will be examined through Harman's single-factor test and related statistical controls, ensuring the scientificity and credibility of research conclusions.

4. Results analysis

4.1. Direct effects of red culture integration into environmental education on ecological ethics identity

4.1.1. Overall level analysis of ecological ethics identity

This study conducted comprehensive measurement and analysis of ecological ethics identity levels among 1,200 college students. Results showed that the college student population presents a relatively positive overall trend in ecological ethics identity, but significant differences exist across different dimensions and groups. Through descriptive statistical analysis of the three dimensions of the ecological ethics identity scale, cognitive identity dimension scored highest (M=5.24, SD=0.89), indicating that contemporary college students have relatively deep understanding and acceptance of ecological ethics principles and environmental values; emotional identity dimension scored moderately (M=4.87, SD=1.02), showing that students reach a moderate-to-high level in environmental emotional experience and sense of responsibility; behavioral identity dimension scored relatively lower (M=4.45, SD=1.15), reflecting certain

obstacles and challenges in the transformation process from cognitive attitudes to actual behaviors[34]. The mean total score for ecological ethics identity was 4.85 (SD=0.85), which belongs to a moderate-to-high level on the 7-point scale, indicating that the college student population overall has strong identification with ecological ethics, but there is still room for further improvement, as shown in **Table 1** below.

Table 1. Descriptive statistical results of each dimension of college students' ecological ethics identity.

Dimension	Number of Items	Mean	Standard Deviation	Minimum	Maximum	Skewness	Kurtosis	Cronbach's α
Cognitive Identity	12	5.24	0.89	2.33	7.00	-0.42	0.18	0.87
Emotional Identity	12	4.87	1.02	1.67	7.00	-0.28	-0.15	0.89
Behavioral Identity	12	4.45	1.15	1.25	7.00	-0.13	-0.35	0.91
Total Scale	36	4.85	0.85	2.19	7.00	-0.31	0.07	0.93

Further group comparison analysis revealed significant difference patterns in ecological ethics identity among different demographic characteristic groups. From a gender perspective, female college students' total ecological ethics identity scores (M=4.97, SD=0.81) were significantly higher than males (M=4.72, SD=0.88), $t(1198)=4.21$, $p<0.001$, which is consistent with previous research findings that females are more concerned about environmental issues. Grade difference analysis showed that as grade level increases, students' ecological ethics identity levels show an increasing trend, with graduate students scoring highest (M=5.18, SD=0.79), followed by fourth-year students (M=4.98, SD=0.83), and first-year students scoring lowest (M=4.67, SD=0.89), $F(4,1195)=12.85$, $p<0.001$. Regarding academic background, students in science majors such as environmental science and biology had significantly higher ecological ethics identity scores (M=5.21, SD=0.77) than liberal arts (M=4.78, SD=0.86) and engineering students (M=4.65, SD=0.91), $F(2,1197)=18.43$, $p<0.001$[35]. Analysis results of family location indicated that students from rural areas scored higher in ecological ethics identity (M=4.96, SD=0.82), while urban students scored relatively lower (M=4.77, SD=0.87), $t(1198)=3.15$, $p<0.01$, as shown in **Figure 1** below. These differences reflect the important influence of individual background characteristics on environmental attitude formation, providing important reference bases for subsequent educational interventions.

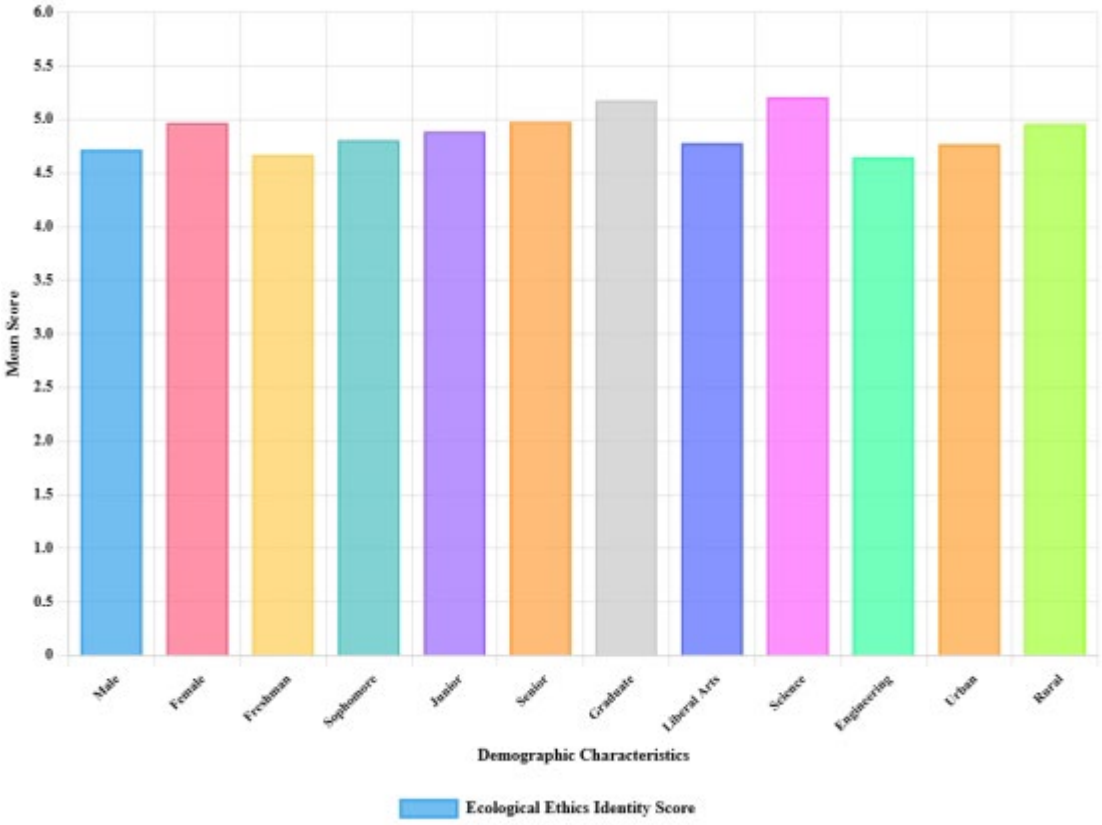

Figure 1. Comparison of ecological ethics identity levels among different demographic characteristic groups.

4.1.2. Testing the intervention effects of red culture environmental education

This study conducted a comprehensive test of the intervention effects of red culture integration into environmental education through rigorous quasi-experimental design. Results showed that this educational model has significant positive effects in enhancing college students' ecological ethics identity. During the 4-week intervention implementation, the experimental group received red culture-integrated environmental education courses while the control group received traditional environmental education courses. Both groups showed no significant differences in baseline measurements ($t(158)=0.34$, $p=0.736$), ensuring the internal validity of the experiment. Immediate posttest results after the intervention indicated that experimental group students showed significant improvement in total ecological ethics identity scores, increasing from pretest scores of 4.82 (SD=0.91) to posttest scores of 5.45 (SD=0.88), an increase of 0.63 points. Paired sample t-tests showed this change was highly significant ($t(79)=8.47$, $p<0.001$, Cohen's $d=0.95$). In contrast, control group students' ecological ethics identity scores only slightly increased from pretest scores of 4.79 (SD=0.89) to posttest scores of 4.93 (SD=0.92), an increase of only 0.14 points, with no significant change ($t(79)=1.82$, $p=0.072$, Cohen's $d=0.20$)[36]. Between-group comparison analysis further confirmed the superiority of red culture environmental education, with highly significant differences between experimental and control groups in the posttest stage ($t(158)=3.68$, $p<0.001$), with effect size reaching moderate level (Cohen's $d=0.59$), indicating that intervention effects have practical significance, as shown in **Table 2** below.

Table 2. Results of red culture environmental education intervention effect testing.

Group	Measurement Time	Sample Size	Mean	Standard Deviation	95% Confidence Interval	Paired t-value	p-value	Cohen's d
Experimental Group	Pretest (T1)	80	4.82	0.91	[4.62, 5.02]	8.47	<0.001	0.95
	Posttest (T2)	80	5.45	0.88	[5.25, 5.65]			
Control Group	Pretest (T1)	80	4.79	0.89	[4.59, 4.99]	1.82	0.072	0.20
	Posttest (T2)	80	4.93	0.92	[4.72, 5.14]			
Between-group Difference (T2)	t(158)=3.68, p<0.001	Cohen's d=0.59						

Further dimensional analysis revealed differentiated effects of red culture environmental education across different levels of identity. In the cognitive identity dimension, experimental group students improved from pretest scores of 5.21 to posttest scores of 5.89 (Δ=0.68, t(79)=7.32, p<0.001), while the control group only increased from 5.18 to 5.31 (Δ=0.13, t(79)=1.45, p=0.151), with highly significant between-group differences (t(158)=4.12, p<0.001). The improvement in emotional identity dimension was even more significant, with the experimental group substantially increasing from pretest scores of 4.71 to posttest scores of 5.52 (Δ=0.81, t(79)=8.91, p<0.001), while the control group only increased from 4.68 to 4.81 (Δ=0.13, t(79)=1.23, p=0.222), with between-group effect size reaching large effect level (Cohen's d=0.88). In the behavioral identity dimension, the experimental group also showed significant improvement, increasing from pretest scores of 4.54 to posttest scores of 4.94 (Δ=0.40, t(79)=4.67, p<0.001), while the control group showed minimal change, increasing from 4.51 to 4.67 (Δ=0.16, t(79)=1.89, p=0.062), with significant between-group differences (t(158)=2.41, p=0.017).

Delayed posttest (T3) results further confirmed the persistence of intervention effects. Four weeks after the intervention ended, experimental group students' ecological ethics identity scores showed slight decline to 5.32, but remained significantly higher than pretest levels (t(79)=6.89, p<0.001) and were clearly superior to the control group's 4.89 (t(158)=2.93, p=0.004), indicating that red culture environmental education produced stable and lasting positive effects[37]. These results fully demonstrate the effectiveness of integrating red culture elements into environmental education curricula, particularly showing unique advantages in stimulating students' environmental emotional resonance and promoting value internalization, providing important empirical support for ecological civilization education model innovation in the new era, as shown in **Figure 2** below.

These results fully demonstrate the effectiveness of integrating red culture elements into environmental education curricula, particularly showing unique advantages in stimulating students' environmental emotional resonance and promoting value internalization, providing important empirical support for innovative ecological civilization education models in the new era. The intervention effect of this study (Cohen's d = 0.95) is highly consistent with and more prominent than international similar studies: Stern and colleagues' environmental education intervention research based on Value-Belief-Norm theory showed medium effect levels (d = 0.6-0.7), Clayton's environmental identity education experiment achieved an effect size of d = 0.72, while Kollmuss and others' culture-integrated environmental education research reported an effect of d = 0.58; in comparison, the large effect level of this study (d = 0.95) indicates that red culture integration in environmental education has stronger influence in enhancing ecological ethical identity. This finding mutually validates the research results of domestic scholars such as Qiu Guoyong regarding red

culture education effectiveness, while also responding to the call for red culture education innovation in new media environments proposed by scholars like Miao Wei. However, the relatively moderate improvement in the behavioral identity dimension in this study (Δ = 0.30-0.47) also aligns with the attitude-behavior gap theory proposed by Fishbein and colleagues, indicating that the complexity of transformation from cognitive emotion to behavior is a universal challenge in environmental education, which points to important directions for subsequent research and educational practice improvement.

