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Enhancing pro-environmental behavior through nature-contact environmental education: an empirical analysis based on randomized controlled experiment design

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Environmental education is vital for promoting pro-environmental behavior, and nature-contact environmental education has progressively emerged as an important form of environmental education. Therefore, exploring the effects and mechanisms of nature-contact environmental education is crucial to enhancing pro-environmental behavior. This manuscript focuses on the Qinling ecological environmental education course at a Chinese university, which exemplifies a form of nature-contact environmental education. The research employs the randomized controlled experimental design as the research methodology. A total of 112 students who participated in the course served as the study sample, with the aim of investigating whether nature-contact environmental education can effectively improve students' pro-environmental behavior. Additionally, the study also explores the underlying mechanisms driving this effect. The findings indicate that nature-contact environmental education significantly contributes to improving students' pro-environmental behavior. Furthermore, environmental attitudes and environmental responsibility are identified as key mediators in the relationship between nature-contact environmental education and pro-environmental behavior. These conclusions provide valuable insights for both theoretical research and practical applications of environmental education and pro-environmental behavior.

KEYWORDS

environmental education, pro-environmental behavior, environmental attitudes, environmental responsibility, randomized controlled experimental design, empirical analysis

1 Introduction

Ecological and environmental issues have become increasingly severe, emerging as a focal points that affect individual wellbeing and constrains sustainable development. Environmental protection has thus garnered widespread attention from various stakeholders (Otto et al., 2014). As environmental protection is closely tied to individual actions, the importance of personal behavior, particularly concerning

environmental preservation, is paramount. Consequently, pro-environmental behavior (PEB) has become a critical focus in both theoretical research and practical exploration (Markel, 2013; Rees et al., 2015; Ro et al., 2017; Xiao and Hong, 2018; Lim and Moon, 2020). PEB refers to actions that reduce environmental harm, conserve natural resources, support ecosystem health, promote sustainability, mitigate negative environmental impacts, or prevent environmental risks (Stern, 2000; Khashe et al., 2015). In practice, nature-contact environmental education has been gaining increasing attention. Nature-contact environmental education refers to programs that incorporate elements of direct interaction with natural environments. Through engaging with and interacting in these settings, participants gain a deeper understanding of ecosystems, acquire environmental knowledge, and strengthen their awareness of conservation (Bogner, 1998; Asah et al., 2017). This approach enhances the effectiveness of environmental education, fostering changes in environmental attitudes and behaviors (Ekenga et al., 2019). Therefore, exploring the impact of nature-contact environmental education on PEB has become a vital academic issue of concern.

PEB is a multifaceted issue influenced by a range of factors, including sociodemographic variables, psychological factors, personal knowledge and norms, as well as various situational contexts (Gifford and Chen, 2017; Pauw and Petegem, 2017; Casaló and Escario, 2018; Lacroix et al., 2019). Recent studies have shed light on the effectiveness of environmental education, its impact on personal PEB, and the factors underlying such effects (Hsu, 2004; He and Zhan, 2018; Liu et al., 2019; Zakharova et al., 2021). However, the causal relationship between environmental education and PEB remains unclear and requires further investigation. Additionally, the specific impact pathways and underlying mechanisms linking environmental education to PEB have received limited attention and warrant in-depth exploration. Few existing studies have explored the impact and mechanisms of nature-contact environmental education on PEB. Given these gaps, this research seeks to address the following questions: (1) What are the actual effects of nature-contact environmental education? Can it genuinely enhance PEB? (2) What are the underlying mechanisms between nature-contact environmental education and PEB? Therefore, this study focuses on the nature-contact environmental education commonly implemented in colleges and universitis, with college students as the sample population. To evaluate the actual effect of nature-contact environmental education, this manuscript employs the randomized controlled experiment design to analyze the causal relationship between environmental education and PEB, and then further explores the influencing paths and potential mechanisms comprehensively.

The remainder of the manuscript is organized and presented as follows: In the next section, we review related literature on environmental education, nature-contact and influencing factors of PEB. We also conclude research gaps and propose directions for future studies. Section 3 introduces theoretical analysis and hypothesis development relevant to our research questions. Subsequently, in Section 4, we provide a detailed description of the methodology employed in this study. Section 5 focuses on explaining the main results derived from empirical analysis. Finally, in the discussion and conclusion section, we present conclusions of key findings, limitations, and suggestions for future research studies.

2 Material and hypotheses

2.1 Environmental education and PEB

Environmental education is a multidisciplinary field that aims to enhance awareness and instill proper environmental values, equipping individuals with the knowledge, skills, and attitudes necessary to address environmental issues (Varela-Candamio et al., 2018). Research underscores its effectiveness in improving environmental knowledge and fostering the development of pro-environmental attitudes and values (Torkar, 2016). Furthermore, it enhances individuals' ability to engage with and solve environmental problems, thereby contributing significantly to change PEB (Dutta and Chandrasekharan, 2018). Several studies have demonstrated the positive impact of environmental education on PEB across different demographics (Hsu, 2004; Erdogan, 2011; Dutta and Chandrasekharan, 2018; Chen, 2020). For instance, Hsu (2004) confirmed the beneficial effects of environmental education programs on college students' PEB. Lee and Kim (2014) found that environmental education significantly improves children's environmental knowledge, attitudes, and behaviors. Erdogan (2011) showed that ecologically-based curricula significantly enhance participants' responsible environmental behaviors. Similarly, Dutta and Chandrasekharan (2018) observed that school-based environmental education motivates students to participate in and take environmentally responsible actions. Chen (2020) reported that eco-education fosters students' interest in environmentalism and promotes responsible environmental behaviors. Rachman et al. (2021) reported that environmental education activities in schools lead to a stronger awareness of environmental management and a greater inclination toward environmental friendliness among students. Wang et al. (2022) further indicated that scenario-oriented environmental education positively affects the PEB of tourists. As evidenced by these findings, scholars have extensively discussed the pivotal role of environmental education in shaping PEB.

