

Article

How School Environmental Education Affects University Students' Green and Low-Carbon Behavior?

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Abstract

Environmental education is crucial for promoting individual green and low-carbon lifestyles and constructing sustainable societies. However, it is still unclear about the internal mechanism and external boundary conditions of how school environmental education affects university students' green and low-carbon behavior. From an educational perspective, this paper develops an integrated model of students' green and low-carbon behavior grounded in social cognitive theory to explore the impacts of two dimensions of school environmental education: teacher-led environmental education and campus low-carbon climate. Structural equation modeling with bootstrapping estimation and moderating effects was performed using a representative sample of 763 respondents from Sichuan Province, China. The results show that teacher-led environmental education not only directly influences students' green and low-carbon behavior, but also indirectly affects it through mediating effects and serial mediating effects of low-carbon knowledge and attitude. The total indirect mediating effect of teacher-led environmental education is larger than its direct effect. The mediating effect of low-carbon knowledge is 3.3 times that of attitude. Thus, the primary target of teacher-led environmental education is promoting low-carbon knowledge. Moreover, campus low-carbon climate significantly moderates students' intention–behavior relationship. The higher the low-carbon climate students perceive, the more likely their behavioral intentions are to translate into actual behaviors.

Keywords: green and low-carbon behavior; teacher-led environmental education; campus low-carbon climate; social cognitive theory



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1. Introduction

As the global response to climate change has advanced, a universal consensus has gradually been reached: daily human activities are a significant source of carbon emissions [1,2]. Because of this, the promotion of green and low-carbon lifestyles at the individual level has become a popular topic in both practical and theoretical research [3,4]. The United Nations released its 2030 Sustainable Development Goals, with explicit commitments to climate action, responsible consumption and production worldwide [5]. China launched the Action Plan for Energy Conservation and Carbon Reduction (2024–2025), which promotes simple green and low-carbon lifestyles nationwide. When considering individual participation in this program, a very important group has possibly been overlooked: young adults, especially university students. These students are key stakeholders in green and

low-carbon lifestyles and the response to climate change [6]. On one hand, university students constitute a large population group. And its average annual growth rate reached 8.99% over the past five years in China. On the other hand, the young university student cohort is receptive to emerging concepts and prone to adopting ecological values. They currently participate in energy-intensive daily lifestyles and will emerge as the backbone of future society [7]. Thus, to some extent, university students' green and low-carbon behavior is receiving increasing attention. University students' green and low-carbon behavior (GLB) indicates students' specific daily consumption behaviors contributing to carbon reduction, including household energy consumption, personal low-carbon transportation and green merchandise consumption [8,9].

Recent studies have shed light on students' low-carbon behavior and its influencing factors, such as psychological factors [10,11], demographic variables [9,12], situational factors [3,8,13], as well as monetary income and financial assets [4]. However, these studies have largely focused on general individual environmental behavior and have mostly relied on classic pro-environmental behavior theory models, such as the theory of planned behavior, value-belief-norm theory, the norm-activated model, and attitude-behavior-condition theory [12,13]. Meanwhile, in the context of environmental protection, education serves as a foundational driver for cultivating individual pro-environmental behavior [14–16]. Some scholars have addressed the role of environmental education in students' low-carbon behavior. First, scholars generally noted that students with higher levels of environmental education typically demonstrate a better understanding of the value inherent in a green and low-carbon lifestyle, and are consequently more inclined to adopt environmental practices in their lives, such as adopting public transportation (e.g., buses and trains) instead of private cars or air travel [6]. Kroesen et al. [17] also indicated that, in the context of occasional high-carbon activities, more comprehensive education may be needed to prevent the unintended side effects of environmental education, such as the moral licensing effect. They usually indicated that school environmental education positively affects students' low-carbon behavior [2]. Whereas recent studies still have indicated that the effect of environmental education is sometimes inadequate [18]. Suárez-Perales et al. [19] confirmed that environmental education has only a slight influence on environmental behavior. More sophisticated underlying influence mechanisms may exist. While few existing studies have yet explored the in-depth internal mechanism between school environmental education and students' green and low-carbon behavior [20].

Second, for university students, campus low-carbon climate is an important constituent of school environmental education. In previous pro-environmental studies, scholars have discussed the effect of climate. Zhang et al. [21] estimated that green climate can directly and indirectly affect individuals' public sphere pro-environmental behavior. Norton et al. [22] noted that a green psychological climate enhances the link between employees' green intention and green behavior. However, limited studies have examined the effect of campus low-carbon climate on students' low-carbon behavior. In practice, administrative authorities have begun to cultivate a campus low-carbon climate. For instance, China's Ministry of Education released the Implementation Plan for National Education System Construction of Green and Low-Carbon Development in order to strengthen green and low-carbon education across schools. However, despite gaining a certain degree of environmental knowledge through school education, students' actual engagement in green and low-carbon behaviors remains unsatisfactory. As shown in many previous studies, there may be an intention-behavior or attitude-behavior gap, which can be solved through campus low-carbon climate [13,23]. Similarly, few existing studies have yet explored the specific impact of campus low-carbon climate on students' green and low-carbon behavior [24].