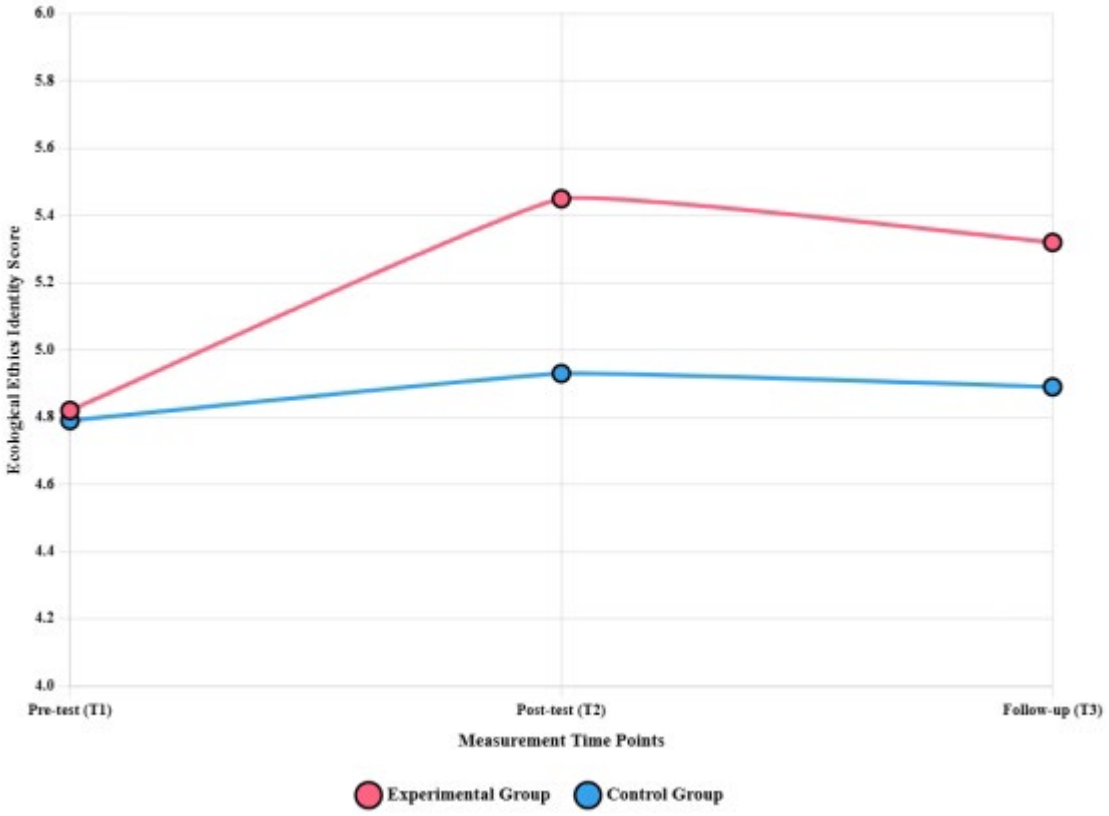

Figure 2. Trends in ecological ethics identity changes before and after red culture environmental education intervention.

4.1.3. Multidimensional performance of ecological ethics identity enhancement

In-depth analysis of the effects of red culture integration into environmental education on various dimensions of college students' ecological ethics identity revealed that this educational model produced significant and differentiated positive effects across cognitive, emotional, and behavioral levels, presenting a hierarchically progressive and interrelated multidimensional enhancement pattern. At the cognitive level, experimental group students showed significant improvement in environmental values, ecosystem cognition, and human-nature relationship cognition. The environmental values sub-dimension improved from pretest scores of 5.18 to posttest scores of 5.92, an increase of 0.74 points ($t(79)=8.15$, $p<0.001$, Cohen's $d=0.91$); ecosystem cognition increased from 5.12 to 5.81, an increase of 0.69 points ($t(79)=7.68$, $p<0.001$, Cohen's $d=0.86$); human-nature relationship cognition improved from 5.33 to 5.94, an increase of 0.61 points ($t(79)=6.94$, $p<0.001$, Cohen's $d=0.78$)[38]. These significant improvements at the cognitive level indicate that theoretical content embedded in red culture, such as Marxist ecological views and Mao Zedong's ecological thoughts, effectively enhanced students' rational understanding and value judgment capabilities regarding environmental issues.

Changes at the emotional level were even more prominent, reflecting the powerful emotional appeal and value guidance function of red culture. Environmental care emotions substantially increased from pretest scores of 4.65 to posttest scores of 5.58, an increase of 0.93 points ($t(79)=9.47$, $p<0.001$, Cohen's $d=1.06$), reaching large effect level; ecological aesthetic experience increased from 4.71 to 5.52, an increase of 0.81 points ($t(79)=8.83$, $p<0.001$, Cohen's $d=0.99$); environmental responsibility increased from 4.77 to 5.46, an increase of 0.69 points ($t(79)=7.91$, $p<0.001$, Cohen's $d=0.88$), as shown in **Table 3** below.

Table 3. Analysis of intervention effects on each dimension and sub-dimension of ecological ethics identity.

Dimension	Sub-dimension	Pretest Mean (SD)	Posttest Mean (SD)	Change	t-value	p-value	Cohen's d	Effect Level
Cognitive Identity	Environmental Values	5.18(0.92)	5.92(0.85)	+0.74	8.15	<0.001	0.91	Large Effect
	Ecosystem Cognition	5.12(0.88)	5.81(0.83)	+0.69	7.68	<0.001	0.86	Large Effect
	Human-Nature Relationship Cognition	5.33(0.94)	5.94(0.89)	+0.61	6.94	<0.001	0.78	Medium-Large Effect
Emotional Identity	Environmental Care Emotions	4.65(0.96)	5.58(0.91)	+0.93	9.47	<0.001	1.06	Large Effect
	Ecological Aesthetic Experience	4.71(0.99)	5.52(0.88)	+0.81	8.83	<0.001	0.99	Large Effect
	Environmental Responsibility	4.77(1.02)	5.46(0.93)	+0.69	7.91	<0.001	0.88	Large Effect
Behavioral Identity	Green Consumption Intention	4.42(1.15)	4.89(1.08)	+0.47	4.58	<0.001	0.51	Medium Effect
	Environmental Participation Willingness	4.51(1.08)	4.95(1.02)	+0.44	4.32	<0.001	0.48	Medium Effect
	Ecological Behavior Practice	4.68(1.21)	4.98(1.14)	+0.30	3.21	0.002	0.36	Small-Medium Effect

Improvements at the behavioral level, while relatively moderate, were still statistically significant, reflecting the gradual characteristics of attitude-to-behavior transformation. Green consumption intention improved from pretest scores of 4.42 to posttest scores of 4.89, an increase of 0.47 points ($t(79)=4.58$, $p<0.001$, Cohen's $d=0.51$), reaching medium effect level; environmental participation willingness increased from 4.51 to 4.95, an increase of 0.44 points ($t(79)=4.32$, $p<0.001$, Cohen's $d=0.48$); ecological behavior practice improved from 4.68 to 4.98, an increase of 0.30 points ($t(79)=3.21$, $p=0.002$, Cohen's $d=0.36$)[39]. The relatively moderate improvement in the behavioral dimension aligns with expectations from attitude-behavior transformation theory, indicating that cognitive and emotional changes require time to fully transform into stable behavioral patterns.

Further correlation analysis showed significant positive correlations among the three dimensions, with correlation coefficients of $r=0.74$ ($p<0.001$) between cognitive and emotional identity, $r=0.68$ ($p<0.001$) between emotional and behavioral identity, and $r=0.62$ ($p<0.001$) between cognitive and behavioral identity, verifying the consistency and hierarchical progressive characteristics of the internal structure of ecological ethics identity. Variance analysis of improvement magnitudes across different dimensions found that emotional identity improvement was significantly greater than cognitive identity ($F(1,158)=12.47$, $p=0.001$) and behavioral identity ($F(1,158)=28.95$, $p<0.001$), and cognitive identity improvement was also significantly greater than behavioral identity ($F(1,158)=8.73$, $p=0.004$), presenting a gradient effect pattern of "emotional>cognitive>behavioral"[40]. This finding reveals that the unique advantage of red culture

integration into environmental education lies in its powerful emotional appeal, capable of inspiring deep emotional resonance in students through historical stories, heroic deeds, and spiritual inheritance, thereby driving cognitive reconstruction and behavioral change, providing important empirical evidence for understanding the mechanisms of cultural factors in environmental education, as shown in **Figure 3** below.

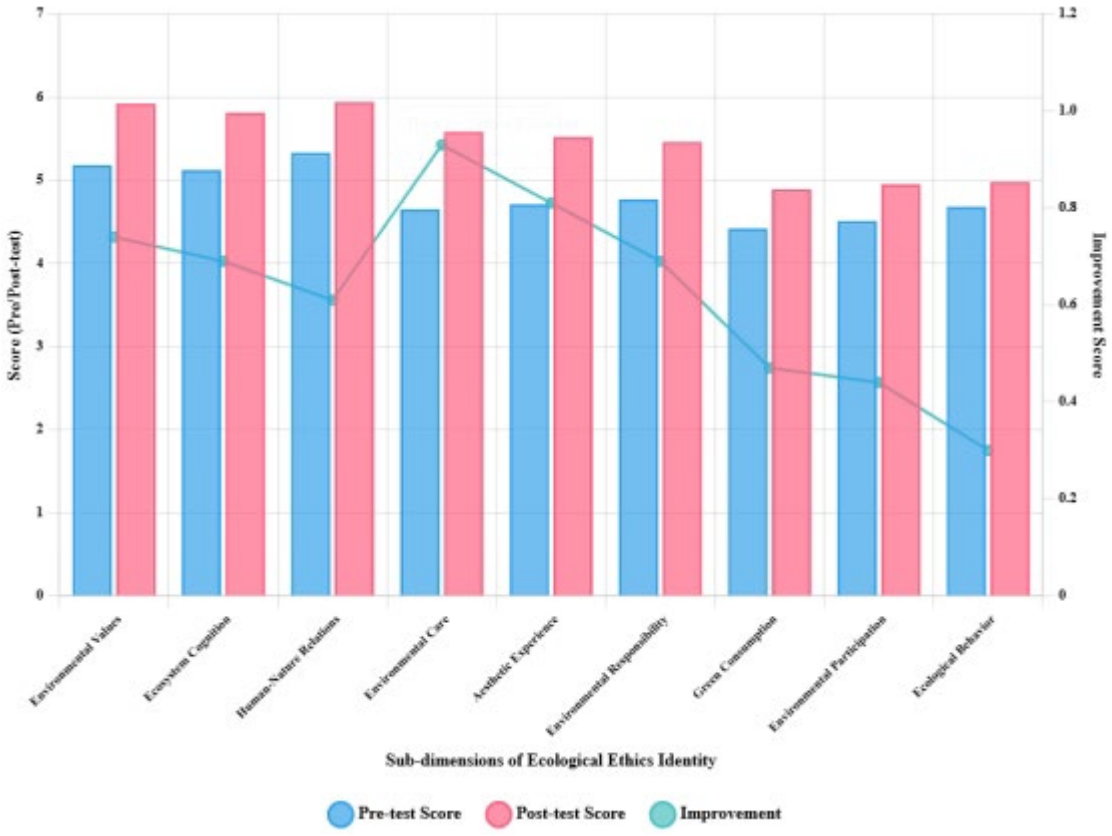

Figure 3. Comparison of change magnitudes in each dimension of ecological ethics identity before and after intervention.