Natural contact refers to the interactive engagement between humans and both the natural environment and other non-human species. This engagement can be categorized into three types: direct, indirect, and symbolic (Kellert, 2002). The Stimulus-Organism-Response (SOR) model suggests that external physical environments and social experiences can trigger changes in individual emotions and cognitions, leading to specific behavioral responses (Mehrabian and Russell, 1974). Academic research widely recognizes natural contact as an external stimulus that can enhance individuals' willingness and actual engagement in PEB. Sommer (2003) observed that residents of urban suburbs who frequently interact with nature show a heightened resistance to tree cutting and similar activities, indicating that nature contact can enhance environmental awareness and foster environmentally friendly behaviors. Moreover, increased opportunities for natural contact are believed to enhance individuals' understanding of nature and elevate its significance in their consciousness, thereby promoting willingness to protect nature and enhancing PEB (Rosa et al., 2018). The consensus among researchers supports the idea that nature contact effectively inspires personal pro-environmental willingness and behavior (Lee et al., 2015; Martin et al., 2020). Otto and Pensini (2017) demonstrated that natural contact significantly fosters

children's pro-environmental willingness and behaviors. Additionally, Rosa and Collado (2019) found that individuals with frequent nature interactions develop a stronger emotional bond with nature and are more likely to engage in positive environmental behaviors.

PEB refers to deliberate actions taken by individuals aimed at reduce the negative environmental impact of their behaviors (Kollmuss and Agyeman, 2002). Some scholars categorized PEB into public-sphere and private-sphere actions (Stern, 2000; Hunter et al., 2004; Kaida and Kaida, 2016). Public-sphere behavior refers to activities aimed at influencing others or policies in public settings, such as participating in environmental organizations or advocating for environmental policies. Private-sphere behavior encompasses actions individuals taken in their daily lives, like waste sorting and water conservation, which typically do not directly impact others. Existing studies have discussed the influencing factors of PEB from multiple perspectives, including sociodemographic variables, psychological variables, and structural variables. For instance, Mensah (2012) discovered that women tend to engage in more environmental protection behaviors than men. Additionally, studies indicate that women are more concerned about climate change compared to men (Linder, 2015; Casalo and Escario, 2018). Age is another significant factor, with research showing a complex relationship. Wiernik et al. (2016) found that older individuals display more PEB than younger ones, contradicting common stereotypes. Conversely, Pauw and Petegem (2017) suggest that younger people are more engaged with environmental issues. Educational and income levels also influence PEB. Higher education and family income are associated with more environmentally friendly practices, such as reduced household waste and minimal use of plastic bags (Bortoleto et al., 2012; Madigele et al., 2017). Values play a crucial role as well, individuals or communities holding positive environmental values are more likely to support natural conservation (Zhang et al., 2014; Stefano et al., 2017; Yang and Arhonditsis, 2022). Additionally, psychological factors like environmental attitudes significantly affect PEB. Berenguer (2007) noted that individuals with strong empathy towards nature tend to develop positive environmental attitudes and are more proactive in environmental actions and sustainability efforts.

Environment knowledge (EK) is another nonnegligible factor for PEB (Adam et al., 2021). Environment knowledge (EK) encompasses not only knowledge of environmental problems and consequences but also knowledge of how to take action (Thoker et al., 2024), greater knowledge leads to a higher likelihood of practicing PEB (Vicente-Molina et al., 2013; Yang and Arhonditsis, 2022). Nahavandian et al. (2022) examined the impact of environmental knowledge on students' pro-environmental actions and found that a higher level of environmental knowledge positively and significantly affects their environmental behavior. Certainly, structural factors such as natural conditions, economic development, and cultural environment also play roles in shaping PEB, which emerges from the interplay of these diverse elements (Thøgersen, 2005; Bolderdijk et al., 2012; Kalamas et al., 2014; Asensio and Delmas, 2015; Cho and Kang, 2017; Tam and Chan, 2017). Thus, PEB reflects a complex interaction of multiple factors, making it a multifaceted and dynamic field of study.

While previous studies offer insights into the influence of environmental education on PEB, there exists space for improvement. Despite the existing research exploring the effects of environmental education on PEB, many studies have failed to address endogeneity issues arising from omitted variable bias (due to unobserved confounding factors) and selection bias (related to sample characteristics). The causal relationship between environmental education and PEB has not been adequately investigated. Moreover, a noticeable gap exists in the exploration of the specific pathways and mechanisms through which environmental education influences PEB. Additionally, these studies typically reveal only correlational relationships, lacking detailed analyses of specific causal effects and net effects. Consequently, to address these gaps, this study employs randomized controlled experiment design to meticulously investigate the effects of nature-contact environmental education on PEB. This approach provides a more precise exploration of the causal impacts and examines the influence of environmental education through the lenses of environmental attitude and environmental responsibility. By doing so, this research aims to provide a deeper understanding of how nature-contact environmental education can enhance PEB, offering more targeted and effective recommendations for future practices and policies.

2.2 Hypotheses development

Environmental education plays a crucial role in enhancing individuals' skills and capabilities to engage with and address environmental issues, thus fostering environmental literacy and empowering them to undertake environmental protection activities (Tibury, 1995; Kaya and Elster, 2019). As a vital instrument for shaping PEB, it has attracted considerable attention in both academic and practical realms. Pothitou et al. (2016) have noted that environmental education raises individuals' awareness of the importance of energy conservation, which in turn promotes PEB. Kukkonen et al. (2018) have found that environmental education courses significantly foster the development of environmental values, thereby accelerating PEB among college students. Jin and Li (2020) emphasized the importance of environmental education in motivating people to adopt environmentally friendly practices and enhancing their willingness to pay for environmental protection. Furthermore, Aytun and Akin (2021) empirically demonstrated the causal link between environmental education and reductions in CO_2 emissions, highlighting its role as a critical tool in preventing environmental degradation. Additionally, the concept of nature-contact-direct interaction with the natural environment—has been shown to positively influence PEB (Otto and Pensini, 2017; Hoover, 2020; Whitburn et al., 2020). Moreover, previous studies have confirmed the stimulating effects of nature-contact on PEB (Lee et al., 2015; Rosa and Collado, 2019; Martin et al., 2020; Pan and Hsu, 2020). Given these findings, it is reasonable to conclude that nature-contact environmental education, which integrates the educational function and the stimulating effect of nature-contact, can significantly enhance the PEB of individuals. Hence, we propose that:

H1: nature-contact environmental education positively promotes the PEB of individuals.