In summary, the causal relationship between school environmental education and students' green and low-carbon behavior remains unclear and requires in-depth study. Given the above-mentioned gaps, this research tries to construct an integrated students' green and low-carbon behavior model grounded in social cognitive theory to investigate the underlying internal mechanisms and external boundary conditions of how school environmental education affects university students' green and low-carbon behavior. Specifically, it makes two key contributions to current literature. First, by dividing school environmental education into two dimensions: teacher-led environmental education and campus low-carbon climate, we clarify the specific connotations of the term. In practice, school environmental education encompasses not only teacher-led environmental education but also the campus low-carbon atmosphere. They may exert different impacts on students' green and low-carbon behavior, respectively. Second, this study is the first to combine school environmental education with social cognitive theory to establish an integrated green and low-carbon model for students, with two school environmental education dimensions as external factors and low-carbon knowledge and attitude as internal factors. It can be used to comprehensively assess the possible internal mechanisms between teacher-led environmental education and intention via the mediating effects of low-carbon knowledge and attitude, as well as its external boundary condition through the moderating effect of campus low-carbon climate on students' green and low-carbon intention and behavior [5]. Our study comprehensively explores the effects of formal school environmental education on students' low-carbon behavior, while compensating for the intention–behavior gap in education practice interventions.

2. Literature Review and Research Hypotheses

2.1. Theoretical Basis

Social cognitive theory (SCT) is a typical behavioral psychology theory that originates from Bandura's early social learning theory [25]. It establishes a core triadic interaction model encompassing individual, environment, and behavior [11,26]. It postulates that there are reciprocal interactions among personal internal factors (P, including cognition, beliefs, and emotions), the external environment (E), and human behavior (B) [25]. Accordingly, individual behavioral change relies on the joint interplay between these three components. In order to achieve this change, it is necessary to strengthen individual cognition and skills, establish supportive policies and physical environments, and reinforce desirable behaviors through successful experiences. SCT focuses on human behavior formation and change, is especially robust in explaining why and how individuals adjust their behaviors to address environmental challenges, and is widely applied in related individual pro-environmental behavior studies. For instance, green purchasing [11,27], sustainable education [28], and employee digital voice behavior [29].

In the present study, we construct a theoretical framework based on this SCT, examining how school environmental education, by influencing students' internal cognitive systems, can cultivate students' green and low-carbon behavior. Specifically, as an external environmental factor (E), school environmental education is manifested as two dimensions: teacher-led environmental education and campus low-carbon climate. The former dimension, which is mainly conducted by teachers, can directly shape students' environmental cognition, skills, and self-efficacy through regular curricula, practical activities and value guidance. The latter dimension, which is established by schools in response to the requirements of relevant national administrative departments, can potentially reinforce students' green and low-carbon behavior through campus management regulations, low-carbon facility configuration, and low-carbon activities across the campus. From an environmental education perspective, individual internal cognitive factors (P) are defined as students'

low-carbon knowledge and attitude. Based on the instruction of teachers in their curricula, students can acquire more environmental knowledge and behavioral skills, including knowledge of global climate consequences and carbon reduction methods, by imitating others, thereby deepening their scientific comprehension of the global warming crisis. This form of education also helps to cultivate students' positive attitude toward a green and low-carbon lifestyle. Human behavior (B) focuses on both students' intention and actual behavior in participating in green and low-carbon practices during their daily activities. For example, taking public transportation, energy saving activity and low-carbon purchases, etc. [30]. Our theoretical framework, which includes a total of six variables, is illustrated in Figure 1.

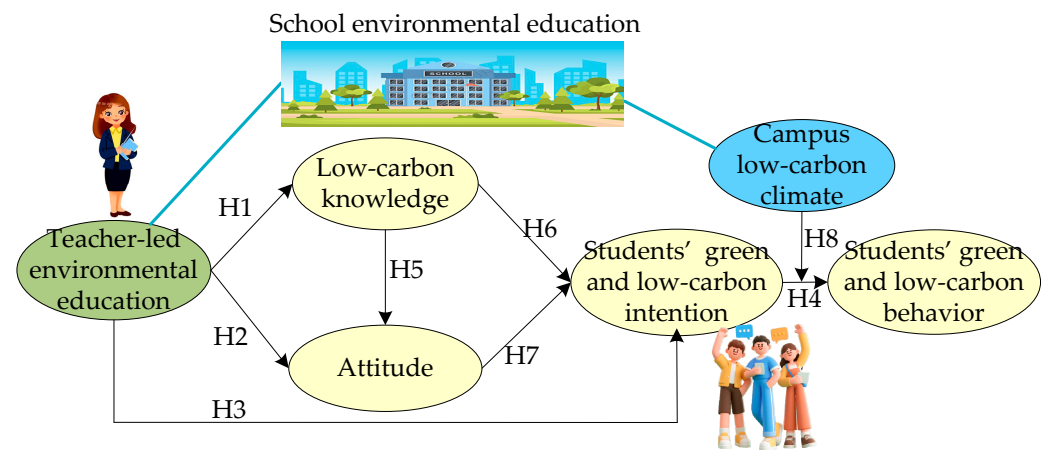


Figure 1. The theoretical framework.

2.2. Variables and Corresponding Hypotheses

2.2.1. Teacher-Led Environmental Education

In the current study, students' green and low-carbon intention (GINT) means the degree to which they are willing to participate in specific green and low-carbon behaviors [31,32]. Teacher-led environmental education (TEDU) refers to the multidisciplinary actions performed by teachers, which aim to equip students with environmental knowledge, ecological skills, and an attitude essential for environmental protection through formal curriculum design, teaching practices, and campus-based experiential learning [20]. Environmental education was formally proposed in the 1960s and has since evolved into a major component of school education [16]. For university students, teacher-led environmental education serves as the main direct channel for acquiring environmental knowledge. According to SCT, such external factors can effectively influence students' cognition and behavior [25,26]. In general, since students possess a highly developed ability for observational learning, teacher-led environmental education can enable them to construct their own cognitive frameworks and behavioral skills by imitating their teachers [15]. Aligning with SCT and education theory, many previous studies have validated the relationships between environmental education, environmental knowledge, and attitude [33]. However, Uddin [18] did not find a robust effect of environmental education on sustainable development in Bangladesh. In current research, China's Ministry of Education has issued official documents to achieve carbon reduction across primary, secondary, and college schools. With the support of nationwide curriculum reform, environmental education on global warming and green and low-carbon concepts has been widely incorporated into interdisciplinary teaching classes. Through the process of ideological and political education, teachers can effectively deliver related low-carbon information to students during courses. Accordingly, in this study, we postulate that teacher-led environmental education

can enhance students' environmental knowledge and foster a positive attitude toward green and low-carbon behavior engagement. Thus, it is reasonable to hypothesize:

