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ARTICLE

The Impact of Environmental Education on College Students' Low-carbon Behaviour: A Chain Mediation Model Moderated by Prosocial Behaviour

Maobao Yang[1,2], Gaofei Ren[1,2,3] and Lei Guo[1]

[1]School of Management, Jiujiang University, Jiujiang, China, [2]Jiangxi Yangtze River Economic Zone Research Institute, Jiujiang, China and [3]Jiangxi Provincial Key Laboratory of River Basin Ecological Processes and Information, Jiujiang, China
Corresponding author: Gaofei Ren; Email: gaofei_ren@163.com

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Abstract
Low-carbon behaviour is a crucial pathway to addressing current climate change and promoting sustainable economic and social development. The importance of environmental education has become a widely recognised consensus among higher education institutions. However, the mechanisms through which environmental education influences the low-carbon behaviour of the new generation of college students remain insufficiently explored. This study introduces environmental attitude and green perceived value as mediators, while prosocial behaviour is a moderator. A moderated chain mediation model is developed from new perspectives of psychological, social and environmental values, and this theoretical model is empirically tested using 759 college students in China surveyed by a questionnaire. The findings reveal that environmental education positively drives college students' low-carbon behaviour, with environmental attitude and green perceived value playing a partial chain mediation role between environmental education and low-carbon behaviour. Additionally, prosocial behaviour positively moderates the relationships between environmental attitude, green perceived value and college students' low-carbon behaviour, significantly moderating the mediating effect of green perceived value.

Keywords: Environmental attitude; environmental education; green perceived value; low-carbon behaviour; prosocial behaviour

Introduction

Addressing climate change and promoting a low-carbon societal transition is now a global priority. In China, a recent survey on public awareness and behaviour revealed a notable knowledge-action gap, with only 69.3% of individuals frequently engaging in low-carbon practices. Low-carbon behaviour involves minimising environmental impact through reduced energy use, lower emissions and sustainable daily choices (Xiao *et al.,* 2021). Such behaviour is vital for mitigating climate change, preserving the environment and advancing sustainable development. In this context, higher education plays an essential role in shaping students' values and behavioural patterns (Zhang & Cao, 2024). Integrating ecological education at the university level is particularly important for cultivating environmental responsibility and fostering enduring low-carbon habits, thereby supporting broader societal transformation (Cheng *et al.,* 2024).

Understanding how ecological education influences university students' low-carbon behaviour is essential to advancing higher education practices and supporting national and global

sustainability goals (Meng *et al.,* 2024). As an interdisciplinary field, ecological education aims not only to transfer knowledge but also to foster environmental awareness, values and practical skills for living in harmony with nature (Scalabrino *et al.,* 2022). This study focuses on the Chinese higher education context to examine how ecological education courses — typically spanning multiple semesters and including topics such as environmental science, sustainability and ecological ethics — influence students' low-carbon behaviour. While previous research has emphasised the role of values, policies and responsibility, the internal mechanisms and external conditions through which ecological education promotes low-carbon behaviour-particularly via psychological and social value pathways — remain underexplored.

This study draws on the specific practices of ecological education in Chinese universities to empirically examine how such education influences students' low-carbon behaviour and the moderating influence of social context. The findings aim to advance theoretical understanding of how ecological education shapes behaviour and to provide practical evidence for improving curriculum design and educational outcomes in Chinese higher education. In doing so, the study supports higher education's role in promoting green lifestyles and contributing to global climate governance. Data were collected via questionnaire surveys and analysed using structural equation modelling to offer empirical support for the value of ecological education in driving the low-carbon transition.

Theoretical background and research hypothesis

Environmental education and low-carbon behaviour

Environmental education developed in response to growing environmental degradation and rapid economic growth. It promotes values such as life, environmental protection and energy conservation, encouraging individuals to live in harmony with nature (Wang & Lu, 2019; Yang & Lei, 2020). Low-carbon behaviour involves minimising environmental impact by reducing energy use and emissions, and adopting sustainable living habits (Xiao *et al.,* 2021). The core of environmental education lies in cultivating environmental awareness and the ability to act, not merely transferring knowledge but also shaping values and encouraging behaviour (Prayogo *et al.,* 2024). Integrating environmental education throughout all levels of schooling is essential for developing future citizens capable of contributing to sustainable development (Dastgir *et al.,* 2024. It introduces concepts such as environmental science, climate change and energy efficiency, while also emphasising practical skills like energy-saving techniques and participation in environmental initiatives (Collins *et al.*, 2025; Imran *et al.,* 2024). Through knowledge, emotion, skills and community engagement, environmental education supports the adoption of low-carbon behaviour. Based on this, this paper proposes the following hypothesis:

H1: Environmental education has a positive impact on low-carbon behaviour.

Environmental education and environmental attitudes, green perceived value

Environmental attitude refers to a psychological predisposition toward the environment and its condition, encompassing individuals' feelings, evaluations and behavioural tendencies regarding environmental issues (Jia & Fan, 2023; Tolppanen & Kang, 2021; Ugulu *et al.,* 2013; Zhang & Cao, 2024). Studies show that students who participate in nature-based activities, such as community gardening or environmental surveys, develop stronger nature connectedness and support pro-environmental actions (Spano *et al.,* 2023). In Indonesia, locally-informed curricula improve environmental stewardship, especially in areas such as sustainable agriculture and water management (Abas *et al.,* 2022). Among Chinese students, science-based environmental education promotes environmental behaviour more effectively than politically oriented

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instruction (Wang *et al.,* 2021). Studies also show that national park-based environmental education significantly improves tourists' environmental attitudes and encourages responsible behaviour (Park *et al.,* 2022). By transferring knowledge, engaging emotions and shaping values, environmental education plays a central role in cultivating positive environmental attitudes and advancing sustainable behaviour.