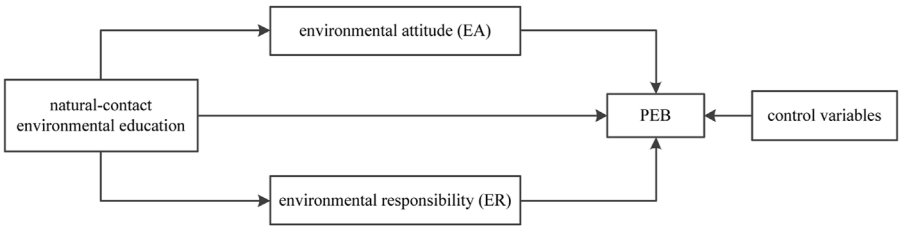

FIGURE 1
Research model.

Scholars generally agree that environmental education positively influences individuals' PEB, but other factors like environmental values and attitudes often mediate this impact (Lee and Kim, 2014; Pothitou et al., 2016). Findings that environmental education enhances environmental awareness and cognition, which in turn affects PEB, support this indirect influence (Kukkonen et al., 2018). Orbanić and Kovač (2021) further elaborated on this by demonstrating how environmental education enhances college students' awareness of environmental consequences and their sense of environmental responsibility, subsequently prompting their moral norms and pro-environmental behaviors. These studies highlight the complex pathways through which environmental education affects PEB, emphasizing the roles of intermediary variables such as environmental attitudes (EA) and environmental responsibility (ER).

Environmental attitude (EA) reflects an individual's psychological inclination towards engaging in eco-friendly behaviors and serves as a crucial predictor of PEB. It is often manifested in support for PEB and a strong understanding of environmental issues (Qian et al., 2021). Cognitive dissonance theory suggests that individuals strive to maintain consistency between their attitudes and behaviors. When a dissonance occurs—where attitudes and actions are misaligned—the individual is likely to alter their behavior to restore harmony, thereby aligning their attitudes with their actions (Festinger, 1957). Additionally, the theory of planned behavior posits that attitudes represent a psychological process whereby the more favorably an individual views a specific behavior, the more likely they are to engage in it (Ajzen, 1991). Empirical research supports the influence of environmental attitude on PEB, indicating that positive environmental attitude enhances the likelihood of adopting PEB (Milfont and Duckitt, 2010; Schroder and Wolf, 2017).

Environmental responsibility (ER) encapsulates both the sense of duty and moral obligation individuals feel towards adopting PEB to safeguard the environment, as well as the consciousness required to avoid actions that negatively impact it (Janmaimool and Chudech, 2020). According to norm-activation theory, the strength of an individual's moral emotions significantly influences their willingness to engage in specific actions (Shi et al., 2017). Failing to uphold moral norms and a sense of responsibility can lead to feelings of guilt and self-reproach. Conversely, adhering to a strong sense of environmental responsibility fosters affirmation, satisfaction, and self-esteem. Thus, environmental responsibility can activate and influence PEB (Shi et al., 2017; He and Zhan, 2018). In essence, the more pronounced an individual's environmental responsibility, the greater the probability they will practice PEB (Janmaimool and Chudech, 2020; Chen et al., 2022). Hence, this paper proposes the following assumptions:

H2: environmental attitude (EA) mediates the relationship between environmental education and PEB.

H3: environmental responsibility (ER) mediates the relationship between environmental education and PEB.

Considering the objectives of this research and the existing studies on the factors influencing pro-environmental behavior (PEB), this manuscript aims to better explore the impact of environmental education on PEB and to analyze the underlying mechanisms. We have incorporated several control variables, such as gender, place of registration, political affiliation, environmental knowledge (EK), prior experience with environmental education, and the relationship between parents' occupations and the ecological environment, to achieve this. Figure 1 displays the research model.

3 Methodology and analysis results

3.1 Methodology

3.1.1 Research method and sample

To more effectively evaluate the causal relationship between environmental education and PEB, this paper employs a randomized controlled experiment design. This approach specifically assesses the impact of environmental education on PEB using a pre-test and pos-ttest design. The design involves both an experimental group and a control group, with subjects measured both before and after the intervention. In contrast to general observation research or quasi-experiment methods, randomized controlled experiments can assign participants to groups randomly, minimizing selection bias. This ensures that any observed effects are due to the intervention rather than external factors (Bhide et al., 2018). As a result, randomized controlled experiments can effectively isolate other interfering variables, provide more reliable causal inferences, and thus enable a more scientific evaluation of the relationship between environmental education and PEB.

This study, which targets freshmen majoring in humanities and social sciences, is based on a university's Qinling Environmental Education Practice Course. We recruited participants through

voluntary sampling and subsequently randomly assigned them to either an experimental or a control group. The environmental education program was conducted in a natural mountainous setting, with careful consideration given to factors such as course design, safety concerns, participant capacity limits, and potential environmental impacts. Consequently, the number of participants in the experimental group was limited to approximately 50, while the control group sample size was designed to be roughly double that of the experimental group. A total of 128 participants were recruited, including 48 in the experimental group and 80 in the control group. Due to the requirement for participants in the experimental group to complete the full pro-environmental education program, 13 participants withdrew from the study due to time conflicts, health issues, and other unforeseen circumstances. In the control group, 3 participants completed the pre-test but were excluded from the analysis as they could not be contacted for the post-test. As a result, we obtained a total of 112 valid samples, comprising 35 from the experimental group and 77 from the control group. Importantly, because we adhered to the principle of random assignment throughout the study, we minimized potential bias in the intervention. This approach effectively ensures the robustness and validity of our research conclusions.