H1. *Teacher-led environmental education significantly affects students' low-carbon knowledge.*

H2. *Teacher-led environmental education significantly affects students' attitude toward green and low-carbon behavior.*

Likewise, consistent with SCT, teacher-led environmental education can directly motivate students to make the decision to adopt green and low-carbon behaviors [5,8]. In their classes, teachers may persuade students to turn off lights and computers or purchase low-carbon products. Ao et al. [33] confirmed that environmental publicity and education exert a strong influence on the waste classification behavior of individuals. In the current study, the behavior process is described using two dimensions: students' green and low-carbon intention and actual behavior. As posited by the theory of planned behavior (TPB), students exhibiting a stronger intention to pursue a green and low-carbon lifestyle demonstrate a higher propensity for actual behavior engagement [10,32]. Similar conclusions have also been confirmed in prior studies. Therefore, we propose the following:

H3. *Teacher-led environmental education significantly affects students' green and low-carbon intention.*

H4. *Students' green and low-carbon intention positively affects their actual green and low-carbon behavior.*

2.2.2. Low-Carbon Knowledge and Attitude

In line with SCT, low-carbon knowledge and attitude are two core internal cognitive factors [3]. Low-carbon knowledge (LCK) refers to students' general awareness of green and low-carbon concepts, including climate warming consequences, mitigation strategies and the impact of human behavior on carbon reduction [34,35]. Attitude toward green and low-carbon behavior (ATT) indicates students' negative or positive evaluations of these behaviors [31,36]. Meanwhile, environmental knowledge and attitude are two core elements of the responsible environmental behavior model (REBM), another classic theoretical framework for studying environmental behavior [37]. REBM posits that environmental knowledge and attitude can enhance an individual's willingness to be environmentally responsible. Multiple previous studies have emphasized their efficacy in predicting pro-environmental behaviors [20,33,35]. It is widely recognized that enriching an individual's low-carbon knowledge and positively enhancing their evaluation may facilitate their pro-environmental behaviors [38,39].

In addition, researchers have discussed the correlation between environmental knowledge and attitude [13]. For example, Mago et al. [34] demonstrated that environmental knowledge greatly influences students' attitude toward participating in environmental behavior. The university student cohort is at a critical age characterized by prolonged learning, through which students acquire low-carbon knowledge and form rational pro-environmental attitudes. The accumulation of such low-carbon knowledge, in turn, greatly fosters students' positive attitude toward these behaviors. Thus, from a low-carbon school education perspective, students' low-carbon knowledge can undoubtedly enhance their appraisal of green and low-carbon concepts. We believe that low-carbon knowledge and attitude jointly exert salient influences on students' intention to adopt green and low-carbon behavior. The following hypotheses are presented:

H5. *Low-carbon knowledge positively affects students' attitude.*

H6. *Low-carbon knowledge positively affects students' green and low-carbon intention.*

H7. *Attitude positively affects students' green and low-carbon intention.*

2.2.3. Campus Low-Carbon Climate

Climate is often used to describe the dynamic relationship between environmental stimuli and human behavior, which aligns with SCT. Initially applied to organizational research for examining innovation and ethical climate, this construct has gradually been extended to social studies [21]. In the current paper, campus low-carbon climate (CLC) refers to the collective environmental awareness, normative expectations, and institutional constructions that guide students to respond to carbon reduction via the daily operations and publicity campaigns of schools [24]. According to SCT, in addition to their direct influence on behavioral intention, environmental factors may also indirectly shape behavior by bridging the intention–behavior gap [25]. Prior studies have pointed out that a green climate exerts impacts on individual pro-environmental behavior and requires greater attention [4,22]. Khan and Terason [24] estimated the positive moderating role of green culture on university staff environmental behavior in Thailand. Similarly, this school organization functions as a miniature society, carrying out diversified green and low-carbon initiatives that cover educational instruction, energy-saving infrastructure configuration, campus cultural construction, and institutional management. Beyond teacher-led environmental education, university students still have to comply with school regulations and advocacy, such as green transportation and electricity-saving, etc. [2]. They are deeply embedded in the campus low-carbon climate of behavioral demonstrations, discourse systems, and collective identity. When exposed to a strong low-carbon climate, students' green and low-carbon intentions are more likely to transform into actual action. Thus, we put forward the following hypothesis:

H8. *Campus low-carbon climate positively moderates the correlation between students' green and low-carbon intention and actual behavior.*

3. Materials and Methods

3.1. Sample and Data Collection

The study aims to investigate the effects of two school environmental education dimensions on students' green and low-carbon behavior. To ensure balanced disciplinary representation within the sample, participants were recruited from a university in Sichuan Province, China. This university offers a comprehensive and evenly distributed range of disciplines, as well as a well-established campus low-carbon climate and systematic low-carbon curriculum arrangements. First, this university is a comprehensive public university that enrolls undergraduates from all provinces across China. Its student body covers diverse family economic backgrounds, urban–rural household registration types, and disciplines (science, engineering, management, arts, medicine, law, etc.). The demographic structure of its students aligns closely with the overall characteristics of general Chinese undergraduates. Second, as core regions of the national Chengdu–Chongqing Economic Circle strategy, Sichuan and Chongqing are in the process of jointly constructing a regional green and low-carbon economic system. Aligned with national policies, Sichuan issued the Sichuan Carbon Peaking Implementation Plan in 2022, which incorporated green and low-carbon concepts into the formal education system. This policy supports universities that set up disciplines and majors related to carbon neutrality and carbon peaking, thereby promoting a widespread inclusion of green and low-carbon education on campuses and in curricula. Third, the selected university was awarded the titles of