Green perceived value refers to individuals' overall judgment of environmentally friendly products and services, based on their environmental concerns, sustainability expectations and values related to health and social responsibility (Li *et al.,* 2024; Woo & Kim, 2019; Zhao *et al.,* 2024). A cross-national survey by Li *et al.* (2024) shows a strong link between environmental education and students' appreciation of green values, reinforcing education's key role in shaping environmentally responsible citizens. Environmental education goes beyond facts to shape values that promote respect for nature and sustainable living (Yan *et al.,* 2024). When individuals understand the close link between environmental health and human well-being, they are more likely to adopt pro-environmental actions (Park *et al.,* 2022). It also builds critical thinking and decision-making skills, enabling individuals to make environmentally conscious choices in daily life, such as selecting eco-friendly products or conserving energy (Zhang & Shi, 2019). Environmental education strengthens green value perceptions through knowledge, experience and cultural engagement, supporting the transition to green lifestyles. Based on this, the paper proposes the following hypotheses:

H2: Environmental education positively affects environmental attitudes.

H3: Environmental education positively affects green perceived value.

Environmental attitude, green perceived value and low-carbon behaviour

According to the theory of planned behaviour (TPB), an individual's behavioural intention is shaped by attitude, subjective norms and perceived control. Among college students, positive low-carbon attitudes encourage eco-friendly decisions such as using public transit or avoiding disposables (He *et al.,* 2024). When students view low-carbon behaviour as crucial for environmental protection, they are more likely to conserve energy and reduce emissions. Similarly, the value-belief-norm theory suggests that environmental values translate into moral responsibility, which then drives pro-environmental actions (Yang *et al.*, 2024). Low-carbon awareness strongly predicts behaviour, with students who understand sustainability issues more likely to adopt low-carbon lifestyles. Zhan *et al.* (2024) found environmental attitudes significantly predict low-carbon behaviour, aligning with TPB. Existing research examines diverse drivers of low-carbon behaviour, enriching our understanding of how attitudes shape action and informing more targeted environmental strategies.

The green perception of college students significantly influences their low-carbon behaviour, a finding supported by numerous studies. Green perception reflects individuals' environmental attitudes and values and strongly shapes daily behaviour, particularly among youth. It is closely tied to growing environmental awareness and serves as a catalyst for a societal shift toward low-carbon practices (Shah & Asghar (2024). He *et al.* (2024) explored this relationship from a social psychological perspective, while Zhan *et al.* (2024) noted that green perception triggers intrinsic environmental motivation, leading to more consistent low-carbon actions. This includes changes in daily habits such as conserving energy or choosing green transport, as well as influencing peers through social networks. Recent studies highlight that environmental education plays a vital role in strengthening students' green perception by helping them better understand the urgency of environmental issues and encouraging environmentally responsible decisions. Based on these findings, this paper proposes the following hypotheses:

H4: Environmental attitude positively influences low-carbon behaviour.

H5: The perceived value of green initiatives positively influences low-carbon behaviour.

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The mediating role of environmental attitude and green perceived value

Park *et al.* (2022) found that environmental education significantly shapes individual environmental attitudes, a view that also applies to college students. Through systematic environmental education, students can deepen their understanding of environmental issues, thereby fostering more positive environmental attitudes. Those with greater environmental knowledge and action skills are more likely to exhibit such attitudes, which often translate into low-carbon behaviours (Yan *et al.*, 2024). Environmental attitudes thus play a significant mediating role between environmental education and low-carbon behaviour. Environmental education helps foster foundational environmental understanding through the dissemination of knowledge on ecological issues, ecosystem functions and sustainability principles (Li *et al.*, 2024). Heightened awareness encourages individuals to consider the long-term environmental impact of their behaviour, increasing their willingness to adopt low-carbon actions (Ji *et al.,* 2023b). When individuals recognise the urgency of environmental challenges and their responsibilities, their attitudes become more positive and responsible (Oe *et al.,* 2022). This attitudinal shift is pivotal in driving low-carbon behaviour, as positive environmental attitudes lead individuals to value and adopt low-carbon lifestyles (Abeysekera *et al.,* 2022). Based on the literature, it is reasonable to infer that environmental attitudes mediate the relationship between environmental education and low-carbon behaviour.

According to the theory of green perceived value, consumers' green perceived value reflects their assessment of environmentally beneficial products based on green needs and sustainability expectations (Abdou *et al.*, 2022). This framework also applies to college students, who gradually develop green value perceptions as they engage with environmental education. Research in environmental psychology suggests that individuals' environmental attitudes and behaviours are often driven by intrinsic values. Thus, it is reasonable to infer that green perceived value, as a core component of these values, significantly influences students' low-carbon behaviour (Ji et *al.,* 2023a). Students exposed to environmental education are more likely to become leaders and advocates for sustainable development. They not only adopt low-carbon lifestyles but also promote green policies and practices, thus contributing to long-term societal sustainability (Zhang & Shi, 2019). By cultivating and reinforcing green perceived value, environmental education not only directly promotes low-carbon behaviour but also indirectly fosters broader societal sustainability. Based on existing literature, it is reasonable to conclude that green perceived value plays a critical mediating role between environmental education and low-carbon behaviour.