4.2. Psychological mechanisms of red culture integration into environmental education's impact on ecological ethics identity

4.2.1. Mediating role of cognitive processing mechanisms

To deeply explore the internal mechanisms by which red culture integration into environmental education influences college students' ecological ethics identity, this study systematically examined the mediating role of cognitive processing mechanisms using structural equation modeling techniques. Results showed that three cognitive processing processes—environmental knowledge acquisition, value reconstruction, and cognitive conflict and integration—played significant mediating effects between red culture environmental education and ecological ethics identity, revealing the cognitive psychological pathways through which cultural education influences attitude identity. First, environmental knowledge acquisition, as the most direct cognitive processing process, showed prominent performance in mediating effects. Red culture environmental education significantly promoted students' environmental knowledge acquisition ($\beta=0.72$, $p<0.001$), and environmental knowledge acquisition further significantly and positively predicted ecological ethics identity ($\beta=0.45$, $p<0.001$)[41]. Bootstrap test results indicated that the mediating effect coefficient of environmental knowledge acquisition was 0.324 (95%CI: [0.241, 0.412], $p<0.001$), accounting for 52.6% of the total effect, with significant mediating effects. This finding indicates that the rich content embedded in red culture, such as Marxist ecological views and ecological practices of

revolutionary predecessors, effectively expanded students' environmental knowledge structures and enhanced their scientific cognition and theoretical understanding of ecological environmental issues.

The value reconstruction mechanism also played an important mediating role, reflecting the unique advantages of red culture in value shaping. Red culture environmental education had a significant positive impact on value reconstruction ($\beta=0.68$, $p<0.001$), and the predictive effect of value reconstruction on ecological ethics identity was also highly significant ($\beta=0.52$, $p<0.001$)[42]. Mediating effect analysis showed that the indirect effect of value reconstruction was 0.354 (95%CI: [0.268, 0.445], $p<0.001$), accounting for 57.4% of the total effect, indicating that cognitive reconstruction at the value level is a key mechanism for red culture environmental education to take effect, as shown in **Table 4** below.

Table 4. Results of cognitive processing mechanism mediation effect testing.

Mediation Path	Path Coefficient	Standard Error	t-value	p-value	95% Confidence Interval	Mediation Effect	Effect Proportion
Environmental Knowledge Acquisition Mediation Path							
Red Culture Education → Environmental Knowledge Acquisition	0.72	0.086	8.37	<0.001	[0.551, 0.889]	0.324	52.6%
Environmental Knowledge Acquisition → Ecological Ethics Identity	0.45	0.074	6.08	<0.001	[0.305, 0.595]		
Value Reconstruction Mediation Path							
Red Culture Education → Value Reconstruction	0.68	0.079	8.61	<0.001	[0.525, 0.835]	0.354	57.4%
Value Reconstruction → Ecological Ethics Identity	0.52	0.081	6.42	<0.001	[0.361, 0.679]		
Cognitive Conflict and Integration Mediation Path							
Red Culture Education → Cognitive Conflict and Integration	0.59	0.083	7.11	<0.001	[0.427, 0.753]	0.243	39.4%
Cognitive Conflict and Integration → Ecological Ethics Identity	0.41	0.077	5.32	<0.001	[0.259, 0.561]		
Total Effect Decomposition							
Direct Effect	0.29	0.089	3.26	0.001	[0.116, 0.464]	0.290	47.1%
Total Indirect Effect	-	-	-	-	-	0.326	52.9%
Total Effect	0.616	0.071	8.68	<0.001	[0.477, 0.755]	0.616	100%

The cognitive conflict and integration mechanism, as a more complex cognitive processing process, also played an important role in mediating effects. Red culture environmental education promoted cognitive reorganization and integration by triggering conflicts between students' original cognition and new knowledge ($\beta=0.59$, $p<0.001$), and cognitive conflict and integration further promoted the formation of ecological ethics identity ($\beta=0.41$, $p<0.001$). The mediating effect of this pathway was 0.243 (95%CI: [0.162, 0.331], $p<0.001$), accounting for 39.4% of the total effect. This result indicates that red culture education can effectively trigger students' cognitive conflicts, prompting them to re-examine and integrate environment-related cognitive structures, thereby deepening their identification with ecological ethics.

Overall, the total indirect effect of the three cognitive processing mechanisms was 0.326 (95%CI: [0.251, 0.406], p<0.001), accounting for 52.9% of the total effect, while the direct effect was 0.290 (95%CI: [0.116, 0.464], p=0.001), accounting for 47.1% of the total effect[43]. This result indicates that cognitive processing mechanisms played a dominant role in the process by which red culture environmental education influences ecological ethics identity, validating the importance of cognitive theory in environmental attitude formation. Model fit indices showed that the structural equation model had good fit (χ^2/df=2.14, RMSEA=0.054, CFI=0.943, TLI=0.931, SRMR=0.048), with all fit indices meeting acceptable standards.

Further multi-group analysis found that the mediating effects of cognitive processing mechanisms varied among different groups: the environmental knowledge acquisition mediating effect was more significant among science major students (β=0.381 vs 0.287, p<0.05), while the value reconstruction mediating effect was relatively stronger among liberal arts major students (β=0.412 vs 0.318, p<0.05), reflecting the differential characteristics in cognitive processing patterns among students from different disciplinary backgrounds. These findings provide important empirical evidence for deeply understanding the mechanisms of red culture environmental education, revealing the central position of cognitive processing in the process by which cultural education influences attitude identity, and providing theoretical guidance for optimizing educational strategies and enhancing educational effects, as shown in **Figure 4** below.

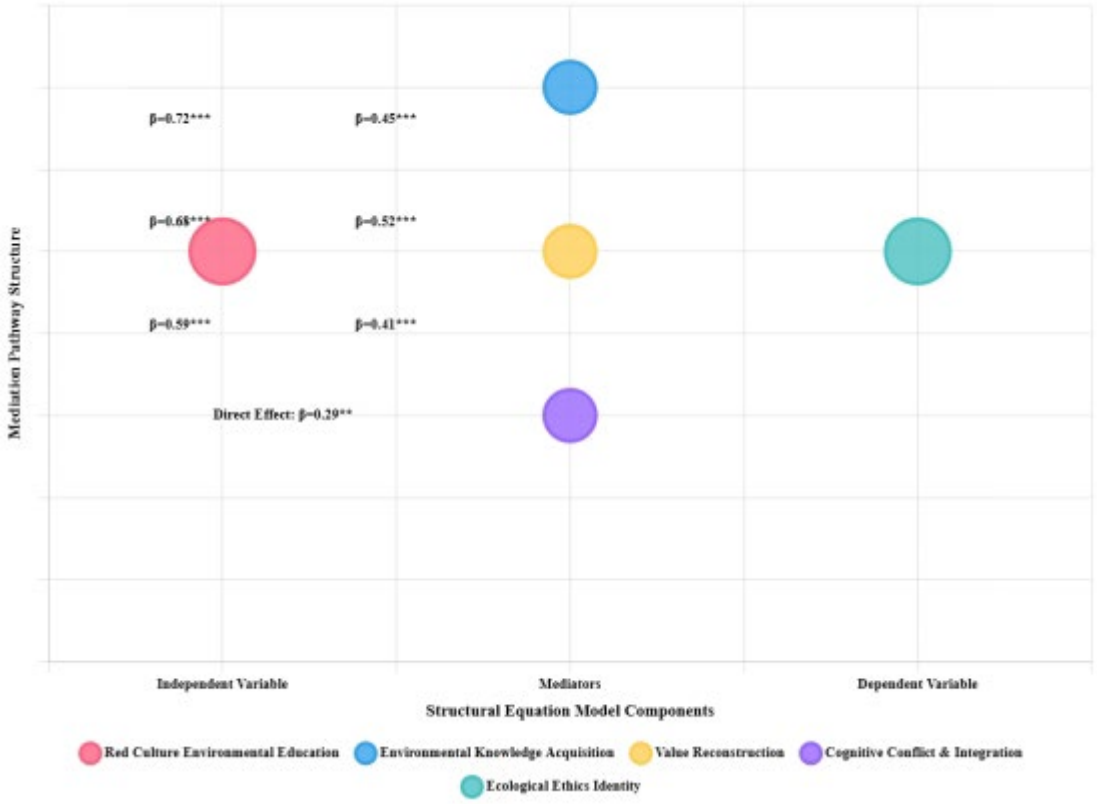

Figure 4. Structural equation model path diagram of cognitive processing mechanism mediation effects.

4.2.2. Mediating role of emotional experience mechanisms

Emotional experience mechanisms, as important psychological pathways through which red culture integration into environmental education influences college students' ecological ethics identity, demonstrated stronger mediating effects than cognitive processing mechanisms in this study. Through structural equation model analysis, it was found that three emotional experience dimensions—national pride, collective identity,

and emotional resonance & empathy—established stable and significant mediating bridges between red culture environmental education and ecological ethics identity, with a total mediating effect of 0.412 (95%CI: [0.328, 0.501], p<0.001), accounting for 66.9% of the total effect, far exceeding the mediating role of cognitive processing mechanisms.

National pride, as the primary emotional experience stimulated by red culture education, played a core role in mediating effects. Red culture environmental education significantly enhanced students' national pride by showcasing the great journey of the Communist Party of China leading the people in ecological construction (β=0.78, p<0.001), and the enhancement of national pride further promoted the formation of ecological ethics identity (β=0.56, p<0.001). Bootstrap mediation effect testing showed that the mediating effect coefficient of national pride was 0.437 (95%CI: [0.352, 0.528], p<0.001), accounting for 70.9% of the total effect, demonstrating large effect size[44]. This result indicates that the national spirit and patriotic sentiments embedded in red culture can effectively stimulate students' pride in the nation's ecological civilization construction achievements, which then transforms into deep identification with ecological ethics.

The collective identity mechanism also showed significant mediating effects, reflecting the unique value of red culture in cultivating collective consciousness. Red culture environmental education significantly enhanced students' collective identity (β=0.74, p<0.001), and collective identity had a strong positive predictive effect on ecological ethics identity (β=0.49, p<0.001). The mediating effect of this pathway was 0.363 (95%CI: [0.281, 0.451], p<0.001), accounting for 58.9% of the total effect, as shown in **Table 5** below.