National Civilized Campus, National Model Public Institution for Energy Conservation, and National Model Water-Saving University. It ranks among the very few undergraduate universities in Sichuan Province to have obtained all three national-level accolades covering civilization, energy, and water conservation. More importantly, this university offers related bachelor majors, such as Environmental Science and Engineering, Energy Storage Science and Engineering, and Environmental Economics and Management, which cover both engineering and social science. Additionally, the university also provides university-wide general education courses for students, including Introduction to Ecological Civilization and Environmental Ethics. Because of these initiatives, students at this university are familiar with green and low-carbon concepts.

Data were collected via stratified sampling following rigorous standardized procedures at the target university. First of all, all 16 constituent colleges, representing the diverse disciplinary fields of the university, were incorporated into the sampling frame. Next, for each college, one to three classes were randomly selected based on their student enrollment size. Then, to ensure survey quality, we contacted the teachers or counselors of these classes in advance, as they are responsible for managing the students' daily studies. After thorough communication about our research aims and study content, we asked them to distribute the survey link (via QR code) to the targeted students via the online platform DingTalk 7.8.5. Finally, prior to filling out the questionnaire, all participants were clearly informed of the survey's anonymity and information confidentiality. They were informed that their responses would only be used for academic research, and that there were no standard correct answers. Students answered the survey independently at their own pace, without teachers on site. The formal survey was conducted over one month commencing on 15 November 2025. A total of 1200 questionnaires were initially dispatched to students, out of which 1038 were withdrawn. Responses with an unreasonably short completion time or identical answers across most items were excluded as invalid. Finally, 763 valid responses were acquired, indicating a valid response rate of 64%. Among these 763 respondents, 410 were female and 353 were male. The education Levels of respondents were relatively balanced: 245 and 205 were freshmen and sophomores, while 203 and 110 were juniors and seniors. In terms of monthly household income, most respondents had an income below 4000 CNY ($n = 218$, 28.6%) or between 4001 and 8000 CNY ($n = 325$, 42.6%). Most of the respondents were from the humanities and social sciences ($n = 321$), while engineering and sciences accounted for 170 and 101 respondents, respectively. Overall, our data indicate that we obtained a representative and acceptable sample for this study.

3.2. Measures

Based on the theoretical model, a questionnaire with three main sections was designed. The first section introduced the research background, including an introduction to the specific green and low-carbon behaviors of students, the research purpose and a confidentiality statement. The second section collected demographic information, including gender, education level, household income and discipline. The third part emphasized measuring the core latent constructs, covering students' green and low-carbon behavior and its five influencing factors. The measurement items of the six latent constructs were originally created from previous research and were suitably modified based on the current Chinese school environmental education background. Teacher-led environmental education was modified from the research of Shin and van Riper [14] and Ao et al. [33]. The five items for campus low-carbon climate were mainly adapted from Zhang et al. [21]. Referring to the work of Akhtar et al. [35], five statements of low-carbon knowledge were developed. Attitude, students' green and low-carbon intention and actual behavior were all borrowed from Gifford et al. [10]. Appendix A provides a detailed summary of the variables and

corresponding measurement items. Moreover, students used a five-point Likert scale, ranging from 1 to 5, to describe their responses, denoting the level of their agreement or evaluations. For the measurement of students' green and low-carbon behavior, a frequency scale was used (1 = never to 5 = very frequently). For all other constructs, a standard Likert agreement scale was employed (1 = strongly disagree to 5 = strongly agree).

4. Results

4.1. Measurement Model Analysis

Prior to structural equation modeling analysis, confirmatory factor analysis (CFA) should be performed to evaluate the reliability and validity. For reliability of the latent constructs, it was examined via both Cronbach's α and composite reliability (CR). The CR values for the six latent constructs ranged from 0.810 to 0.903, and Cronbach's α coefficients varied between 0.790 and 0.893, both exceeding the recommended threshold of 0.70, confirming the scale's internal consistency [40]. Regarding construct validity, it is typically established by evaluating its convergent and discriminant validity. The average variance extracted (AVE) values for the six constructs were above the critical standard of 0.50, ranging from 0.516 to 0.700. With the exception of GLB2 (0.669), the loading values of all other measurement items were above 0.70, collectively demonstrating an adequate convergent validity [13]. Meanwhile, discriminant validity was satisfactory, as the square root of the AVE for each construct exceeded its inter-construct correlations [13]. The comprehensive results of the reliability and validity tests are provided in Tables 1 and 2. Overall, the results demonstrated satisfactory reliability and validity.

Table 1. Results of confirmatory factor analysis.

Constructs	Items	Loadings	Cronbach's α	CR	AVE
TEDU	TEDU1	0.803	0.884	0.883	0.654
	TEDU2	0.812			
	TEDU3	0.789			
	TEDU4	0.831			
LCK	LCK1	0.812	0.870	0.857	0.601
	LCK2	0.756			
	LCK3	0.767			
	LCK4	0.764			
ATT	ATT1	0.813	0.860	0.858	0.602
	ATT2	0.777			
	ATT3	0.744			
	ATT4	0.768			
GINT	GINT1	0.797	0.893	0.891	0.672
	GINT2	0.862			
	GINT3	0.769			
	GINT4	0.848			
CLC	CLC1	0.846	0.886	0.903	0.700
	CLC2	0.844			
	CLC3	0.815			
	CLC4	0.841			
GLB	GLB1	0.765	0.790	0.810	0.516
	GLB2	0.669			
	GLB3	0.725			
	GLB4	0.711			

Table 2. Results of correlation and discriminant validity.