Environmental attitude serves as a critical antecedent in the formation of environmental behaviour and is influenced by external factors such as environmental education. This view also applies to college students, as environmental education shapes behaviour through attitudinal change (Bala *et al.,* 2023). In line with the theory of green perceived value, such value often reflects evaluations shaped by environmental attitudes (Miller *et al.,* 2022). Thus, through environmental education, college students may develop stronger environmental attitudes and heightened green value perceptions, motivating them to engage in low-carbon behaviours. Nogueira *et al.* (2023) found that green perceived value is influenced by environmental attitudes and perceived behavioural control, with environmental awareness and positive attitudes forming the basis for green consumption. Positive attitudes enhance recognition of green products, thereby increasing green perceived value. Environmental attitude not only drives green behaviours but also reinforces green perceived value (Khan, 2024). Environmental education promotes these attitudes by conveying ecological knowledge and sustainability principles. When individuals understand the link between their actions and environmental health, they are more inclined to adopt environmentally responsible behaviours. Ultimately, environmental education not only encourages low-carbon behaviour at the individual level but also supports societal sustainability by shaping environmental attitudes and strengthening green perceived value (Ogilvie & de Crom, 2025). Based on this theoretical foundation, it is reasonable to infer that environmental attitude

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and green perceived value jointly mediate the relationship between environmental education and low-carbon behaviour. Based on the foregoing, this paper proposes the following hypotheses:

H6: Environmental attitude mediates the relationship between environmental education and low-carbon behaviour.

H7: Green perceived value mediates the relationship between environmental education and low-carbon behaviour.

H8: Environmental attitude and green perceived value jointly mediate the relationship between environmental education and low-carbon behaviour.

The moderating effect of prosocial behaviour

Prosocial behaviour encompasses actions that align with social expectations and benefit others, groups or society (Pfattheicher *et al.,* 2022; Zhang & Cao, 2024). It typically involves concern for others and a commitment to the public good. This tendency may promote positive environmental values and is often associated with sharing environmental knowledge and low-carbon lifestyle information (Zeng *et al.,* 2023). It can generate societal demonstration effects; as more individuals adopt environmentally conscious behaviours, these behaviours gradually become normalised (Bala *et al.,* 2023). In adhering to such norms, individuals' environmental attitudes improve, and they increasingly view green behaviour as a social responsibility, enhancing recognition of green product value (He *et al.,* 2024). Chen *et al.* (2022) confirmed that prosocial behaviour, as a positive social interaction, significantly moderates the relationship between environmental attitude and green perceived value. Accordingly, the following hypotheses are proposed:

H9: Prosocial behaviour has a positive moderating effect on the relationship between environmental attitudes and low-carbon behaviour.

H10: Prosocial behaviour has a positive moderating effect on the relationship between environmental attitudes and green perceived value.

Prosocial behaviour directly promotes low-carbon behaviour and supports the development of a low-carbon society through social influence, increased awareness, emotional engagement and innovation (Jeong *et al.,* 2022). Environmental attitude's influence and the chain mediation effect vary across prosocial behaviour contexts (Rana *et al.,* 2024). Prosocial behaviour reinforces environmental attitudes and indirectly strengthens green value perceptions by deepening individuals' understanding of environmentally responsible behaviour. These two factors complement each other and jointly advance sustainable societal development (Chen *et al.,* 2022). As prosocial behaviour increases, both environmental attitude and green perceived value more strongly enhance low-carbon behaviour (Chen *et al.,* 2022). Accordingly, the following hypothesis is proposed:

H11: Prosocial behaviour has a positive moderating effect on the mediating effect of green perceived value in the relationship between environmental attitude and low-carbon behaviour.

Based on the theoretical inferences and research hypotheses presented above, this paper constructs a theoretical model, as illustrated in Figure 1.

Research design

Sample selection and data collection

As members of the younger generation, college students play a key role in influencing societal norms through their behaviours, values and consumption habits. Cultivating their low-carbon awareness and behaviour can shape future societal trends and promote a broader transition to a low-carbon lifestyle. Accordingly, this study targeted college students, and data were collected via online and offline questionnaires. The survey included 23 questions, with items designed to be objective and free from social desirability bias. Four additional questions captured respondents'

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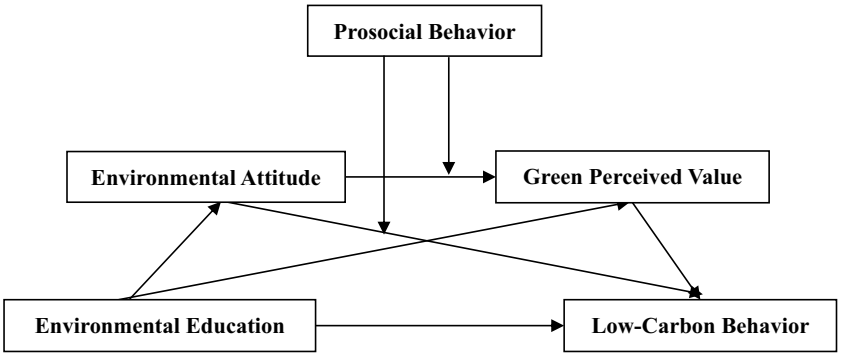

Figure 1. Theoretical model.