3.1.2 Data collection and measurement

Students in the experimental group participated in a one-week Qinling Environmental Education Practice Course in July 2022, receiving hands-on experimental interventions. Furthermore, the control group remained at school and did not engage in this specialized environmental education. The Qinling course differs from traditional environmental education by combining classroom instruction with direct exposure to nature, enhancing students' ecological knowledge and deepening their understanding through firsthand observations, site visits, and investigations. The curriculum consists of two main components: theoretical teaching and field teaching. The theoretical section covers the development and evolution of the Qinling landforms, soil, vegetation, climate changes, and the historical and cultural impact of the Qinling region on Chinese civilization. Additionally, it examines the area's ecological environment, ecosystem dynamics, biological resources, sustainable development practices, and contemporary conservation efforts, particularly in the context of reforesting converted farmland. The field teaching segment focuses on the practical exploration of Qinling's geological features, vegetation, forest meadows, and plant life. It includes activities related to the conservation, development, and scientific management of these ecological resources, alongside field visits and investigative studies aimed at enhancing environmental protection. The field teaching component is particularly effective in amplifying the course's impact, as it allows students to engage directly with the natural environment, observe real-time ecological interactions, and apply their theoretical knowledge in a practical setting. This immersive approach fosters a deeper connection with nature and a more profound understanding of ecological principles. The students in the control group continued their education at school without taking part in any activities that exposed them to the natural environment or environmental education courses.

To evaluate the impact of participating in this environmental education program on students' PEB, the study implemented a pre-test questionnaire 1 week before the course to gather baseline data on environmental attitude (EA), environmental responsibility (ER), and PEB. We administered a follow-up post-test questionnaire 1 weeks after the course's conclusion. The questionnaires collected a range of information, including demographic characteristics (gender, registered residence, political identity), prior experience with similar environmental education programs, parental occupations related to the ecological environment, and environmental knowledge. Based on existing studies, this research develops the questionnaires shown in Table 1 and Appendix 1. The questionnaire comprises 19 measurement items, including 8 items related to PEB, 4 items to EA, 3 items to ER, and 4 items to EK. We used five-point Likert scales to quantify the responses, assigning specific scores to each variable. For PEB, the scale was defined as: 1 = never, 2 = rarely, 3 = sometimes, 4 = often, 5 = very frequently, where higher scores indicate stronger PEB. For environmental attitude (EA), environmental responsibility (ER), and environmental knowledge (EK), the scale was: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, with higher values denoting greater agreement and a stronger presence of the respective variable.

The dependent variable in this study is defined as "an increase in PEB following environmental education." Specifically, this involves comparing responses from pre- and post-test questionnaires related to the environmental education course. If a student's score on any given item of the PEB measurement in the post-test questionnaire exceeds their score on the pre-test, the dependent variable for that item is assigned a value of 1, indicating an improvement. Conversely, if there is no increase, the variable is assigned a value of 0. For instance, if a student rates "rarely" on a PEB item in the pre-test and "often" in the post-test, it signifies a stronger PEB post-education, resulting in a value of 1 for that item. If there is no improvement, the value would be 0.

3.1.3 Analysis method

The study employed both intra-group and inter-group comparative methods to assess the effects of environmental education on PEB. For intra-group comparison, the study analyzed the differences in questionnaire results from the same group before and after the environmental education intervention, using the one-way ANOVA method. For inter-group comparison, the aim is to determine significant differences in PEB between the experimental group and the control group. The dependent variable, "PEB becomes higher after environmental education," is binary. We calculated percentage differences and the odds ratio, along with a 95% confidence interval, to assess the significance of differences between the groups. This approach provided a robust analysis of the impact of the environmental education program on enhancing PEB among participants.

3.1.4 Pre-testing of the small sample

To enhance the reliability and validity of the questionnaire and ensure high-quality data, this study initiated a pilot test using a small sample to evaluate and refine the questionnaire scale. For this purpose, 59 questionnaires were distributed within the target demographic. The outcomes of the reliability and validity tests are displayed in Table 1. The Cronbach's alpha coefficients for all variables surpassed the threshold of 0.7, indicating that the

TABLE 1 Reliability and validity test.

Variables	Items	Factor loading	AVE	Cronbach's α	CR
PEB	PE 1	0.745	0.521	0.848	0.851
	PE 2	0.650			
	PE 3	0.647			
	PE 4	0.787			
	PE 5	0.614			
	PE 6	0.528			
	PE 7	0.601			
	PE 8	0.580			
EA	EA 1	0.712	0.702	0.889	0.903
	EA 2	0.820			
	EA 3	0.899			
	EA 4	0.906			
ER	ER 1	0.816	0.686	0.859	0.867
	ER 2	0.881			
	ER 3	0.785			
EK	EK 1	0.875	0.715	0.911	0.909
	EK 2	0.877			
	EK 3	0.857			
	EK 4	0.748			

TABLE 2 Correlation matrix.

	PEB	EA	ER	EK
PEB	0.722			
EA	0.083	0.838		
ER	0.328[a]	0.02	0.828	
EK	0.532[b]	0.053	0.326[a]	0.846

Note: Each value on the diagonal represents the square root of AVE.
[a]represents $p < 0.05$.
[b]represents $p < 0.01$.

questionnaire items were well-designed and had high internal consistency. Additionally, factor analysis was conducted to further validate the scale. The Kaiser-Meyer-Olkin (KMO) measure yielded a value of 0.721, and the Bartlett's test of sphericity reached a chi-square value of 665.61, significant at the 0.001 level, thus confirming the appropriateness of factor analysis for this dataset. Four factors were extracted, contributing to a cumulative variance of 66.87%. Convergent validity was confirmed as the Average Variance Extracted (AVE) values for all factors were above 0.5 and the values of Composite Reliability (CR) exceeded 0.8. Discriminant validity was also established, as evidenced in Table 2, where the square root of the AVE for each variable was greater than the inter-variable correlation coefficients. Thus, the questionnaire underwent rigorous testing and was shown to have strong reliability and validity, making it a robust tool for measuring the effects of environmental education on PEB.