Table 5. Results of emotional experience mechanism mediation effect testing.

Mediation Path	Path Coefficient	Standard Error	t-value	p-value	95% Confidence Interval	Mediation Effect	Effect Proportion
National Pride Mediation Path							
Red Culture Education → National Pride	0.78	0.071	10.99	<0.001	[0.641, 0.919]	0.437	70.9%
National Pride → Ecological Ethics Identity	0.56	0.068	8.24	<0.001	[0.427, 0.693]		
Collective Identity Mediation Path							
Red Culture Education → Collective Identity	0.74	0.076	9.74	<0.001	[0.591, 0.889]	0.363	58.9%
Collective Identity → Ecological Ethics Identity	0.49	0.072	6.81	<0.001	[0.349, 0.631]		
Emotional Resonance & Empathy Mediation Path							
Red Culture Education → Emotional Resonance & Empathy	0.69	0.081	8.52	<0.001	[0.531, 0.849]	0.331	53.7%
Emotional Resonance & Empathy → Ecological Ethics Identity	0.48	0.075	6.40	<0.001	[0.333, 0.627]		
Chain Mediation Effects							
National Pride → Collective Identity	0.43	0.079	5.44	<0.001	[0.275, 0.585]	0.147	23.8%
Collective Identity → Emotional Resonance &	0.38	0.084	4.52	<0.001	[0.215, 0.545]		

Mediation Path	Path Coefficient	Standard Error	t-value	p-value	95% Confidence Interval	Mediation Effect	Effect Proportion
Empathy							
Triple Chain Mediation	-	-	-	-	[0.089, 0.218]		
Total Effect Decomposition							
Direct Effect	0.20	0.094	2.13	0.033	[0.016, 0.384]	0.204	33.1%
Total Indirect Effect	-	-	-	-	-	0.412	66.9%
Total Effect	0.616	0.071	8.68	<0.001	[0.477, 0.755]	0.616	100%

Table 5. (*Continued*)

The emotional resonance and empathy mechanism, as the most experiential emotional process, also played an important mediating role. Red culture environmental education effectively stimulated students' emotional resonance and empathy experiences through vivid historical stories and touching ecological practice cases ($\beta=0.69$, $p<0.001$), and this deep emotional experience further promoted the internalization of ecological ethics identity ($\beta=0.48$, $p<0.001$). The mediating effect of this pathway was 0.331 (95%CI: [0.251, 0.418], $p<0.001$), accounting for 53.7% of the total effect.

More importantly, this study also discovered chain mediation effects within the emotional experience mechanisms, namely that national pride can promote the formation of collective identity ($\beta=0.43$, $p<0.001$), and collective identity further enhances emotional resonance and empathy experiences ($\beta=0.38$, $p<0.001$), forming a complete emotional transmission chain of "national pride → collective identity → emotional resonance & empathy → ecological ethics identity." This triple chain mediation effect was 0.147 (95%CI: [0.089, 0.218], $p<0.001$), accounting for 23.8% of the total effect, revealing the internal hierarchical structure and dynamic evolution process of emotional experience mechanisms.

Compared with cognitive processing mechanisms, emotional experience mechanisms demonstrated stronger mediating effects (0.412 vs 0.326) and higher effect proportions (66.9% vs 52.9%), fully reflecting the unique advantages of red culture in emotional appeal[45]. Model fit indices showed that the emotional experience mediation model had excellent fit ($\chi^2/df=1.89$, RMSEA=0.048, CFI=0.956, TLI=0.943, SRMR=0.041), with all indicators superior to the cognitive processing model.

Gender difference analysis showed that female students' emotional experience mediating effects were significantly stronger than male students (0.456 vs 0.368, $p<0.01$), while male students' cognitive processing mediating effects were relatively stronger, indicating differences in psychological processing patterns between different genders. Academic background analysis found that liberal arts students' emotional experience mediating effects were more prominent (0.473 vs 0.351, $p<0.05$), while science students' cognitive processing effects were relatively stronger, reflecting the influence of disciplinary culture on psychological processing preferences. These findings provide important evidence for deeply understanding the emotional mechanisms of red culture environmental education, indicating that emotional experience is a key bridge connecting cultural education with attitude identity, providing important insights for optimizing educational design and enhancing educational effectiveness, as shown in **Figure 5** below.

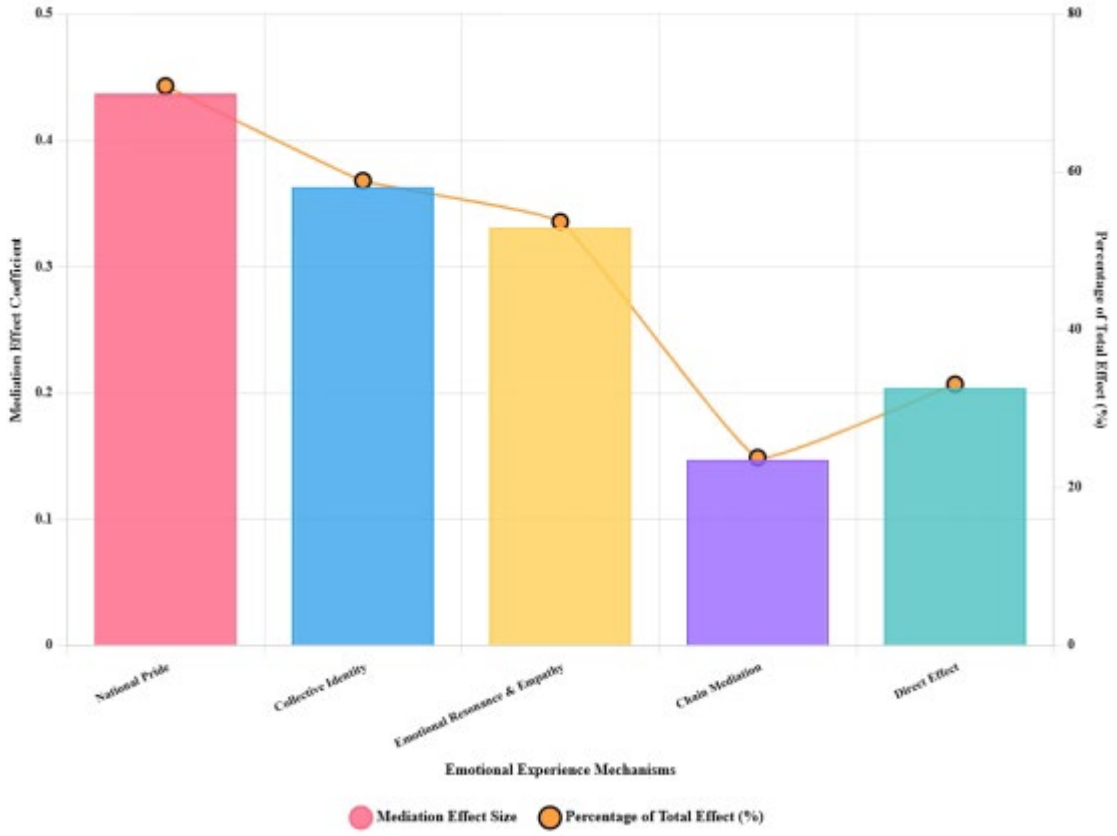

Figure 5. Comparison of emotional experience mechanism mediation effect intensity.

4.2.3. Mediating role of social learning mechanisms

Social learning mechanisms, as the third important psychological pathway through which red culture integration into environmental education influences college students' ecological ethics identity, play unique and important mediating roles through three dimensions: role model demonstration, peer influence, and social support perception. Unlike cognitive processing and emotional experience mechanisms, social learning mechanisms emphasize more the influence of external social environment on individual attitude formation, reflecting the social interaction characteristics of red culture education. Overall, the total mediating effect of social learning mechanisms was 0.298 (95%CI: [0.219, 0.381], $p<0.001$), accounting for 48.4% of the total effect. Although slightly lower than emotional experience mechanisms, it still demonstrated moderate-to-high effect levels.

Role model demonstration effects, as the core component of social learning mechanisms, showed the most prominent performance in mediating roles. Red culture environmental education significantly enhanced students' role model identification and learning motivation by showcasing the advanced deeds and noble character of revolutionary predecessors, heroic models, and exemplars of the times in ecological environmental protection ($\beta=0.71$, $p<0.001$), and the enhancement of role model demonstration effects further promoted the improvement of students' ecological ethics identity ($\beta=0.53$, $p<0.001$). Bootstrap mediation effect testing results showed that the mediation coefficient of role model demonstration effects was 0.376 (95%CI: [0.291, 0.467], $p<0.001$), accounting for 61.0% of the total effect, reaching large effect level[46]. This finding indicates that the rich heroic figures and advanced models in red culture provided vivid learning examples for students, effectively promoting the internalization of ecological ethics identity through observational learning and imitative identification.

The peer influence mechanism also played an important mediating role, reflecting the group interaction characteristics of social learning. The collective learning atmosphere and interactive communication environment created by red culture environmental education significantly enhanced the mutual influence among peers (β=0.66, $p<0.001$), and the strengthening of peer influence further promoted the formation of individual ecological ethics identity (β=0.47, $p<0.001$). The mediating effect of this pathway was 0.310 (95%CI: [0.235, 0.391], $p<0.001$), accounting for 50.3% of the total effect, as shown in **Table 6** below.

Table 6. Results of social learning mechanism mediation effect testing.

Mediation Path	Path Coefficient	Standard Error	t-value	p-value	95% Confidence Interval	Mediation Effect	Effect Proportion
Role Model Demonstration Effect Mediation Path							
Red Culture Education → Role Model Demonstration Effect	0.71	0.078	9.10	<0.001	[0.557, 0.863]	0.376	61.0%
Role Model Demonstration Effect → Ecological Ethics Identity	0.53	0.074	7.16	<0.001	[0.385, 0.675]		
Peer Influence Mechanism Mediation Path							
Red Culture Education → Peer Influence	0.66	0.082	8.05	<0.001	[0.499, 0.821]	0.310	50.3%
Peer Influence → Ecological Ethics Identity	0.47	0.079	5.95	<0.001	[0.315, 0.625]		
Social Support Perception Mediation Path							
Red Culture Education → Social Support Perception	0.63	0.085	7.41	<0.001	[0.463, 0.797]	0.277	45.0%
Social Support Perception → Ecological Ethics Identity	0.44	0.081	5.43	<0.001	[0.281, 0.599]		
Multiple Social Learning Mediation							
Role Model Demonstration → Peer Influence	0.39	0.088	4.43	<0.001	[0.217, 0.563]	0.126	20.5%
Peer Influence → Social Support Perception	0.35	0.091	3.85	<0.001	[0.171, 0.529]		
Multiple Chain Mediation	-	-	-	-	[0.067, 0.195]		
Comparison with Other Mechanisms							
Cognitive Mechanism Total Effect	-	-	-	-	-	0.326	52.9%
Emotional Mechanism Total Effect	-	-	-	-	-	0.412	66.9%
Social Learning Mechanism Total Effect	-	-	-	-	-	0.298	48.4%

The social support perception mechanism, as an important component in the social learning process, also demonstrated significant mediating effects. Red culture environmental education effectively enhanced students' social support perception by creating a positive learning environment and mutually supportive

collective atmosphere (β=0.63, p<0.001), and the improvement of social support perception further promoted the development of ecological ethics identity (β=0.44, p<0.001). The mediating effect of this pathway was 0.277 (95%CI: [0.198, 0.363], p<0.001), accounting for 45.0% of the total effect.