Table 1. Statistical characteristics

Variable		*N*	PCT(%)	Variable		*N*	PCT(%)
Gender	Male	422	55.60	Discipline	Social	464	61.13
	Female	337	44.40		Natural	295	38.87
Type	Research Universities	140	18.45	Education	Graduate	119	15.68
	Teaching Universities	476	62.71		Undergraduate	338	44.53
	Polytechnics	143	18.84		College	302	39.79

basic demographic information. A total of 820 questionnaires were distributed, with 61 excluded due to invalid or incomplete responses, resulting in 759 valid responses and a 92.56% response rate. Sample characteristics are shown in Table 1.

Variable measurement

This paper adopts a well-established scale and modifies it to align with the specific context of the research content and objects. A selection of survey participants was invited to provide suggestions for modifying the scale items in terms of semantic clarity and relevance, ensuring the scale's scientific rigour and accuracy. The pre-survey tested the reliability and validity of the questionnaire, which was subsequently administered both online and offline. This study employs a five-point Likert scale for measurement, ranging from "strongly disagree" to "strongly agree," with scores ranging from 1 to 5.

Environmental Education: The environmental education scale was adapted from Wang & Lu (2019) and includes four items. It emphasises systematic learning experiences, using participation frequency and duration to reflect the depth and structure of educational interventions. Typical items distinguish course content from activity types. Sample questions include: "The total hours of compulsory ecological education courses accounted for a high proportion in non-specialised education curricula" and "I am willing to participate in or organise publicity or practical activities related to environmental protection."

Low-carbon Behaviour: Low-carbon behaviour was measured using the green behaviour intention scale developed by Xiao *et al.* (2021), grounded in the Theory of Planned Behaviour. The scale includes three items, such as "I intend to engage in low-carbon behaviour in daily life." The internal consistency coefficient of the scale is 0.95, demonstrating excellent reliability.

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Environmental Attitude: Environmental attitude was assessed using a four-item scale developed by Jia & Fan (2023) and Ugulu *et al.* (2013). Sample items include: "I am willing to become a community energy-saving publicity volunteer" and "I am willing to purchase energy-saving products when time and financial resources allow."

Green Perceived Value: Green perceived value is measured using the scale developed by Woo & Kim (2019), which includes 4 items, such as "I believe the price of green products is higher than that of regular products" and "I am willing to pay a premium for green products."

Prosocial Behaviour: Drawing on the "Youth Prosocial Tendency Scale" revised by Zhang & Cao (2024) and the scale developed by Baumsteiger & Siegel (2019), a college student prosocial behaviour scale was designed, consisting of 4 items, such as "I tend to help those in urgent need of assistance" and "I am more willing to help others in public settings."

Control Variables: Based on prior research, this study includes gender, major, school type and academic qualifications as control variables. Majors are categorised into two groups: liberal arts and science/engineering. School types are classified into research universities, teaching universities and polytechnics. Academic qualifications are classified into three levels: postgraduate, undergraduate and junior college.

Common method bias and reliability and validity test

Testing for common method variance (CMV) ensures that results are not artefacts of the data collection method, thereby enhancing internal and construct validity. If CMV is present and uncontrolled, it can overestimate the strength or direction of relationships between variables. Harman's single-factor test was applied, using unrotated exploratory factor analysis on all variables except the controls. Five factors had eigenvalues greater than 1, with the largest accounting for 29.89% of the variance — below the 40% threshold — indicating that common method bias is unlikely.

Reliability testing assesses random errors or inconsistencies, determining whether measurements reflect actual traits rather than incidental variations. Validity testing examines whether the tool accurately measures the intended concepts, reflecting measurement accuracy and alignment with theoretical constructs or real-world situations. Using SPSSAU, the study calculated average variance extracted (AVE) and composite reliability (CR). The results in Table 2 show that all standardised factor loadings exceeded 0.6, AVE values (0.721 – 0.680) exceeded 0.5, and CR values (0.912–0.885) exceeded 0.8, indicating good convergent validity. Cronbach's alpha values (0.835 – 0.911) further confirmed high internal consistency. KMO = 0.853 (>0.8) indicated strong suitability for factor extraction. Model fit indices met accepted standards (λ^2/df = 2.57; NFI, CFI, IFI, TLI >0.9; PGFI, PNFI, PCFI >0.5; RMR, RMSEA, SRMR < thresholds). The square roots of AVE values exceeded inter-variable Spearman correlations, confirming good discriminant validity.

Table 2. Reliability and validity (CFA)

Variable	CR	AVE	α	KMO	1	2	3	4	5
EE	0.912	0.721	0.891	0.853	0.849				
EA	0.923	0.750	0.911		0.295	0.866			
GPV	0.879	0.647	0.856		0.259	0.304	0.804		
PB	0.889	0.667	0.851		−0.028	−0.046	−0.224	0.817	
LCB	0.865	0.680	0.835		0.218	0.318	0.347	−0.291	0.825

Note: $^*p < 0.05$ $^{**}p < 0.01$; Environmental Education = EE; Low-carbon Behaviour = LCB; Prosocial Behaviour = PB; Environmental Attitude = EA; Green Perceived Value = GPV.