3.2 Analysis results

3.2.1 Descriptive statistical analysis

The demographic and background characteristics of participants in both the experimental and control groups were analyzed, as detailed in Table 3. The analysis revealed that both groups had a higher proportion of female participants, most of whom came from rural areas, which reflects the actual demographics of the sample. The majority of participants identified as members of the Communist Youth League (CYL), a common affiliation among freshmen, while none identified as members of the Communist Party of China (CPC). Regarding previous exposure to environmental education, over 70% of students in both the experimental and control groups reported no prior participation in similar environmental education courses. Additionally, more than 80% of the participants indicated that their parents' occupations were not related to ecological environmental protection. As for environmental knowledge, the analysis showed no significant difference between the groups, indicating that the participants' baseline levels of environmental knowledge were relatively similar. This baseline similarity ensures a balanced comparison of the impact of the environmental education intervention on the students' PEB.

TABLE 3 Descriptive statistics.

Variables	Experimental group	Percentage (%)	Control group	Percentage (%)
Gender				
Female	25	71.4	57	74.0
Male	10	28.6	20	26.0
Registered residence				
Rural	20	57.1	44	57.0
Urban	15	42.9	33	43.0
Political identify				
CPC member	0	0	0	0
CYL member	33	94.3	72	93.5
Non	2	5.7	5	6.5
Previous experience				
Yes	25	71.4	54	70.1
No	10	28.6	23	29.9
Parental Occupations				
Not related	31	88.6	69	89.6
Related	4	11.4	8	10.4
EK	3.321		3.308	

3.2.2 Intra-group and inter-group comparison analysis

Table 4 illustrates the changes in PEB among students in both the experimental and control groups before and after participating in the ecological environmental education course. The results indicate a notable increase in the number of students in the experimental group who reported engaging in behaviors classified as "often" and "very frequently" according to the PEB measurement indicators after participating in the environmental education course. Notably, most of these changes were statistically significant ($p < 0.05$), suggesting the course had a positive impact on their environmental behaviors. Conversely, while there was also an increase in the frequency of "often" and "very frequently" responses among students in the control group, these changes did not reach statistical significance ($p > 0.05$). This disparity highlights the effectiveness of the environmental education provided to the experimental group in enhancing their PEB compared to the control group, which did not receive the same educational intervention.

Table 5 details the analysis of the effects of environmental education on two dichotomous dependent variables: "becoming more agreed after this environmental education course" and "from disagree to agree after this environmental education course." The analysis reveals that, compared to the control group, the experimental group showed a significant increase in the proportion of students who "became more agreed" on specific PEB items PEM 1, PEM 2, PEM 5, PEM 6, and PEM 7. These items pertain to behaviors such as garbage classification, participation in discussions on environmental protection, water conservation, promotion of environmental protection, and participation in environmental protection activities. Additionally, we have introduced the odds ratio as a metric to represent the likelihood of an event occurring in the experimental group relative to the control group. An odds ratio of 1 indicates that the event has an equal chance of occurring in both groups. If the odds ratio is greater than 1, it suggests that the event is more likely to occur in the experimental group compared to the control group. Conversely, an odds ratio of less than 1 indicates that the event is less likely to occur in the experimental group than in the control group. The odds ratio results indicate that the likelihood of students in the experimental group "becoming more agreed" on these activities are significantly higher compared to those in the control group, with odds ratios of 3.481, 7.5, 1.8, 28.125, and 9.522 respectively. These findings highlight the substantial impact of the environmental education course on enhancing proactive environmental behaviors among the participants. Conversely, the analysis found no significant changes for the variable "from disagree to agree" across all PEB items in both groups, suggesting that shifts from outright disagreement to agreement were not common among the participants. In conclusion, the results affirm that participation in the environmental education course has positively influenced students' PEB to a significant extent, thereby confirming Hypothesis 1 (H1). This supports the efficacy of environmental education in fostering more environmentally responsible behaviors among students.

3.2.3 Influencing mechanisms analysis

In order to explore the mechanisms and logical connections between environmental education and PEB, this study constructs a mediation effect model. In this study, we applied specific treatments to the variables involved. We calculated both the post-test and pre-test values for all sample variables, and the difference between these values

TABLE 4 Pre-test and post-test results of PEB.

Variable		Experimental group (n = 35)			Control group (n = 77)		
		Before (%)	After (%)	*p*	Before (%)	After (%)	*p*
PEB 1	never	0	0		2.6	2.6	
	rarely	8.6	0		24.7	14.3	
	sometimes	68.6	34.3	0.000	55.8	51.9	0.022
	often	22.9	60		15.6	27.3	
	very frequently	0	5.7		1.3	3.9	
PEB 2	never	5.7	0		1.3	0	
	rarely	5.7	0		24.7	15.6	
	sometimes	74.3	48.6	0.000	50.6	66.2	0.369
	often	14.3	45.7		23.4	16.9	
	very frequently	0	5.7		0	1.3	
PEB 3	never	0	0		0	0	
	rarely	5.7	0		13.0	5.2	
	sometimes	14.3	8.6	0.147	26.0	29.9	0.113
	often	60	68.6		49.3	46.8	
	very frequently	20	22.9		11.7	18.2	
PEB 4	never	5.7	0		6.5	1.3	
	rarely	2.9	0		29.9	18.2	
	sometimes	48.6	40	0.050	41.6	37.7	0.002
	often	34.3	51.4		15.6	40.3	
	very frequently	8.6	8.6		6.5	2.6	
PEB 5	never	0	0		0	0	
	rarely	2.9	0		9.1	5.2	
	sometimes	40	25.7	0.050	42.9	42.9	0.562
	often	45.7	60		36.4	41.6	
	very frequently	11.4	14.3		11.6	10.4	
PEB 6	never	2.9	0		1.3	1.3	
	rarely	14.3	0		31.2	29.9	
	sometimes	51.4	34.3	0.000	46.8	50.6	0.631
	often	28.6	60		16.9	18.2	
	very frequently	2.9	5.7		3.8	0	
PEB 7	never	5.7	0		6.5	2.6	
	rarely	8.6	0		40.3	31.2	
	sometimes	65.7	40	0.001	35.1	51.9	0.241
	often	14.3	57.1		18.2	14.3	
	very frequently	5.7	2.9		0	0	
PEB 8	never	5.7	0		3.8	2.6	
	rarely	17.1	0		40.3	19.5	
	sometimes	57.1	45.7	0.000	31.2	48.1	0.075