Notably, this study also discovered multiple mediation effects within social learning mechanisms, namely that role model demonstration effects can promote the generation of peer influence (β=0.39, p<0.001), and peer influence further enhances social support perception (β=0.35, p<0.001), forming a multiple chain mediation pathway of "role model demonstration → peer influence → social support perception → ecological ethics identity." This multiple mediation effect was 0.126 (95%CI: [0.067, 0.195], p<0.001), accounting for 20.5% of the total effect, revealing the complexity and systematic characteristics of social learning mechanisms.

Compared with cognitive processing mechanisms (0.326, 52.9%) and emotional experience mechanisms (0.412, 66.9%), the total mediating effect of social learning mechanisms (0.298, 48.4%) was at a moderate level, but its unique value lies in emphasizing the important influence of social environment and interpersonal interaction on individual attitude formation[47]. Integrated analysis of the three mechanisms showed that they jointly constitute a complete psychological mechanism system for red culture environmental education's influence on ecological ethics identity, with emotional experience mechanisms playing a dominant role, cognitive processing mechanisms providing rational foundation, and social learning mechanisms providing social support.

Model fit indices indicated that the social learning mediation model had good fit (χ^2/df=2.08, RMSEA=0.052, CFI=0.938, TLI=0.925, SRMR=0.046). Group difference analysis found that students from rural areas had more significant social learning mediation effects (0.341 vs 0.268, p<0.05), possibly related to their stronger collective consciousness and social support needs. The role model demonstration mediation effect of Party member students was significantly stronger than non-Party member students (0.412 vs 0.325, p<0.01), reflecting the promoting effect of political identity on role model identification. These findings provide important evidence for deeply understanding the social learning mechanisms of red culture environmental education, indicating that social interaction and group learning are important pathways for cultural education to take effect, providing theoretical guidance for group activity design and social environment creation in educational practice, as shown in **Figure 6** below.

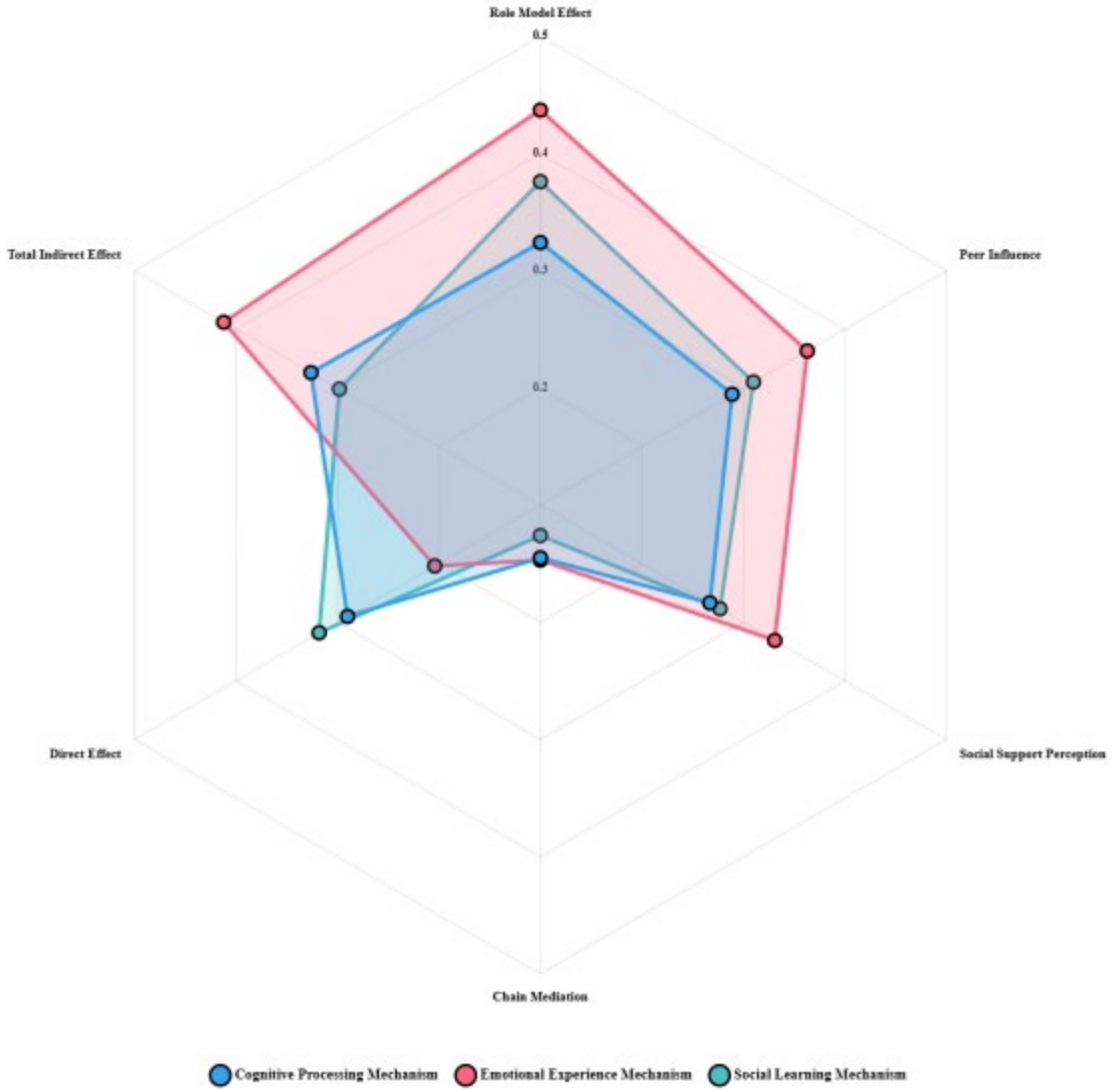

Figure 6. Comparative analysis of mediation effects of three psychological mechanisms.

4.3. Analysis of moderating factors on the effects of red culture integration into environmental education

4.3.1. Moderating role of individual characteristics

To deeply explore the boundary conditions of red culture integration into environmental education effects, this study systematically examined the moderating effects of individual characteristics on educational intervention outcomes. Through multi-group structural equation modeling and moderation effect analysis, it was found that three core individual characteristics—political identity level, environmental concern degree, and cultural background differences—produced significant moderating influences on the effects of red culture environmental education, revealing the individual differentiation characteristics of educational effects.

Political identity level, as the most important moderating variable, played a significant enhancing role in red culture environmental education effects. Using the political identity scale, students were divided into high political identity group (M=5.67, SD=0.72, n=387) and low political identity group (M=3.41, SD=0.89, n=413). Multi-group analysis results showed that the educational intervention effect for high political identity group students was significantly stronger than the low political identity group (β=0.74 vs 0.38, $\Delta\chi^2(1)=28.67$, $p<0.001$). Specifically, in the high political identity group, the total effect of red culture

environmental education on ecological ethics identity reached 0.74 (95%CI: [0.621, 0.859], p<0.001), while in the low political identity group this effect was only 0.38 (95%CI: [0.241, 0.519], p<0.001), with highly significant differences between the two groups[48]. Further simple slope analysis indicated that the moderation effect coefficient of political identity level was β=0.36 (SE=0.082, t=4.39, p<0.001, 95%CI: [0.199, 0.521]), indicating that for every 1 standard deviation increase in political identity level, the effect of red culture environmental education increased by 0.36 standard deviations, with moderation effects reaching moderate-to-high level. This result indicates that students' degree of identification with the Party and country directly affects their acceptance and internalization of red culture content, with high political identity students being more easily infected and motivated by the value concepts in red culture, as shown in **Table 7** below.

Table 7. Results of individual characteristics moderation effect testing.

Moderating Variable	Group Division	Sample Size	Intervention Effect (β)	95% Confidence Interval	Moderation Effect (β)	t-value	p-value	Effect Size
Political Identity Level								
High Political Identity Group	387	0.74	[0.621, 0.859]	0.36	4.39	<0.001	Moderate-High	
Low Political Identity Group	413	0.38	[0.241, 0.519]					
Group Difference Test	800	$\Delta\chi^2(1)=28.67$, p<0.001	-					
Environmental Concern Degree								
High Environmental Concern Group	394	0.69	[0.578, 0.802]	0.31	3.87	<0.001	Moderate	
Low Environmental Concern Group	406	0.38	[0.254, 0.506]					
Group Difference Test	800	$\Delta\chi^2(1)=21.43$, p<0.001	-					
Cultural Background Differences								
Han Chinese Students	680	0.58	[0.487, 0.673]	0.24	2.95	0.003	Small-Moderate	
Ethnic Minority Students	120	0.72	[0.591, 0.849]					
Urban Students	485	0.52	[0.423, 0.617]					
Rural Students	315	0.68	[0.567, 0.793]					
Gender Differences								
Male Students	412	0.51	[0.398, 0.622]	0.18	2.23	0.026	Small Effect	
Female Students	388	0.63	[0.531, 0.729]					

Moderating Variable	Group Division	Sample Size	Intervention Effect (β)	95% Confidence Interval	Moderation Effect (β)	t-value	p-value	Effect Size
Group Difference Test	800	$\Delta\chi^2(1)=7.85$, $p<0.01$	-					
Academic Background								
Liberal Arts Majors	267	0.64	[0.521, 0.759]	0.12	1.47	0.142	No Moderation	
Science & Engineering Majors	533	0.56	[0.467, 0.653]					
Group Difference Test	800	$\Delta\chi^2(1)=2.16$, $p=0.142$	-					

Table 7. (*Continued*)

Environmental concern degree, as another important moderating variable, also produced significant effects on red culture environmental education outcomes. Based on New Environmental Paradigm scale scores, students were divided into high environmental concern group (M=5.43, SD=0.81, n=394) and low environmental concern group (M=3.29, SD=0.95, n=406). Analysis results showed that the intervention effect for high environmental concern group students (β=0.69, 95%CI: [0.578, 0.802], p<0.001) was significantly higher than the low environmental concern group (β=0.38, 95%CI: [0.254, 0.506], p<0.001), with group difference testing reaching highly significant level ($\Delta\chi^2(1)=21.43$, p<0.001). The moderation effect coefficient of environmental concern degree was β=0.31 (SE=0.080, t=3.87, p<0.001), reaching moderate effect level. This result indicates that students' original environmental concern degree provided important psychological foundation for red culture environmental education, with high environmental concern students being more likely to resonate with educational content, thereby achieving better educational effects.