Construct	GINT	CLC	ATT	LCK	TEDU	GLB
GINT	0.919					
CLC	0.223	0.554				
ATT	0.395	0.199	0.681			
LCK	0.393	0.208	0.409	0.628		
TEDU	0.287	0.203	0.245	0.269	0.529	
GLB	0.282	0.163	0.279	0.265	0.230	0.371
Mean	3.59	3.85	3.78	3.74	3.62	3.64
SD	0.82	0.76	0.77	0.77	0.81	0.76

Note: SD: standard deviation. $\sqrt{\text{AVE}}$ values of each construct are located in the diagonal row; and the others below diagonal row are the correlations between constructs.

4.2. Structural Model Analysis

Structural equation modeling (SEM) with AMOS 29.0 software was used to examine the relationships among the six variables. The overall model fit of this structural model was good ($\chi^2/\text{df} = 3.993$, RMSEA = 0.063, CFI = 0.943, IFI = 0.943) [41]. The structural model analysis results are presented in Table 3. It showed that all direct effect hypotheses were supported. That is, all the direct path coefficients were in the expected direction and were statistically significant. Table 3 indicated that teacher-led environmental education significantly and positively affects students' low-carbon knowledge ($\beta_1 = 0.466$, $p < 0.001$), attitude ($\beta_2 = 0.149$, $p < 0.001$), and green and low-carbon intention ($\beta_3 = 0.192$, $p < 0.001$). Thus, consistent with education theory, H1, H2 and H3 were supported. In addition, students' green and low-carbon intention ($\beta_4 = 0.516$, $p < 0.001$) exerted a significant positive effect on actual behavior, thereby supporting H4. Such results revealed that teacher-led environmental education directly affects students' low-carbon knowledge, attitude, green and low-carbon intention and actual behavior. And the enhancement of teacher-led environmental education would improve students' relevant knowledge, positive attitude and intention, which in turn would induce actual behaviors. Furthermore, consistent with SCT, low-carbon knowledge ($\beta_6 = 0.279$, $p < 0.001$) and attitude ($\beta_7 = 0.266$, $p < 0.001$) positively affected students' green and low-carbon intention, separately. In addition, students' low-carbon knowledge ($\beta_5 = 0.555$, $p < 0.001$) simultaneously affected their attitude. Therefore, it provided support for the three hypotheses H5, H6 and H7. These results clearly showed that students' green and low-carbon intention can also be directly influenced by their knowledge and attitude. Students equipped with abundant low-carbon knowledge tend to hold more favorable attitudes, which further predicted stronger intention of engaging in green and low-carbon behaviors.

Table 3. Structural model analysis results and hypothesis testing (N = 763).

Path	Standardized Coefficient	S.E.	C.R./t	p
H1: TEDU $\rightarrow$ LCK	0.466	0.043	11.540	***
H2: TEDU $\rightarrow$ ATT	0.149	0.039	3.717	***
H3: TEDU $\rightarrow$ GINT	0.192	0.037	4.781	***
H4: GINT $\rightarrow$ GLB	0.516	0.043	10.677	***
H5: LCK $\rightarrow$ ATT	0.555	0.041	12.552	***
H6: LCK $\rightarrow$ GINT	0.279	0.044	5.543	***
H7: ATT $\rightarrow$ GINT	0.266	0.046	5.508	***
H8: GINT $\times$ CLC	0.090	0.037	2.725	**

Note: ** ($p < 0.01$) and *** ($p < 0.001$).

4.3. Mediating Effects of Environmental Knowledge and Attitude

Table 3 showed that there was a direct effect between teacher-led environmental education and students' green and low-carbon intention, which may demonstrate an indirect effect [1]. The two potential mediating effects and one serial mediating effect are $TEDU \rightarrow LCK \rightarrow GINT$, $TEDU \rightarrow ATT \rightarrow GINT$ and $TEDU \rightarrow LCK \rightarrow ATT \rightarrow GINT$. These mediating effects serve as the internal mechanisms underlying teacher-led environmental education. A bootstrapping sampling method at a 95% confidence interval with 5000 samples was performed to test these mediating effects [42], and the results were presented in Table 4.

Table 4. Bootstrapping results of LCK and ATT.

Effect	Estimate	Percentile 95%	
		Lower	Upper
$TEDU \rightarrow LCK \rightarrow GINT$	0.130	0.077	0.195
$TEDU \rightarrow ATT \rightarrow GINT$	0.039	0.013	0.072
$TEDU \rightarrow LCK \rightarrow ATT \rightarrow GINT$	0.069	0.038	0.107
Total indirect effect	0.238	0.183	0.298
Direct effect	0.192	0.108	0.275
Total effect	0.431	0.347	0.510
LCK indirect effect proportion	0.302	0.174	0.461
ATT indirect effect proportion	0.092	0.032	0.169
Serial indirect effect proportion	0.160	0.089	0.251
	0.091	0.019	0.172
The difference in indirect effects	0.061	-0.015	0.142
	-0.029	-0.073	0.006

First of all, Table 4 showed that the direct effect of teacher-led environmental education, its total indirect effect, and its total effect were all significant at the 95% confidence interval. The coefficient of the direct effect was 0.192, that of the total indirect effect was 0.238, and that of the total effect was 0.431. To compare the direct and total indirect effects, the coefficient of the total indirect effect was larger than that of the direct effect. These findings indicated that teacher-led environmental education fosters students' green and low-carbon intention primarily by improving their low-carbon knowledge and strengthening their low-carbon attitude. Accordingly, sufficient emphasis should be placed on the indirect pathways of teacher-led environmental education when promoting students' low-carbon behaviors on campus.