(Continued on following page)

TABLE 4 (*Continued*) Pre-test and post-test results of PEB.

Variable		Experimental group (n = 35)			Control group (n = 77)		
		Before (%)	After (%)	*p*	Before (%)	After (%)	*p*
	often	20	51.4		19.5	29.9	
	very frequently	0	2.9		5.2	0	

TABLE 5 Comparison of pre-test and post-test changes of PEB.

Variables		Experimental Group (n = 35)		Control group (n = 77)		Percentage difference	*p*	Odds ratio
		n	Percentage (%)	*n*	Percentage (%)			
PEB 1	agree more	16	45.7	15	19.5	26.2	0.050	3.481
	from disagree to agree	3	8.6	3	3.9	4.7	0.655	2.313
PEB 2	agree more	15	42.9	7	9.1	33.8	0.001	7.50
	from disagree to agree	4	11.4	3	3.9	7.5	1	1.527
PEB 3	agree more	9	25.7	15	19.5	6.2	1	1.431
	from disagree to agree	2	5.7	9	11.7	−6	0.564	0.458
PEB 4	agree more	10	28.6	14	18.2	10.4	0.808	1.80
	from disagree to agree	3	8.6	12	15.6	−7	0.257	0.508
PEB 5	agree more	10	28.6	14	18.2	10.4	0.034	1.80
	from disagree to agree	1	2.9	4	5.2	−2.3	1	0.537
PEB 6	agree more	15	42.9	2	2.6	40.3	<0.0001	28.125
	from disagree to agree	6	17.1	13	16.9	0.2	0.705	1.019
PEB 7	agree more	12	34.3	4	5.2	29.1	0.013	9.522
	from disagree to agree	5	14.3	19	24.7	−10.4	0.257	0.509
PEB 8	agree more	11	31.4	8	10.4	21	0.166	3.953
	from disagree to agree	2	5.7	24	31.2	−25.5	0.527	0.654

was treated as a new variable for further analysis. These newly defined variables are referred to as DEA, DER, DPEB, and DEK, respectively. First, we used DPEB (the difference between the post-test and pre-test values of PEB) as the dependent variable, and the experimental intervention *treat* (whether the participants attended the nature-contact environmental education) as the independent variable (*treat*), and then constructed the model, as shown in Formula 1. Secondly, we adopt the mediator variables DEA (the difference between post-test and pre-test values of EA) and DER (the difference between post-test and pre-test values of ER) as dependent variables, and the experimental intervention *treat* (whether or not participants took part in nature-contact environmental education) as the independent variable (*treat*) to construct the model, as shown in Formula 2. Third, the experimental intervention (*treat*) and the mediator variables are included in the model simultaneously to test their impact on DPEB, as shown in Formula 3. With these formulas, *DPEB* represents the difference between post-test and pre-test results of PEB, *treat* indicates whether the sample has participated in this environmental education course, *mediator* refers to the mediating variable (DEA and DER) and X_i denotes the control variables.

$$\mathrm{DPEB}_i = \lambda_0 + \lambda_1 treat + \sum \gamma_j X_i + \varepsilon_i \quad (1)$$

$$mediator_i = \beta_0 + \beta_1 treat + \sum \gamma_j X_i + \varepsilon_i \quad (2)$$

$$\mathrm{DPEB}_i = \eta_0 + \eta_1 treat + \eta_2 mediator_i + \sum \gamma_j X_i + \varepsilon_i \quad (3)$$

If both β_1 and η_2 are significant, but η_1 becomes less significant or loses significance compared to λ_1, this means that the introduction of mediator variables diminishes the impact of environmental education, suggesting that the mediator variable plays a partial mediating role. Conversely, if η_1 is not significant, it implies that the mediator variable fully mediates the relationship between environmental education and PEB.

The analysis results, presented in Table 6 and Figure 2, employ Model 1, Model 2 and Model 4 to estimate the mediating effect of environmental attitude (EA). Model 1 shows the direct effect of environmental education on PEB, with a significant coefficient for *treat* ($\lambda_1 = 0.210$, $\rho < 0.05$). Model 2 reveals a significant coefficient for *treat* ($\beta_1 = 0.248$, $\rho < 0.05$), indicating that the environmental education positively

TABLE 6 Mechanisms analysis.

Variables	Dependent variable				
	Model1 (DPEB)	Model2 (DEA)	Model3 (DER)	Model4 (DPEB)	Model5 (DPEB)
treat	0.210**	0.248**	0.208**	0.167*	0.163*
DEA				0.171*	
DER					0.223**
gender	0.123	−0.161*	0.016	0.151	0.120
registered residence	0.026	0.091	0.007	0.01	0.024
political identify	0.016	−0.043	−0.071	0.023	0.032
previous experience	0.012	−0.027	−0.096	0.016	0.033
parental occupation	−0.073	−0.005	−0.104	−0.073	−0.050
DEK	0.370***	0.172*	0.362***	0.292*	0.289***
constant	−0.056	0.226	0.723	−0.094	−0.188
R^2	0.204	0.157	0.240	0.228	0.241

*, **, *** represents significance level.