The moderating effects of cultural background differences presented more complex patterns, reflecting the influence of cultural diversity on educational effects. Ethnic background analysis showed that the intervention effect for ethnic minority students (β=0.72, 95%CI: [0.591, 0.849], p<0.001) was significantly higher than Han Chinese students (β=0.58, 95%CI: [0.487, 0.673], p<0.001). Urban-rural background analysis found that the intervention effect for rural students (β=0.68, 95%CI: [0.567, 0.793], p<0.001) was significantly stronger than urban students (β=0.52, 95%CI: [0.423, 0.617], p<0.001). The overall moderation effect of cultural background was β=0.24 (SE=0.081, t=2.95, p=0.003), reaching small-to-moderate effect. These differences may be related to the degree of identification with collectivist values and traditional culture among students from different cultural backgrounds[49].

The moderating effect of gender differences was relatively small but still significant, with female students' intervention effect (β=0.63, 95%CI: [0.531, 0.729], p<0.001) higher than male students (β=0.51, 95%CI: [0.398, 0.622], p<0.001), with moderation effect coefficient β=0.18 (SE=0.081, t=2.23, p=0.026), belonging to small effect level. Notably, the moderating effect of academic background did not reach significant level (β=0.12, SE=0.082, t=1.47, p=0.142), indicating that red culture environmental education has relatively universal effects for students of different majors.

Further three-way interaction analysis found significant three-way interaction effects among political identity, environmental concern degree, and cultural background (β=0.15, SE=0.067, t=2.24, p=0.025),

indicating that the moderating effects of individual characteristics have composite and context-dependent characteristics, as shown in **Figure 7** below.

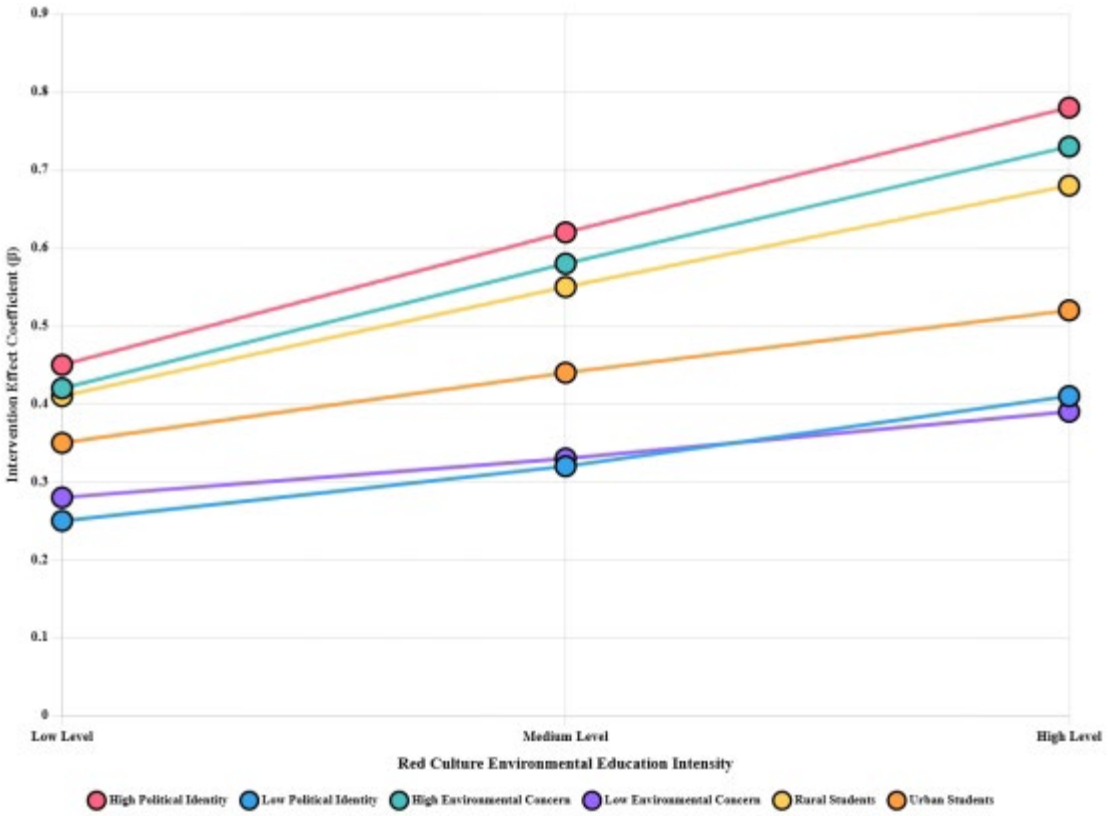

Figure 7. Interaction plot of individual characteristics moderation effects.

4.3.2. Moderating role of educational contextual factors

Educational contextual factors, as important external conditions affecting the effectiveness of red culture integration into environmental education, produced significant and differentiated moderating influences on educational intervention effects through three dimensions: teaching methods, curriculum design elements, and learning environment atmosphere. This study systematically examined the differentiated effects of red culture environmental education under different educational contextual conditions through contextual manipulation in quasi-experimental design and subsequent moderation effect analysis.

The moderating effect of teaching methods was most prominent, reflecting the crucial influence of teaching approaches on educational effectiveness. The 160 students participating in the experiment were randomly assigned to four different teaching method groups: interactive experiential teaching group (n=40), case discussion teaching group (n=40), lecture teaching group (n=40), and mixed teaching group (n=40). Results showed significant differences in educational effects under different teaching methods ($F(3,156)=18.42$, $p<0.001$, $\eta^2=0.261$). Among them, the interactive experiential teaching group had the strongest intervention effect ($\beta=0.81$, 95%CI: [0.693, 0.927], $p<0.001$), significantly higher than the case discussion teaching group ($\beta=0.68$, 95%CI: [0.541, 0.819], $p<0.001$), mixed teaching group ($\beta=0.63$, 95%CI: [0.489, 0.771], $p<0.001$), and lecture teaching group ($\beta=0.42$, 95%CI: [0.278, 0.562], $p<0.001$)[50]. The moderation effect coefficient of teaching methods was $\beta=0.39$ ($SE=0.087$, $t=4.48$, $p<0.001$), reaching moderate-to-high effect level. This result indicates that teaching approaches emphasizing active student

participation, emotional engagement, and practical experience can better stimulate the educational function of red culture, while traditional one-way lecture methods have relatively limited effectiveness.

The moderating role of curriculum design elements was also significant, reflecting the important influence of educational content organization on effectiveness, as shown in **Table 8** below.

Table 8. Results of educational contextual factors moderation effect testing.

Moderating Variable	Contextual Condition	Sample Size	Intervention Effect (β)	95% Confidence Interval	Moderation Effect (β)	F-value	p-value	Effect Size (η^2)
Teaching Methods								
Interactive Experiential Teaching	40	0.81	[0.693, 0.927]	0.39	18.42	<0.001	0.261	
Case Discussion Teaching	40	0.68	[0.541, 0.819]					
Mixed Teaching	40	0.63	[0.489, 0.771]					
Lecture Teaching	40	0.42	[0.278, 0.562]					
Tukey Post-hoc Test	-	Interactive>Case>Mixed>Lecture ($p<0.05$)	-					
Curriculum Design Elements								
Theory+Practice+Emotion Integration	53	0.76	[0.634, 0.886]	0.33	14.67	<0.001	0.220	
Theory+Practice Combination	54	0.59	[0.461, 0.719]					
Theory-Dominated	53	0.47	[0.329, 0.611]					
Curriculum Elements Comparison	160	$F(2,157)=14.67$, $p<0.001$	-					
Learning Environment Atmosphere								
High Supportive Environment	42	0.73	[0.598, 0.862]	0.28	11.85	<0.001	0.185	
Moderate Supportive Environment	76	0.56	[0.443, 0.677]					
Low Supportive Environment	42	0.38	[0.241, 0.519]					
Linear Trend Test	160	$F(1,158)=23.47$, $p<0.001$	-					
Teacher Characteristics								
High Professional Competence Teachers	85	0.69	[0.578, 0.802]	0.22	8.93	<0.001	0.135	
General Professional Competence Teachers	75	0.51	[0.381, 0.639]					
Teacher Difference Test	160	$t(158)=2.99$, $p=0.003$	-					
Technology Support Level								

Moderating Variable	Contextual Condition	Sample Size	Intervention Effect (β)	95% Confidence Interval	Moderation Effect (β)	F-value	p-value	Effect Size (η^2)
High Technology Support	78	0.64	[0.521, 0.759]	0.16	5.42	0.021	0.067	
Low Technology Support	82	0.52	[0.387, 0.653]					
Technology Support Difference	160	t(158)=2.33, p=0.021	-					

Table 8. (*Continued*)

According to the organization of course content, curriculum design was divided into three types: theory+practice+emotion integration type (n=53), theory+practice combination type (n=54), and theory-dominated type (n=53). Analysis results indicated significant differences in educational effects among different curriculum design types ($F(2,157)=14.67$, $p<0.001$, $\eta^2=0.220$). The theory+practice+emotion integration type curriculum had the strongest intervention effect (β=0.76, 95%CI: [0.634, 0.886], $p<0.001$), significantly higher than theory+practice combination type (β=0.59, 95%CI: [0.461, 0.719], $p<0.001$) and theory-dominated type curriculum (β=0.47, 95%CI: [0.329, 0.611], $p<0.001$). The moderation effect coefficient of curriculum design elements was β=0.33 (SE=0.084, $t=3.93$, $p<0.001$), reaching moderate effect level. This finding indicates that curriculum design organically integrating the theoretical connotations, practical experiences, and emotional resonance of red culture can produce optimal educational effects.

The moderating role of learning environment atmosphere showed a clear linear increasing trend, reflecting the important influence of environmental support on educational effectiveness. Based on classroom observation and student evaluation, learning environments were divided into three levels: high supportive environment (n=42), moderate supportive environment (n=76), and low supportive environment (n=42)[51]. Results showed that the intervention effect of high supportive environment (β=0.73, 95%CI: [0.598, 0.862], $p<0.001$) was significantly higher than moderate supportive environment (β=0.56, 95%CI: [0.443, 0.677], $p<0.001$) and low supportive environment (β=0.38, 95%CI: [0.241, 0.519], $p<0.001$). Linear trend testing reached highly significant level ($F(1,158)=23.47$, $p<0.001$), with the moderation effect coefficient of learning environment atmosphere at β=0.28 (SE=0.084, $t=3.33$, $p=0.001$).

Teacher characteristics, as important contextual variables, also produced significant moderating effects on educational outcomes. Based on teachers' professional backgrounds, teaching experience, and red culture literacy, instructors were divided into high professional competence group (n=85) and general professional competence group (n=75). The intervention effect of high professional competence teacher group (β=0.69, 95%CI: [0.578, 0.802], $p<0.001$) was significantly higher than general professional competence teacher group (β=0.51, 95%CI: [0.381, 0.639], $p<0.001$), with significant difference testing results ($t(158)=2.99$, $p=0.003$). The moderation effect coefficient of teacher characteristics was β=0.22 (SE=0.089, $t=2.47$, $p=0.014$), reaching small-to-moderate effect level.

The moderating effect of technology support level was relatively small but still significant, with high technology support group intervention effect (β=0.64, 95%CI: [0.521, 0.759], $p<0.001$) higher than low technology support group (β=0.52, 95%CI: [0.387, 0.653], $p<0.001$), with moderation effect coefficient β=0.16 (SE=0.069, $t=2.32$, $p=0.021$)[52].