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Empirical analysis and results

Correlation analysis

This study employed SPSSAU for correlation analysis. Pearson correlation coefficients (Table 3) were used to assess relationship strength. Environmental education, environmental attitude, green perceived value and low-carbon behaviour all showed significant correlations. Coefficients of 0.295, 0.313 and 0.243 indicated positive correlations between environmental education and environmental attitude, green perceived value and low-carbon behaviour. Significant correlations were also found among the other variables (Zhou & Ma, 2024).

Direct effect test

This study employed SPSSAU to test direct, mediating and moderating effects. As shown in Table 4, DW values indicated no autocorrelation, suggesting the models were well specified (Magno *et al.*, 2024; Zhou & Ma, 2024). Model M1 showed a positive relationship between environmental education and low-carbon behaviour ($\beta = 0.243$). M5 and M6 indicated positive effects on environmental attitude ($\beta = 0.293$) and green perceived value ($\beta = 0.311$), respectively. M2 and M3 revealed positive links from environmental attitude ($\beta = 0.310$) and green perceived value ($\beta = 0.350$) to low-carbon behaviour (all $p < 0.01$). These results confirm Hypotheses H1–H5.

Direct effects were assessed using standardised regression coefficients. As shown in Table 5, all effects were significant ($p < 0.01$) with positive Beta values: strongest for green perceived value (0.313), followed by environmental attitude (0.295) and low-carbon behaviour (0.243). Ecological education thus enhances both environmental cognition and behavioural practice. Strengthening the connection between educational content and specific low-carbon behaviours could further improve behavioural conversion. VIF = 1.000 confirmed no multi-collinearity, and the 95% confidence intervals excluded zero, supporting Hypotheses H1–H3.

Mediation effect test

The percentile bootstrap method was used for the parallel mediation effect test. As shown in Table 6, for the EE→EA→LCB pathway, the total effect (c) was 0.228; EE→EA (a) = 0.158; EA→LCB (b) = 0.362; mediation effect (ab) = 0.057. The 95% CI (0.039 – 0.084) excluded zero, indicating a significant mediation effect. The direct effect (c') was 0.095, and all coefficients (a, b, c') were significant. Matching signs for ab and c' indicated partial mediation by environmental attitude, accounting for 25.086% of the total effect. For the EE→GPV→LCB pathway, $c = 0.228$; $a = 0.294$; $b = 0.257$; ab = 0.076; and the 95% CI (0.051 – 0.109) excluded zero, confirming significance (Zhou & Ma, 2024). The direct effect (c') was 0.095, with all coefficients significant. Matching signs for ab and c' indicated partial mediation by green perceived value, accounting for 33.131% of the total effect. These findings support Hypotheses H6 and H7.

Table 3. Correlation analysis

Variable	*M*	SD	EE	EA	GPV	PB	LCB
EE	3.598	0.924	1				
EA	3.230	0.497	0.295**	1			
GPV	3.530	0.869	0.313**	0.292**	1		
PB	2.654	0.454	−0.071*	−0.052	−0.260**	1	
LCB	3.430	0.870	0.243**	0.312**	0.349**	−0.314**	1

Note: *$p < 0.05$ **$p < 0.01$; Environmental Education = EE; Low-Carbon Behaviour = LCB; Prosocial Behaviour = PB; Environmental Attitude = EA; Green Perceived Value = GPV.

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Table 4. Regression results analysis

Variable	LCB				EA	GPV		
	M1	M2	M3	M4	M5	M6	M7	M8
Gender	−0.037	−0.031	−0.052	−0.042	−0.032	0.032	0.036	0.027
Discipline	0.045	0.040	0.035	0.032	0.014	0.028	0.023	0.016
Type	0.004	0.015	0.005	0.006	0.006	0.028	0.044	0.037
Education	0.016	0.016	0.014	0.025	−0.015	−0.005	−0.007	−0.000
EE	0.243**				0.293**	0.311**		
EA		0.310**		0.302**			0.292**	0.286**
GPV			0.350**					
PB				−0.288**				−0.234**
PB*EA				0.082*				0.072*
R^2	0.063	0.100	0.127	0.196	0.088	0.100	0.089	0.153
Adj. R^2	0.057	0.095	0.121	0.189	0.082	0.094	0.083	0.145
DW	1.929	1.938	1.947	2.011	2.037	1.951	1.971	2.039

Note: $^*p < 0.05$ $^{**}p < 0.01$; Environmental Education = EE; Low-Carbon Behaviour = LCB; Prosocial Behaviour = PB; Environmental Attitude = EA; Green Perceived Value = GPV.

Table 5. Regression coefficients

	B	SE	Beta	*t*	*p*	95% CI	VIF
EE→LCB	0.228	0.033	0.243	6.889	0.000**	0.163 ~ 0.293	1.000
EE→EA	0.158	0.019	0.295	8.485	0.000**	0.122 ~ 0.195	1.000
EE→GPV	0.294	0.032	0.313	9.060	0.000**	0.230 ~ 0.358	1.000

Note: $^*p < 0.05$ $^{**}p < 0.01$; Environmental Education = EE; Low-Carbon Behaviour = LCB; Prosocial Behaviour = PB; Environmental Attitude = EA; Green Perceived Value = GPV.