Furthermore, regarding the specific indirect effects, Table 4 showed that the two mediating effects of low-carbon knowledge and attitude, as well as the serial mediating effect, were significant at the 95% confidence interval. Specifically, mediation through low-carbon knowledge ($TEDU \rightarrow LCK \rightarrow GINT$) was 0.130, explaining 30.2% of the total effect. The mediating effect of attitude ($TEDU \rightarrow ATT \rightarrow GINT$) was 0.039, representing 9.2% of the total effect. The serial mediating effect of low-carbon knowledge and attitude ($TEDU \rightarrow LCK \rightarrow ATT \rightarrow GINT$) was 0.069, which accounted for 16.0% of the total effect. Moreover, in comparison with the two mediators, the mediating effect of low-carbon knowledge was 3.3 times that of attitude ($0.130/0.039 = 3.3$), with a relatively large effect difference of 0.083 ($0.130 - 0.039 = 0.091$). Table 4 also demonstrated that the effect difference between the two was significant at the 95% confidence interval. These results indicated that teacher-led environmental education operated primarily via low-carbon knowledge to indirectly foster students' green and low-carbon intention.

However, when integrating the serial mediating effect, the total mediating effect of attitude summed to 0.108 ($0.039 + 0.069 = 0.108$). Although this value remained lower

than the mediating effect of low-carbon knowledge, it was markedly enhanced. A possible explanation for this was that the mediation of attitude involved two pathways: $TEDU \rightarrow ATT \rightarrow GINT$ and $TEDU \rightarrow LCK \rightarrow ATT \rightarrow GINT$. In other words, the mediating role of attitude stemmed not only from the direct enhancement of green consumption attitude by teacher-led environmental education, but also from the indirect influence exerted via low-carbon knowledge.

Overall, based on Tables 3 and 4, we found that the most direct and important effect of teacher-led environmental education was in enhancing students' low-carbon knowledge, rather than their attitude. The direct effect of teacher-led environmental education on low-carbon knowledge ($\beta_1 = 0.466$) was much larger than its effects on attitude ($\beta_2 = 0.149$) and intention ($\beta_3 = 0.192$). The mediating effect exerted by low-carbon knowledge was greater than that of attitude, and low-carbon knowledge also played a critical role in the serial mediating effect. Thus, the primary direct target of teacher-led environmental education remained low-carbon knowledge.

4.4. Moderating Effect of Campus Low-Carbon Climate

A widely used product-indicator approach with SPSS 26 was adopted to estimate the moderating effect of campus low-carbon climate and explore its external boundary conditions [3,31]. Table 3 provided the corresponding results. It indicated that this moderating effect of campus low-carbon climate on the relationship between students' green and low-carbon intention and actual behavior was statistically significant ($\beta_8 = 0.090$, $p < 0.01$), thereby confirming H8. Moreover, the inclusion of this moderating effect also significantly increased the explained variance of the model by 0.6% ($\Delta R^2 = 0.6\%$, $p < 0.01$).

To examine the nature of this significant moderation effect, we conducted a simple slope analysis and plotted the interaction pattern, as shown in Figure 2 [43]. Two groups were created by selecting cases where the moderator (CLC) was one standard deviation above and below its mean. The sloped regression lines in Figure 2 showed that the relationships between students' green and low-carbon intention and actual behavior were significant and positive for both campus low-carbon climate levels. Moreover, the predictive power of intention on behavior was significantly stronger under a high campus low-carbon climate ($\beta = 0.417$, $p < 0.001$) compared to a low climate ($\beta = 0.277$, $p < 0.001$). In brief, campus low-carbon climate significantly moderated the relationship between students' low-carbon intention and actual behavior. As the level of the campus low-carbon climate rose, the positive predictive effect of intention on actual behavior became much stronger.

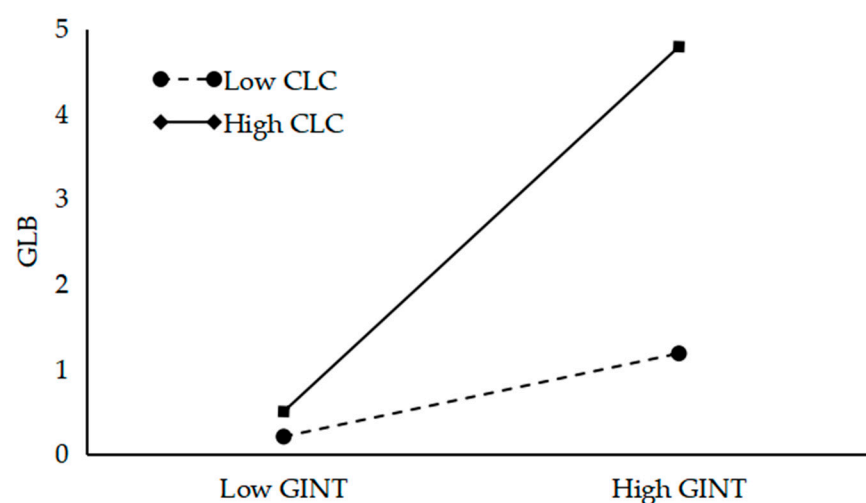


Figure 2. Moderating effect of CLC on the GINT–GLB relationship.