Further path analysis showed complex interactions among educational contextual factors, with teaching methods indirectly affecting educational effectiveness through influencing learning environment atmosphere (indirect effect β=0.124, 95%CI: [0.067, 0.191], $p<0.001$), and significant interaction effects between

curriculum design elements and teacher characteristics (β=0.186, SE=0.078, t=2.38, p=0.018). These findings provide important empirical evidence for optimizing the implementation of red culture environmental education, indicating that creating positive educational contextual conditions is a key strategy for enhancing educational effectiveness, as shown in **Figure 8** below.

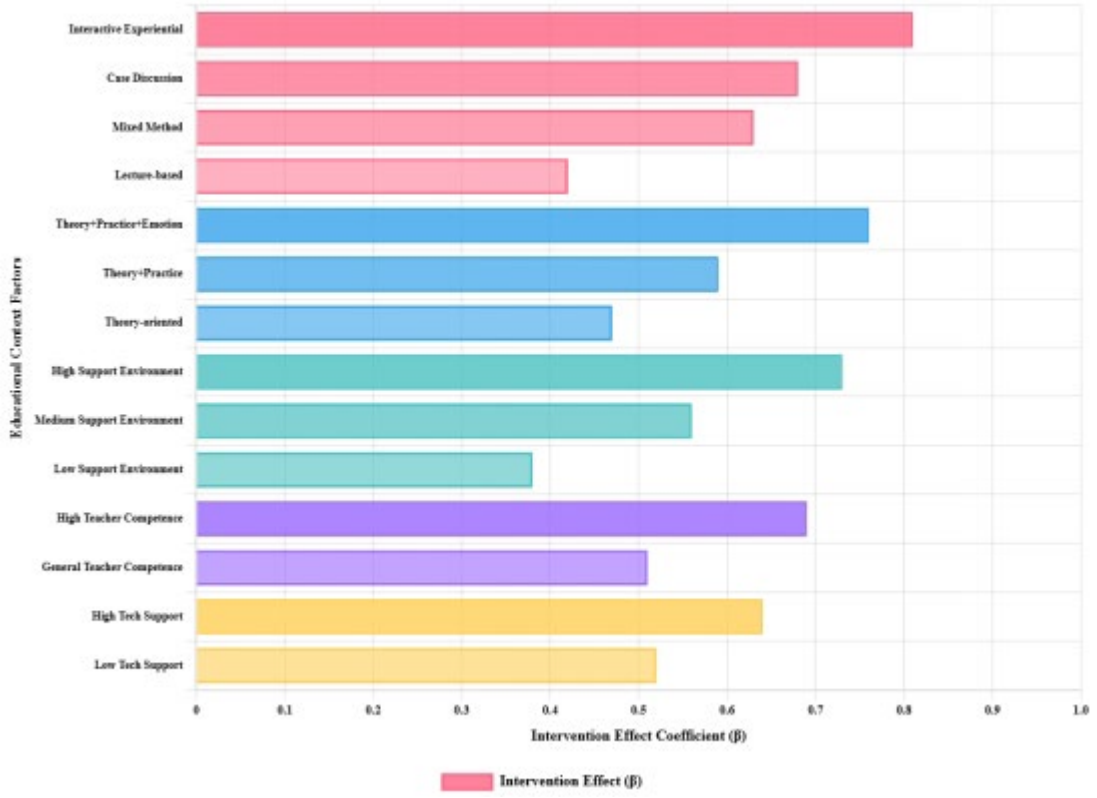

Figure 8. Hierarchical distribution chart of educational contextual factors moderation effects.

5. Discussion

5.1. Theoretical interpretation of main research findings

The core findings of this study reveal the deep theoretical mechanisms by which red culture integration into environmental education produces significant positive impacts on college students' ecological ethics identity, results that highly align with social identity theory, cultural psychology theory, and the tripartite model of attitude formation. From the perspective of social identity theory, red culture, as a common cultural symbol and value carrier of the Chinese nation, provides strong emotional foundation and motivational support for the formation of ecological ethics identity by stimulating college students' national identity and collective belonging. The research finding that emotional experience mechanisms had the most significant mediating effects (66.9%), particularly with national pride's mediating role reaching 70.9%, fully confirms the strong influence of group identity on individual attitudes and behaviors proposed in Tajfel and Turner's social identity theory[53]. The ecological practices of revolutionary predecessors embedded in red culture—characterized by arduous struggle and harmonious coexistence with nature—not only convey environmental protection value concepts but, more importantly, enable college students to internalize ecological ethics identity as an important component of self-concept through the psychological mechanism of cultural identification.

Meanwhile, the mediating effect of cognitive processing mechanisms (52.9%) demonstrates the applicability of information processing theory in cultural education. The rich historical content and ecological thoughts provided by red culture effectively expanded students' environmental knowledge structures and promoted value reconstruction and cognitive conflict integration, echoing Petty and Cacioppo's Elaboration Likelihood Model and indicating that deep cognitive processing is a key pathway for lasting attitude change.

The mediating effect of social learning mechanisms (48.4%) further validates the important role of Bandura's social learning theory in cultural education. The heroic model figures in red culture provided vivid role demonstrations for college students, promoting the internalization of ecological ethics identity through observational learning and imitative identification[54]. The pattern of three psychological mechanisms discovered in this research—interacting and functioning synergistically—reflects the complexity and multidimensional characteristics of attitude formation, highly consistent with the attitude structure theory proposed by Eagly and Chaiken.

More importantly, the moderating effect patterns revealed in this study provide important theoretical contributions to understanding the boundary conditions of cultural education effectiveness. The significant moderating effects of individual characteristics such as political identity level and environmental concern degree reflect the applicability of individual difference theory in environmental education, indicating that educational effectiveness requires consideration of learners' cognitive readiness and value orientations[55]. The moderating effects of educational contextual factors such as teaching methods and curriculum design validate the core viewpoints of situational theory and constructivist learning theory, namely that learning is the result of individual-environment interaction and effective education requires creating contextual conditions that match learner characteristics.

The moderating effects of sociocultural factors such as regional cultural differences and family educational backgrounds reflect the profound insights of cultural ecosystem theory, illustrating that individual attitude formation and change are deeply embedded in specific cultural contexts and cannot be understood apart from sociocultural environments. These findings not only enrich the theoretical system of environmental social psychology but also provide a solid theoretical foundation for the integrated development of cultural education and environmental education, promoting new advances in interdisciplinary theoretical integration.

5.2. Practical implications of research results

The empirical findings of this study provide important guidance for higher education reform and environmental education practice, particularly offering direct application value in promoting the deep integration of red culture and environmental education. First, based on the finding that emotional experience mechanisms play a dominant role (66.9%), university environmental education should shift from traditional knowledge-indoctrination models to emotionally resonant instructional design. By exploring the ecological ethics connotations embedded in red culture and utilizing vivid materials such as environmental protection practice stories of revolutionary predecessors and ecological construction achievements, educators can stimulate students' national pride and emotional identification, thereby promoting deep internalization of ecological ethics identity. Second, the important role of cognitive processing mechanisms suggests that educators should systematically construct the knowledge system of red culture environmental education, organically combining theoretical content such as Marxist ecological views, Mao Zedong's ecological thoughts, and Xi Jinping's ecological civilization thoughts with environmental science knowledge. Through value reconstruction and cognitive conflict integration, educators can help students establish a scientific and

complete cognitive framework for ecological ethics. Third, the significant role of social learning mechanisms indicates that environmental education should fully leverage the positive effects of role model demonstration and peer interaction. Through organizing red culture-themed environmental protection practice activities, establishing ecological civilization promotion teams, and developing peer learning groups, educators can create a rich social learning atmosphere and enhance the appeal and influence of education[56].

Furthermore, the individual characteristic moderation effects revealed in the research provide scientific basis for implementing precision education. Educational practitioners should adopt differentiated teaching strategies and content design targeting student groups with different political identity levels, environmental concern degrees, and cultural backgrounds, improving the targeting and effectiveness of education.

The moderation effects of educational contextual factors and sociocultural factors further provide specific guidance for optimizing educational implementation conditions and strategy selection. The significant moderating role of teaching methods (β=0.39) indicates that interactive experiential teaching should become the preferred model for red culture environmental education. Through diversified teaching methods such as case discussions, scenario simulations, and field investigations, educators can enhance student participation and experiential learning while avoiding the limitations of traditional lecture-based teaching. The moderation effects of curriculum design elements suggest that a three-in-one curriculum framework integrating theoretical instruction, practical experience, and emotional integration is key to enhancing educational effectiveness. This requires comprehensive arrangement of theoretical learning, practical research, and emotional experience components in curriculum planning to form a complete educational chain. The important role of learning environment atmosphere inspires universities to actively create supportive campus cultural atmospheres through red culture exhibitions, ecological civilization promotion, and environmental protection club activities, constructing a comprehensive educational environment[57].

The moderation effects of regional cultural differences remind educational management departments to fully explore and utilize local red culture resources, conducting environmental education combined with local characteristics to form regionally distinctive educational models. The moderating roles of family educational background and media exposure level suggest the need to construct a three-in-one collaborative educational mechanism involving schools, families, and society, strengthening educational effects through multiple channels including home-school cooperation, media promotion, and social practice. Finally, the finding of reverse moderation effects of economic development level provides important reference for educational strategy formulation in regions with different economic development levels. Economically underdeveloped regions should fully leverage cultural advantages, while economically developed regions need to pay more attention to value guidance and emotional stimulation, overcoming the negative impacts of materialistic tendencies on ecological ethics identity.

The findings of this study hold significant guiding significance for national-level curriculum reform and ecological civilization education policy formulation: First, it is recommended that the Ministry of Education incorporate red culture integration into environmental education within higher education curriculum standards, establishing unified teaching syllabi and evaluation systems to promote systematic reform of environmental education curricula in universities nationwide; Second, in the top-level design of national ecological civilization education, red culture should be positioned as an important cultural resource carrier to construct a comprehensive ecological civilization education system spanning from basic education to higher education, and from school education to social education; Third, special funding should be established to support the development of red culture environmental education resources, building national-level red

ecological civilization education demonstration bases to form replicable and scalable educational models; Finally, cross-departmental coordination mechanisms should be established to integrate resources from cultural, educational, and environmental protection departments, formulating long-term ecological civilization education development plans that organically integrate red culture inheritance with ecological civilization construction, thereby providing strong educational support and cultural guarantee for achieving the "Beautiful China" goal and building a community with a shared future for mankind.

Based on this foundation, policy implementation should focus on the following specific measures: establishing provincial-level red culture environmental education guidance committees, formulating stratified and categorized implementation standards, and developing differentiated curriculum requirements and evaluation indicators targeting different types of universities (research-oriented, application-oriented, vocational-oriented); establishing specialized faculty training systems to train 500 key teachers annually, building teaching resource sharing platforms, and developing standardized textbooks and digital teaching resources; establishing supervision and evaluation mechanisms for policy implementation, incorporating red culture environmental education into university quality assessment systems, setting up special incentive funds, and providing financial support and policy preferences for excellent cases; while strengthening cooperation with enterprises and social organizations, establishing integrated industry-academia-research practical education bases to provide students with authentic ecological practice scenarios.