The Bootstrap method with 5,000 iterations was used to test mediation effects. The results in Table 7 indicate that, for EE→EA→LCB, the 95% CI (0.039 – 0.084) excluded zero, confirming the effect and supporting H6. For EE→GPV→LCB, the 95% CI (0.038 – 0.091) also excluded zero, supporting H7 (Zhou & Ma, 2024). For the chain mediation path EE→EA→GPV→LCB, the 95% CI (0.010 – 0.024) excluded zero, indicating a chain mediation effect that accounts for 7.02% of the total effect. These results support Hypothesis H8.

Moderating effect test

Model M4 tested prosocial behaviour's moderation of the environmental attitude–low-carbon behaviour link; Model M8 tested its moderation of the environmental attitude–green perceived value link. The interaction term (EA × PB) had a significant positive effect on low-carbon behaviour ($\beta = 0.082$) and green perceived value ($\beta = 0.027$; both $p < 0.05$), confirming prosocial behaviour as a moderator in both relationships (Zhou & Ma, 2024). These results support Hypotheses H9 and H10.

A simple slope analysis was conducted for the EA–LCB relationship. Table 8 shows EA's effects on LCB and GPV at low, mean, and high PB levels. At low PB, coefficients were 0.376 for LCB and

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Table 6. Results of mediation effect size

	c	a	b	a*b	z	95% BootCI	c'	PCT
EE→EA→LCB	0.228**	0.158**	0.362**	0.057	5.039	0.039~0.084	0.095**	25.086%
EE→GPV→LCB	0.228**	0.294**	0.257**	0.076	5.133	0.051~0.109	0.095**	33.131%

Note: *$p < 0.05$ **$p < 0.01$; Environmental Education = EE; Low-Carbon Behaviour = LCB; Prosocial Behaviour = PB; Environmental Attitude = EA; Green Perceived Value = GPV.

Table 7. Chain mediation effect analysis

	Effect	SE	*t*	*p*	95% CI	Proportion
Total Effect	0.228	0.033	6.889	0.000	0.163~0.293	100.00%
Direct Effect	0.095	0.034	2.849	0.005	0.030~0.161	41.67%
Total indirect effect	0.133	0.016	8.370	0.000	0.109~0.173	58.33%
EE→EA→LCB	0.057	0.011	5.039	0.000	0.039~0.084	25.00%
EE→GPV→LCB	0.060	0.013	4.577	0.000	0.038~0.091	26.32%
EE→EA→GPV→LCB	0.016	0.004	4.321	0.000	0.010~0.024	7.02%

Note: *$p < 0.05$ **$p < 0.01$; Environmental Education = EE; Low-Carbon Behaviour = LCB; Prosocial Behaviour = PB; Environmental Attitude = EA; Green Perceived Value = GPV.

Table 8. Simple slope analysis

	Levels of moderating	RC	SE	*t*	*p*	95% CI	
GPV	AVG	0.500	0.059	8.481	0.000	0.384	0.615
	HIGH (+1SD)	0.640	0.092	6.975	0.000	0.460	0.820
	LOW (−1SD)	0.359	0.084	4.279	0.000	0.195	0.524
LCB	AVG	0.531	0.058	9.228	0.000	0.418	0.643
	HIGH (+1SD)	0.686	0.090	7.655	0.000	0.510	0.861
	LOW (−1SD)	0.376	0.082	4.585	0.000	0.215	0.536

Note: *$p < 0.05$ **$p < 0.01$; Environmental Education = EE; Low-Carbon Behaviour = LCB; Prosocial Behaviour = PB; Environmental Attitude = EA; Green Perceived Value = GPV.

0.359 for GPV. At high PB, EA's positive effects on LCB ($\beta = 0.531$) and GPV ($\beta = 0.500$; both $p < 0.01$) were amplified, reinforcing PB's moderating role. Figures 2 and 3 illustrate these effects for LCB and GPV (Zhou & Ma, 2024). These findings thereby provide additional empirical support for Hypotheses H9 and H10.

Test of moderated mediation effect

The results are presented in Table 9. A moderated mediation analysis was performed for Model 8. At low GPV, the bootstrapped 95% CI excluded zero (effect = 0.076), indicating significance. At mean GPV, the CI excluded zero (effect = 0.106); at high GPV, it also excluded zero (effect = 0.135). Effect sizes varied significantly across levels, confirming moderated mediation. Table 10