5. Discussion and Implication

5.1. Discussion of Findings

School environmental education plays a pivotal role in fostering students' green and low-carbon behavior. The significant results regarding total effects and moderating effects verify that teacher-led environmental education and campus low-carbon climate are two key dimensions of such education. First, teacher-led environmental education is found to positively affect students' low-carbon knowledge, attitude and green and low-carbon intention. This is consistent with related pro-environmental behavior research originating from education theory [15,33]. The root cause of this effect lies in the vital role of environmental education in shaping pro-environmental behaviors [4,16]. In the research on environmental education, teacher-led low-carbon education is regarded as the core formal environmental education channel for students [6]. Specifically, such education is primarily delivered by teachers via classroom instruction, guidance on curricular practical activities, and thematic lectures and seminars. Through face-to-face instruction, teachers can effectively convey scientific knowledge on the principles of climate change and carbon mitigation strategies, while directly guiding students to develop positive attitudes and behavioral intention. Thus, the current study reaffirms the pivotal role of teacher-led environmental education in shaping students' low-carbon behavior [26]. However, it is surprising that the indirect effect of teacher-led environmental education on intention is larger than its direct effect. That is, teacher-led environmental education mainly promotes students' low-carbon intention through mediators. This provides a good explanation for the opposing findings of Uddin [18], who focuses only on the direct effect of environmental education and believes its role is insufficient. Thus, it indicates that greater attention should be paid to indirect effects, and that the functions of indirect variables should be leveraged to boost students' green and low-carbon behaviors. Furthermore, based on this perspective, Liu et al. [1] suggest expanding the diversity of environmental education channels for students, with social media and family also providing valuable channels for environmental education [44].

Second, low-carbon knowledge and attitude were confirmed to mediate the relationships between teacher-led environmental education and students' green and low-carbon intention. These results align with several prior environmental behavior studies that underscore the vital role of internal mechanisms between environmental education and individual behavior [1,11]. It indicates that, under environmental education interventions, low-carbon knowledge and attitude serve as two key representative internal factors [20,35]. However, it is noteworthy that the mediating effect of low-carbon knowledge (0.130) was greater than that of attitude (0.039), even when integrating the serial mediating effect (0.069). This finding shows that the primary target of teacher-led environmental education remains low-carbon knowledge. It can be mainly attributed to the influencing mechanism of students' internal cognitive factors, according to SCT [20]. That is, through teacher-led environmental education focused on climate change and green and low-carbon concepts, students first internalize low-carbon knowledge on excessive carbon danger, carbon reduction methods, specific individual low-carbon behaviors, etc. Subsequently, students develop increasingly positive attitudes toward carbon reduction. This internalization then continuously fosters their consistent behavioral intentions, which include preferring public transport and purchasing low-carbon products [34]. In addition, to some extent, these findings help to distinguish teacher-led environmental education from low-carbon knowledge. Both fall within the scope of environmental education. However, the former serves as an environmental education channel that provides practical platforms for educational delivery, while the latter represents the core educational content and constitutes the ultimate goal of environmental education [35].

Third, we find that a low-carbon climate significantly moderates the intention–behavior relationship, effectively explaining the common phenomenon of intention–behavior gaps [22]. Such a finding emphasizes the importance of cultivating a supportive low-carbon climate via school environmental education in encouraging students’ actual low-carbon behavior. In existing environmental studies, the intention–behavior gap continues to be a critical barrier restricting the transformation of intention into behavior. When discussing this problem, studies have suggested exploring and constructing external boundary conditions, as this low-carbon climate does [45]. Moreover, it is worth noting that the moderating effect of a higher low-carbon climate level ($\beta = 0.417$) is larger than that of the lower level ($\beta = 0.277$). The government sector has issued official policies, aiming to embed green and low-carbon concepts into formal school education. However, in our study, Table 2 shows that most of the students surveyed have not yet felt a strong low-carbon atmosphere in their daily campus life ($M = 3.85$). This discrepancy mainly arises from one-sided governance measures: universities may only focus on institutional design while neglecting to drive students’ participation via detailed instructional guidance and extensive publicity.

5.2. Theoretical Implications

The research offers two key theoretical contributions to the existing literature on education for sustainable development. First, by integrating educational theory and social cognitive theory, this research constructs an integrated students’ green and low-carbon behavior model. It is particularly useful for exploring how school environmental education shapes students’ low-carbon behavior. This framework emphasizes the significant role of the university student cohort in carbon reduction from a school environmental education perspective [46–48]. Environmental education has become an effective measure, drawing the attention of national administrative departments. Yet, school environmental education is a precisely targeted measure aimed at promoting students’ green and low-carbon behavior [49]. From this point of view, it may further offer novel theoretical insights on the environmental education of residents. Second, within the framework of environmental education, this study defines the specific connotations of school environmental education and individual internal cognitive factors. It lays a foundation for exploring the internal mechanisms and external boundaries of students’ green and low-carbon behavior. Specifically, school environmental education is regarded as an external environmental factor that is manifested through two dimensions: teacher-led environmental education and low-carbon climate. The former exerts a direct influence, while the latter exerts a moderating effect. Individual internal cognitive factors are defined as students’ low-carbon knowledge and attitude, both of which exert mediating effects.