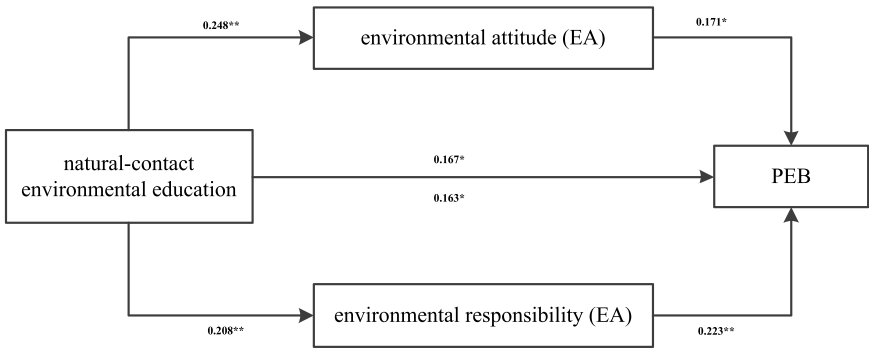

FIGURE 2
Analysis results.

affects environmental attitude (EA). Model 4 displays coefficients for *treat* (η_1 = 0.167, ρ < 0.1) and environmental attitude (EA) (η_2 = 0.171, ρ < 0.1). The decrease in magnitude and significance level of η_1 and λ_1 suggests that environmental attitude (EA) played a partial mediating role between environmental education and PEB, thus confirming hypothesis H2. Similarly, Model 1, Model 3 and Model 5 estimate the mediating effect of environmental responsibility (ER). Model 1 presents the direct effect of environmental education on PEB, with a significant *treat* coefficient (λ_1 = 0.210, ρ < 0.05). Model 3 finds that the *treat* coefficient (β_1 = 0.208, ρ < 0.05) significantly indicates a positive effect on environmental responsibility (ER). Model 5 shows that the coefficients of *treat* (η_1 = 0.163, ρ < 0.1) and environmental responsibility (ER) (η_2 = 0.223, ρ < 0.05) also reflect a decrease in the magnitude and significance level of η_1 and λ_1, supporting the conclusion that environmental responsibility (ER) partially mediates the relationship between environmental education and PEB, thereby validating hypothesis H3.

4 Discussion and conclusion

This study employs the randomized controlled experiment method to evaluate the impact of nature-contact environmental education on PEB. It also investigates potential underlying mechanisms by examining the roles of environmental attitude (EA) and environmental responsibility (ER), offering a comprehensive analysis of how these educational interventions can shape environmental behaviors. The main conclusions are as follows:

4 1 The impact of nature-contact environmental education on PEB

The results show that students in the experimental group who participated in nature-contact environmental education reported higher frequencies of engagement (“often” and “very frequently”) across all measured indicators of pro-environmental behavior (PEB). The findings of this study once again demonstrate that

environmental education can significantly promote PEB, which is consistent with existing research conclusions (Dutta and Chandrasekharan, 2018; Rachman et al., 2021; Wang et al., 2022). At the same time, we observed that environmental education improves the indicators of PEB such as waste sorting, participation in discussions about environmental protection, water conservation, advocacy for environmental protection, and involvement in environmental activities. Waste sorting, discussion participation, and water conservation fall under private-sphere PEB, while advocacy for environmental protection and participation in activities are categorized as public-sphere PEB. This indicates that nature-contact environmental education effectively promotes both private-sphere and public-sphere PEB. Although previous studies have indicated that environmental education can promote PEB, they have not differentiated between various types of PEB (Kaya and Elster, 2019; Jin and Li, 2020; Aytun and Akin, 2021). The findings of this study can further contribute to research on the relationship between environmental education and PEB.

Moreover, the data suggest that, compared to the control group, students in the experimental group were more likely to report stronger alignment with public-sphere PEB indicators than with private-sphere ones, indicating a potentially greater impact on public behaviors. Despite these positive outcomes, the study also noted that there was no significant difference in shifting attitudes from "disagree" to "agree" on PEB measures between the experimental and control groups. A possible explanation is that the duration of environmental education programs is a significant positive factor influencing their effectiveness in promoting PEB (Sellmann and Bogner, 2013). Programs that are longer and more frequent are more likely to have an impact on environmental behavior compared to short-term initiatives (Otto and Pensini, 2017). This underscores the significance of sustained engagement in environmental education programs for fostering significant and lasting behavioral changes. To address these issues, it is advisable to integrate nature-based environmental education into the broader educational framework, thereby providing students with systematic and long-term opportunities for environmental learning.

4.2 Mechanisms analysis of EA and ER

The results of the mechanism analysis indicate that environmental attitude (EA) and environmental responsibility (ER) act as partial mediators in the relationship between environmental education and PEB. Nature-contact environmental education influences PEB not only directly but also indirectly through environmental attitude. Research has shown that increased exposure to environmental information can shape an individual's beliefs, attitudes, and intentions, thus promoting PEB (Jane, 2021; Zeng et al., 2023). Participants in environmental education programs acquire theoretical knowledge about the ecological environment and gain a deeper understanding of its actual conditions through close natural contact and on-site observation. This immersive exposure enhances public awareness of the necessity and significance of adopting PEB (Berenguer, 2007; Schroder and Wolf, 2017; Rosa and Collado, 2019). Nature-contact environmental education positively influences environmental attitude by enhancing cognition and recognition of PEB, thereby increasing participants' enthusiasm and commitment to adopting environmentally friendly actions.