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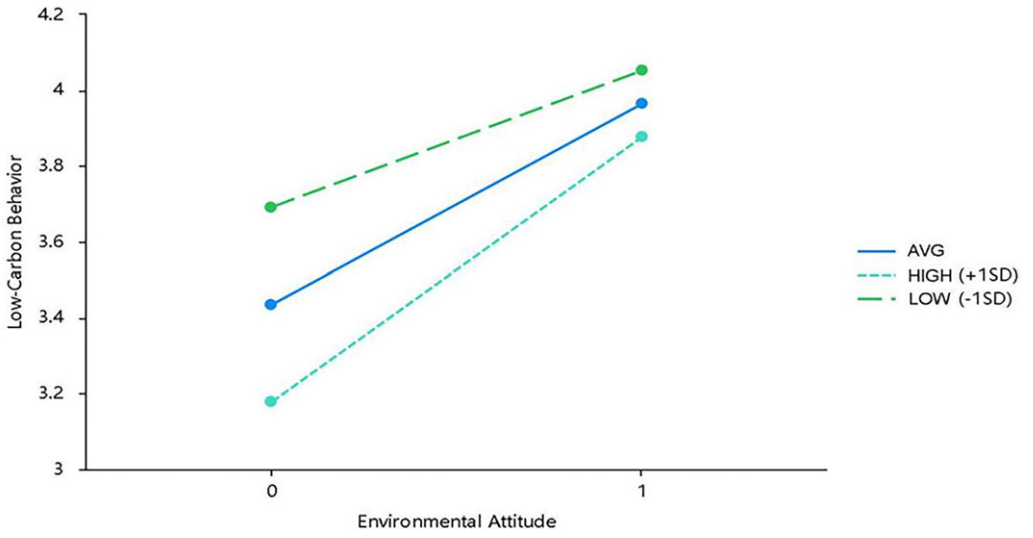

Figure 2. The moderating effect of prosocial behaviour on environmental attitude and green perceived value.

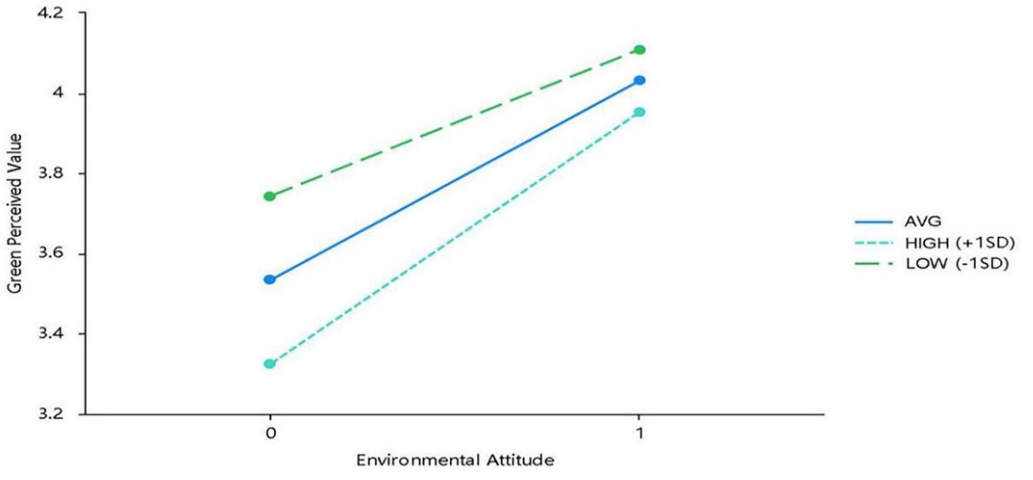

Figure 3. The moderating effect of prosocial behaviour on environmental attitude and low-carbon behaviour.

Table 9. Moderated mediation analysis

Mediating variables	Levels of moderating	Value	Effect	Boo tSE	95% CI	
EA	AVG	3.523	0.039	0.018	0.008	0.076
	HIGH (+1SD)	4.299	0.068	0.029	0.014	0.129
	LOW (−1SD)	2.747	0.010	0.012	−0.011	0.038
GPV	AVG	3.523	0.076	0.020	0.038	0.116
	HIGH (+1SD)	4.299	0.106	0.028	0.055	0.163
	LOW (−1SD)	2.747	0.045	0.027	−0.010	0.097

Note: $^{*}p < 0.05$ $^{**}p < 0.01$; Environmental Education = EE; Low-Carbon Behaviour = LCB; Prosocial Behaviour = PB; Environmental Attitude = EA; Green Perceived Value = GPV.

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Table 10. Index of moderated mediation

Moderator variables	Mediating variables	Index	Boot SE	Boot LLCI/ULCI	
PB	GPV	0.065	0.028	0.013	0.128

Note: $^{*}p < 0.05$ $^{**}p < 0.01$; Environmental Education = EE; Low-Carbon Behaviour = LCB; Prosocial Behaviour = PB; Environmental Attitude = EA; Green Perceived Value = GPV.

shows LLCI = 0.013 and ULCI = 0.128, both excluding zero, indicating significant moderated mediation (Zhou & Ma, 2024). These results support Hypothesis H11.

Conclusion and implications

Promoting low-carbon behaviour is essential for addressing global environmental challenges, safeguarding environmental security and fostering sustainable economic transformation. It aligns with sustainable development principles, supports clean energy, green transport and energy-efficient infrastructure, and creates new growth opportunities while meeting high-quality development goals. Environmental education acts as a catalyst for low-carbon behaviour, with environmental attitudes and green perceived value as key facilitators. This study examines how environmental education and prosocial behaviour influence college students' low-carbon behaviour through the pathway: environmental education → environmental attitude → green perceived value → low-carbon behaviour. Key findings:

(1) Environmental education, environmental attitudes and green perceived value all positively affect low-carbon behaviour, with education as the main driver and the others as key pathways.

(2) Environmental education also indirectly affects low-carbon behaviour through chained mediation via environmental attitudes and green perceived value.

(3) Prosocial behaviour strengthens the influence of environmental attitude on both low-carbon behaviour and green perceived value, particularly in the mediation pathway via green perceived value.