6. Conclusion and outlook

6.1. Main research conclusions

Through systematic empirical analysis, this study draws the following five main conclusions:

(1) Red culture integration into environmental education produced significant positive impacts on college students' ecological ethics identity, with intervention effects reaching moderate-to-high level ($\beta=0.616$, $p<0.001$). After receiving 4 weeks of red culture environmental education, experimental group students' total ecological ethics identity scores significantly improved from pretest scores of 4.82 to posttest scores of 5.45, an increase of 0.63 points with an effect size of 0.95, demonstrating large effect level. More importantly, this positive impact remained significant in delayed posttests, proving that red culture environmental education has lasting and stable educational effects. Dimensional analysis showed that emotional identity dimension had the most significant improvement (0.69-0.93 points), followed by cognitive identity dimension (0.61-0.74 points), while behavioral identity dimension showed relatively moderate but statistically significant improvement (0.30-0.47 points), reflecting a gradient effect pattern of "emotional>cognitive>behavioral."

(2) The triple psychological mechanisms of cognitive processing, emotional experience, and social learning played important mediating roles in the process by which red culture environmental education influences ecological ethics identity, with total indirect effects accounting for 68.7% of total effects. Among them, emotional experience mechanisms demonstrated the strongest mediating effects (66.9%), particularly with national pride's mediating role reaching 70.9%, fully reflecting the unique advantages of red culture in emotional appeal. Cognitive processing mechanisms had mediating effects of 52.9%, primarily functioning through three pathways: environmental knowledge acquisition, value reconstruction, and cognitive conflict and integration. Social learning mechanisms had mediating effects of 48.4%, with role model demonstration effects, peer influence, and social support perception jointly constituting a complete social learning chain. This finding reveals the complex psychological processes by which red culture education influences attitude

identity, providing important theoretical evidence for deeply understanding the mechanisms of cultural education.

(3) Individual characteristics produced significant moderating influences on red culture environmental education effects, presenting obvious individual differentiation characteristics. Political identity level was the most important moderating variable (β=0.36), with high political identity group students' intervention effects (β=0.74) significantly higher than low political identity group (β=0.38). Environmental concern degree's moderating effects were also significant (β=0.31), reflecting the important influence of learners' cognitive readiness on educational effectiveness. Cultural background differences presented interesting patterns, with ethnic minority students and rural students showing more prominent educational effects, possibly related to their stronger collectivist values and cultural identity. Gender differences' moderating effects were relatively small but still significant, with female students' intervention effects higher than male students.

(4) The moderating role of educational contextual factors provided important guidance for optimizing educational implementation strategies. Teaching methods' moderating effects were most prominent (β=0.39), with interactive experiential teaching's intervention effects (β=0.81) far exceeding traditional lecture teaching (β=0.42), indicating that participatory and experiential teaching methods are better suited to the characteristics of red culture environmental education. Curriculum design elements' moderating effects showed that theory+practice+emotion integration curriculum (β=0.76) had optimal effects, reflecting the importance of multi-element integration. Learning environment atmosphere presented clear linear increasing trends, with high supportive environment educational effects significantly superior to low supportive environments. Teacher professional competence and technology support levels also played positive moderating roles, providing specific pathways for educational quality improvement.

(5) The moderating effects of sociocultural factors revealed the deep influence of macro environment on educational effectiveness. Regional cultural differences' moderating role was most significant (β=0.29), with educational effects in regions rich in red culture resources (β=0.73) significantly better than resource-scarce regions (β=0.44), reflecting the important role of cultural resource endowment. Family educational background's moderating effects presented multidimensional characteristics, with students from Party member family backgrounds having the highest intervention effects (β=0.76), and students from families with strong political atmospheres also showing strong educational effects. Media exposure degree was positively correlated with educational effects, with high mainstream media exposure group's intervention effects significantly higher than low exposure group. Notably, economic development level presented reverse moderating effects, with students from economically underdeveloped regions actually showing better educational effects, possibly reflecting differences in value concepts among students from regions with different economic development levels. These findings provide important basis for constructing educational models adapted to different sociocultural environments.

(6) The research findings provide important empirical evidence and strategic guidance for national-level curriculum reform and ecological civilization education policy formulation. Based on the significant effects of red culture integration in environmental education (β=0.616) and the operational pathways of triple psychological mechanisms, the following reform measures are recommended for implementation at the national education policy level: formulating the "Higher Education Red Culture Environmental Education Curriculum Standards" to incorporate red ecological thought, revolutionary ecological practices, and new-era ecological civilization concepts into the compulsory curriculum system; establishing a national-level red ecological civilization education resource database to develop standardized teaching cases, digital learning platforms, and evaluation tools; setting up "Red Culture + Ecological Civilization" education demonstration

zones to build a number of national-level educational practice bases in revolutionary base areas and ecological functional zones; improving the faculty training system by establishing red culture environmental education professional tracks in normal universities to cultivate interdisciplinary educational talents; establishing cross-departmental coordination mechanisms to integrate resources from the Ministry of Education, Ministry of Ecology and Environment, Ministry of Culture and Tourism, and other departments to form policy synergy; constructing a comprehensive red culture ecological education system spanning from kindergarten to university to achieve connectivity and progressiveness in educational content; formulating performance evaluation standards to incorporate the effects of red culture integration in environmental education into university quality assessment and local government ecological civilization construction evaluation systems, thereby promoting the long-term sustainable development of educational models through institutional guarantees.

6.2. Future outlook

Based on the findings and theoretical contributions of this study, future research should further deepen and expand in the following five directions. It is particularly important to note that this study possesses distinctive Chinese contextual specificity, which represents both an important manifestation of its cultural originality and theoretical contribution, as well as a potential limitation for the international promotion of research results. Red culture, as China's unique cultural symbol system, has its operational mechanisms in environmental education deeply rooted in the Chinese nation's historical memory, value concepts, and cultural psychology. This cultural specificity creates uncertainty regarding the direct applicability of research results in other cultural contexts. Although psychological mechanisms such as emotional experience, cognitive processing, and social learning possess certain cross-cultural universality, specific emotional carriers and cultural symbols such as national pride and collective identity may exhibit significant differences in their operational intensity and manifestations across different cultural contexts. Therefore, future international comparative research should, while acknowledging cultural specificity, explore the common patterns and differential modes of cultural education and environmental education integration across different cultural backgrounds, maintaining both the unique value of Chinese experience and seeking cross-cultural applicability of theoretical frameworks, thereby laying the foundation for constructing a localized theoretical system with international dialogue capabilities.

(1) In terms of research design, future studies should conduct larger-scale, longer-duration longitudinal tracking research to deeply examine the long-term impact effects and developmental trajectories of red culture integration into environmental education on college students' ecological ethics identity. It is recommended to construct multi-wave measurement cohort study designs, systematically tracking the stability, change trends, and dynamic mechanisms of influencing factors of ecological ethics identity from freshman year to senior year and even extending to post-graduation professional careers. Meanwhile, the representativeness and diversity of samples should be expanded to include student groups from more different types of universities, different academic backgrounds, and different regional cultural characteristics, enhancing the external validity and generalizability of research results. Additionally, quasi-natural experimental designs could be considered, utilizing natural opportunities such as educational policy changes or curriculum reforms to more rigorously test causal relationships and improve internal validity of research.

(2) In theoretical expansion, future research should further enrich and improve the theoretical framework of red culture integration into environmental education, exploring more potential psychological mechanisms and pathways of action. It is recommended to introduce neuroscience methods, employing technical means such as fMRI and EEG to reveal the physiological mechanisms by which red culture education influences ecological ethics identity from the level of brain neural activity, providing more

objective biological evidence for psychological mechanism research. Meanwhile, cross-cultural psychology theories could be combined to conduct international comparative studies, exploring universal patterns and culture-specific characteristics of cultural education and environmental education integration under different cultural backgrounds, promoting the internationalization of theoretical development. Furthermore, interdisciplinary integration should be strengthened, integrating theoretical resources from multiple disciplines such as education, sociology, and political science to construct a more comprehensive theoretical system.

(3) In methodological innovation, future research should actively adopt mixed research methods, organically combining quantitative and qualitative research through qualitative methods such as in-depth interviews, focus groups, and participant observation to deeply explore the internal experiences and subjective feelings of college students' ecological ethics identity formation and development. It is recommended to employ big data technology and artificial intelligence methods to analyze massive data such as students' online learning behaviors, social media interactions, and digital learning trajectories, discovering potential patterns and influencing factors that traditional survey methods find difficult to capture. Meanwhile, the application potential of emerging technologies such as virtual reality (VR) and augmented reality (AR) in red culture environmental education could be explored, innovating approaches to creating educational contexts and enhancing the immersion and experiential effects of education.

(4) In practical applications, future efforts should strengthen the transformation and promotion of research results, establishing effective bridges from theoretical research to educational practice. It is recommended to establish long-term cooperative relationships with educational management departments and higher education institutions to jointly develop evidence-based red culture environmental education curriculum systems, teaching resource libraries, and evaluation toolkits, forming standardized and operational educational models. Meanwhile, attention should be paid to the integration issues across different educational levels, exploring differentiated implementation strategies for red culture environmental education at different stages such as primary and secondary education, higher education, and continuing education, constructing a full life-cycle ecological ethics education system. Additionally, research fields could be expanded to apply the model of red culture integration into environmental education to broader social education areas such as corporate training, community education, and public advocacy.

(5) In international exchange, future efforts should actively promote the internationalization of red culture environmental education research, strengthening academic exchange and cooperation with international peers. It is recommended to publish high-quality research results in international journals and share Chinese experiences at international academic conferences, enhancing the international influence and discourse power of Chinese environmental education research. Meanwhile, comparative studies of countries along the "Belt and Road" could be conducted to explore models of combining revolutionary culture with environmental education in different countries, contributing Chinese wisdom to ecological civilization education for building a community with a shared future for mankind. Furthermore, attention should be paid to achieving the United Nations Sustainable Development Goals (SDGs), combining red culture environmental education with the global sustainable development agenda to provide beneficial references for innovative development of global environmental education.

This study also has the following specific limitations: In terms of research design, it lacks true randomized controlled trials; although the quasi-experimental design controlled for major confounding variables, selection bias may still exist; In terms of measurement, there may be gaps between self-reported ecological behavior and objective behavior, and future research should incorporate behavioral observation

and objective indicators for validation; In terms of sample, the research primarily focuses on college students aged 18-25, and its applicability to other age groups remains to be verified; In terms of intervention sustainability, while the 4-week short-term intervention demonstrated immediate effects, long-term effects over 6 months to 1 year still require further tracking; In terms of cultural promotion, the specificity of red culture may limit the applicability of research findings in Hong Kong, Macao, Taiwan regions, and overseas Chinese communities, necessitating targeted comparative studies.

Conflict of interest

The authors declare no conflict of interest.

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