Furthermore, this type of education also directly impacts environmental responsibility (ER), fostering PEB through an increased sense of duty. Close interactions with the natural environment enable participants to better understand the vulnerability of ecological systems, highlighting the urgency of taking protective actions (Rosa et al., 2018; Martin et al., 2020). Consequently, nature-contact environmental education enhances personal awareness and responsibility, promoting the adoption of PEB (Shi et al., 2017; He and Zhan, 2018; Janmaimool and Chudech, 2020). In summary, through direct engagement with nature and the acquisition of skills and knowledge related to environmental protection, participants in environmental education programs strengthen their sense of responsibility and environmental awareness, which in turn influences their PEB. These educational interventions not only inform but also empower individuals, enabling them to become proactive participants in environmental conservation efforts.

4.3 Analysis of control variables

The study found insignificant effects of gender, registered residence, political identity, prior experience, and parental occupations on PEB when examining the control variables. While prior research indicates that variables of gender, residence, political identify, and prior experience can influence PEB (Berenguer et al., 2005; Xiao et al., 2013; Wang and Kang, 2018; Liu and Feng, 2020), this study found that the effects of these variables were not statistically significant. One potential explanation pertains to the characteristics of our study population. The research focused on the first-year students majoring in humanities and social science at the university, who predominantly spend their time in various educational institutions (middle school, high school, and university). Consequently, their perceptions regarding PEB tend to be largely homogeneous and are less influenced by external factors.

Additionally, environmental knowledge (EK) showed a positive correlation with PEB, suggesting that individuals with higher levels of environmental knowledge are more likely to engage in PEB. This finding is consistent with existing studies (Zeng et al., 2023; Thoker et al., 2024; Jia and Wang, 2024), which indicate that higher levels of environmental knowledge positively and significantly influence environmental behaviors. Although studies indicate that this relationship is not direct or may be quite weak (Otto and Pensini, 2017; Obiagu et al., 2024), this is primarily because environmental knowledge acts as a distal variable, with its effects mediated by emotional factors (Orion and Arnon, 2015). In this study, students participated in a week-long nature-contact environmental education program, which provided a substantial duration for engagement. Additionally, the post-test was conducted 1 weeks after the environmental education, which is a relatively short interval that minimizes interference from external factors. As a result, our findings indicate a significant positive effect of environmental knowledge on PEB. Given this result, it is essential for the curriculum of nature-contact environmental education to encompass a comprehensive range of content that enhances environmental knowledge. This should include detailed information on the distribution of animal

and plant resources, the broad dissemination of relevant environmental protection policies and regulations, and the provision of practical knowledge and skills pertinent to PEB.

Of course, this study faces several limitations due to practical constraints. First, regarding the research methodology, the study utilizes a randomized controlled experiment design and relies on a volunteer sampling method for recruiting research samples. This method of self-selected participation is inherently non-random and may introduce a non-response bias. Although this is a common challenge in survey research, in future studies, we aim to gather more information about non-respondents through various channels to mitigate potential selection biases. Second, in terms of sample size, this study gathered 112 samples through voluntary recruitment, with a specific focus on freshmen majoring in humanities and social sciences. This method helps eliminate other factors that might be confusing and keeps sample differences to a minimum, but it also means that the sample size is smaller. Additionally, due to constraints related to course design and funding, the sample size of the experimental group was approximately half that of the control group. In future research, we plan to gather as many multi-dimensional samples as possible while maintaining research accuracy to enhance the external validity of the study's conclusions. Third, regarding the study design, this research established an experimental group (participants in nature-contact environmental education) and a control group (non-participants). This approach enabled the evaluation of nature-contact environmental education's impact on PEB but did not allow for the separate assessment of nature contact and environmental education as independent factors influencing PEB. To address this limitation, future studies should consider a more nuanced design that includes a group with both nature contact and education, a group with nature contact only, a group with education only, and a control group. This expanded approach would allow for a more precise understanding of the distinct effects of each factor.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by College of. Humanities and Social Development, Northwest A&F University. Written informed consent was obtained from the participants to participate in this study in accordance with the national. legislation and the institutional requirements.

Author contributions

YZ: Conceptualization, Data curation, Formal Analysis, Methodology, Project administration, Writing–review and editing. XL: Data curation, Resources, Writing–original draft. XH: Methodology, Supervision, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2024.1491780/full#supplementary-material

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Appendix 1: Variables measurement

Variables	Items	Measurement	Source
PEB	PEB 1	Do you categorize waste materials such as glass, aluminum cans, plastics, and newspapers according to their types?	Stern (2000) Kaida and Kaida (2016)
	PEB 2	Do you engage in discussions about environmental issues with family or friends?	
	PEB 3	Do you reuse plastic bags for environmental purposes?	
	PEB 4	Do you carry reusable shopping bags when purchasing necessities?	
	PEB 5	Do you consciously conserve water for environmental reasons?	
	PEB 6	Do you actively participate in environmental awareness and education campaigns organized by the government or your workplace?	
	PEB 7	Do you engage in environmental protection activities organized by non-governmental organizations?	
	PEB 8	Do you take action to voice complaints about environmental issues, either online or offline?	
EA	EA 1	Pro-environmental behavior is beneficial	López-Mosquera et al. (2015) Gao et al. (2017) Gkargkavouzi et al. (2019)
	EA 2	Eco-protection and energy efficiency are commendable initiatives	
	EA 3	You maintain a positive attitude towards implementing pro-environmental behaviors	
	EA 4	You advocate for the adoption of pro-environmental practices	
ER	ER 1	You believe that there is a moral obligation to engage in pro-environmental behavior	Harth et al. (2013) He and Zhan (2018)
	ER 2	You feel personally responsible for implementing pro-environmental actions	
	ER 3	You experience guilt when failing to engage in pro-environmental behavior	
EK	EK 1	You are knowledgeable about the local flora and fauna	Moss et al. (2016) Zhang et al. (2021) Fan (2022)
	EK 2	You are familiar with environmental protection policies and regulations	
	EK 3	You possess a solid understanding of pro-environmental behavior	
	EK 4	You have acquired various skills related to pro-environmental practices	