These results inform curriculum, pedagogy and evaluation design for more rigorous and effective environmental education. Integrating education with practice can foster a culture of low-carbon living, promote environmental responsibility and ultimately help mitigate climate change and protect global environmental balance.

Theoretical contribution

This study contributes a novel behavioural perspective, examining how environmental education influences low-carbon behaviour among college students. Low-carbon behaviour is pivotal for reducing emissions and meeting China's "dual-carbon" goals, shaped by both individual values and contextual factors. Going beyond the conventional "attitude–behaviour" framework, this study builds a chain-mediated model with environmental attitudes and green perceived value as mediators, and prosocial behaviour as a moderator. Findings show that environmental education directly enhances low-carbon behaviour and also works through chained mediation involving environmental attitudes and green perceived value. This aligns with prior research and underscores education's role as a key behavioural driver. Prosocial behaviour significantly moderates these effects, amplifying their influence and enriching existing literature.

The main theoretical contribution is a validated multidimensional framework explaining how environmental education shapes low-carbon behaviour. Based on "Attitude–Context–Behaviour" theory, it integrates environmental attitudes, green perceived value and prosocial behaviour in a chain-mediated pathway with moderation. This approach moves beyond isolated mediation or

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moderation models to explain multi-tiered behavioural mechanisms. Environmental education not only drives low-carbon behaviour directly but also reinforces it indirectly through progressive mediation. Validating these pathways offers a new lens on how education drives behaviour through psychological and social value changes.

This study is the first to incorporate prosocial behaviour as a moderator in environmental education research, expanding theoretical boundaries. Prosocial behaviour strengthens the link between environmental attitudes and both low-carbon behaviour and green perceived value, highlighting the role of social interactions and group norms. In high-prosocial contexts, environmental attitudes are more readily internalised as green values, increasing low-carbon actions. Identifying this moderating mechanism bridges social psychology and environmental behaviour studies and opens avenues for exploring additional social moderators.

Practice implications

This study highlights the essential role of environmental education in fostering college students' low-carbon behaviour, especially via the mediating influences of environmental attitudes and green perceived value, as well as the moderating role of prosocial behaviour. These findings offer actionable insights for policymakers, educational institutions, corporations and community leaders:

(1) Strengthening the systematic and practical integration of environmental education

Educational systems should integrate environmental education into core curricula, prioritising not only the dissemination of environmental knowledge but also the cultivation of students' environmental awareness, values and emotional engagement. Diversified pedagogical approaches, such as project-based learning, field studies and sustainability initiatives, ought to be adopted to enhance experiential engagement and internalise green principles.

(2) Elevating public perception of green value

Multichannel campaigns (e.g., media outreach, public seminars and community programmes) should disseminate environmental knowledge and demonstrate the tangible benefits of low-carbon lifestyles, thus enhancing public recognition of green living as both socially desirable and personally beneficial.

(3) Incentivising prosocial behaviour through positive reinforcement

Governments and corporations should implement incentive mechanisms, such as carbon credit systems and green consumption rebates, to motivate individuals and communities to adopt low-carbon behaviours. Highlighting role models and sharing success stories can strengthen societal recognition of low-carbon actions and encourage emulative behaviours, thereby cultivating a supportive cultural environment.

(4) Fostering cross-sector collaboration for systemic change

Cross-sector collaborations among governments, businesses, educational institutions and NGOs must be established to co-create a socio-environmental system that institutionalises low-carbon behaviour. For instance, businesses can adopt green supply chain practices, schools can integrate environmental education, communities can promote low-carbon lifestyles and governments can provide regulatory and financial scaffolding, collectively forming a synergistic force for sustainable societal transformation.

In summary, by operationalising these findings, universities can cultivate interdisciplinary talent equipped with environmental literacy and practical skills, while also serving as societal exemplars to promote environmental civilisation. Collectively, these strategies empower stakeholders to accelerate the mainstreaming of low-carbon practices, driving sustainable development and coordinated climate action.

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Limitations and future research

This study has several limitations. First, the reliance on cross-sectional data does not capture temporal dynamics in how environmental education influences low-carbon behaviour over time. Future research should employ dynamic longitudinal designs to rigorously validate the causal relationship between environmental education and low-carbon behaviour. Second, the assumption of a linear relationship between environmental education and low-carbon behaviour, combined with limited sample diversity and size, restricts the generalizability of the findings. Future studies should utilise large-scale cross-level samples to explore potential non-linear mechanisms and enhance external validity. Third, while the moderated mediation model identifies key pathways, unmeasured variables may further shape these relationships. Subsequent research should integrate complementary antecedents and apply configuration analysis to examine how variable combinations differentially drive low-carbon outcomes, thus advancing context-specific theoretical frameworks.

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Author Biographies

Maobao Yang is an Associate Professor at the Management School of Jiujiang University. He also serves as the director of the Cross-border E-commerce Teaching and Research Department of Jiujiang University. His research interests include Environmental Education, Green Marketing and E-commerce Marketing.

Gaofei Ren is a Professor, Tutor for Master at the Management School of Jiujiang University. He enjoys interdisciplinarity research and teaching focusing on the Low-carbon Behaviour and Environmental Regulation for the green and low-carbon development of society.

Lei Guo is an Associate Professor at the Management School of Jiujiang University. He has more than 20 years of teaching experience. His primary research interests cover Environmental Policies and Green Development.

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