5.3. Policy Implications

This study offers three implications for school and governmental policymakers to encourage students’ low-carbon lifestyles. First, given the positive role of teacher-led environmental education, universities should make substantial efforts to fully guarantee this educational channel [6]. For example, the specialized curriculum setting should be enhanced for students majoring in environmental protection and related fields, as is done at the sampled university. Teachers are expected to deliver professional knowledge of carbon reduction and its underlying principles to these students. This university student group constitutes the core cohort leading future low-carbon lifestyles. Furthermore, general environmental education courses are suggested to be popularized campus-wide. Then, green and low-carbon concepts can even be incorporated into all courses via course-based ideological and political education components. Under such circumstances, teachers can extensively and frequently disseminate low-carbon knowledge to as many students as pos-

sible [26]. Moreover, special reports by experts in the field of environmental protection and practical courses delivered by front-line enterprise workers can be included as supplements to teacher-led environmental education [35]. Their novelty and practicality will arouse students' engagement. In addition, universities may also formulate daily low-carbon behavioral guidelines for teachers, as students tend to imitate their teachers' behaviors [4].

Second, considering the significant and larger mediating effects of low-carbon knowledge and attitude, universities can devote more efforts to these two mediators, especially low-carbon knowledge. Specifically, with regard to low-carbon knowledge, it serves as the core environmental education content. With the continuous advancement of green and low-carbon concepts, the connotation of low-carbon knowledge ought to be further enriched [50]. First of all, except for general environmental knowledge, specific green and low-carbon knowledge is supposed to be emphasized. The former addresses resource shortages, ecological damage, environmental pollution, etc., endowing students with basic environmental protection awareness. The latter focuses on related green and low-carbon concepts, enabling students to fully understand global warming and carbon reduction [45]. Moreover, low-carbon knowledge also needs to be further refined and optimized. This might involve not only the phenomena and adverse impacts of global warming, but also specific individual carbon reduction measures, platforms and practices [13]. The former enables students to gain a basic grasp of climate risks, whereas the latter further equips them with practical capabilities to translate awareness into daily routines, such as adopting low-carbon travel modes. With regard to attitude, it is a rational and internal variable according to TPB and SCT theories [51]. It is essential to clearly convey positive governmental low-carbon viewpoints to students. Subsequently, teachers can guide students to develop a positive attitude toward low-carbon lifestyles through group discussions and interactive sharing.

Third, the findings also reveal that low-carbon climate significantly moderates the intention–behavior relationship. It provides an effective solution for bridging the potential intention–behavior gap in students' low-carbon behavior [21]. To foster a positive low-carbon campus climate, a top-down collaborative mechanism linking governments, universities, and students might be established, as at the sampled university. For governments, after issuing relevant policies, they should continuously supervise universities' policy implementation. Moreover, they may launch more scientific and technological competitions focused on low-carbon for university students. For universities, they are the primary subjects responsible for fostering a campus low-carbon atmosphere. First of all, universities should formulate customized quantitative carbon reduction indicators and operational guidelines tailored to campus conditions. Such as, waste sorting, electricity-saving, and paperless operations, as at the sampled university. They can provide institutional support for promoting a campus low-carbon atmosphere [22]. Furthermore, universities need to vigorously publicize these rules and regulations across campus. For instance, special publicity boards and display panels can be placed in teaching zones, dormitories, and canteens to disseminate information to students. More importantly, universities ought to encourage students to engage in relevant lectures and competitions, such as the China International College Students' Innovation Competition. These can enable students to deepen their low-carbon awareness through participation. Finally, as is done at the sampled university, by leveraging campus digital platforms, actual dormitory power consumption can be regularly provided for students, rendering green behaviors observable.

6. Conclusions and Limitations

Students' green and low-carbon behavior is vital in promoting carbon reduction and establishing a low-carbon lifestyle. The main conclusions of our study are as follows: (1) This

study constructs a students' green and low-carbon behavior model grounded in social cognitive theory and explores the effects of school environmental education from an educational perspective. It is applicable to university student cohorts in Sichuan, China, within the context of campus environmental education. It addresses two school environmental education dimensions (i.e., teacher-led environmental education and campus low-carbon climate) as external environmental factors and two environmental education content variables (i.e., low-carbon knowledge and attitude) as internal cognitive factors. The specific connotations of the two school environmental education dimensions are clarified. They serve as the principal directions for environmental education among students. (2) The SEM results demonstrate that all path coefficients in the full model are significant. Teacher-led environmental education directly and positively influences students' green and low-carbon intention. More importantly, the bootstrapping results show that teacher-led environmental education still indirectly affects students' intention through two mediating effects and a serial mediating effect of low-carbon knowledge and attitude via three distinct pathways (TEDU $\rightarrow$ LCK $\rightarrow$ GINT, TEDU $\rightarrow$ ATT $\rightarrow$ GINT, and TEDU $\rightarrow$ LCK $\rightarrow$ ATT $\rightarrow$ GINT). And the total indirect mediating effect is relatively larger than the direct effect; thus, we should pay sufficient attention to these mediating effects. (3) The mediating effect of low-carbon knowledge is 3.3 times that of attitude. However, when the serial mediating effect is integrated, the total mediating effect of attitude, while substantially increased to 0.108, remains comparatively lower than that of low-carbon knowledge. This indicates that the mediating role of attitude is not only attributed to the direct enhancement of green consumption attitude by teacher-led environmental education, but also to the influential role of low-carbon knowledge on attitude. (4) Campus low-carbon climate significantly moderates the relationship between students' green and low-carbon intention and actual behavior, which may help alleviate the barrier of the intention-behavior gap. And the higher the low-carbon climate perceived by students, the more likely their intentions are to be transformed into actual behavior.

Despite this research offering significant contributions, there are still certain limitations to be addressed. First, the research sheds light on the university student cohort and its corresponding school environment education. School environment education is estimated to be representative of formal education for students. However, other types of informal education channels may also be considered in the future, such as family education and online media campaigns [11,13]. In the present period of rapid development, these channels might also be powerful supplementary educational means. Second, due to the difficulty of data acquisition, this research adopted a cross-sectional survey, which only reflects students' low-carbon behavior at the present moment rather than tracking dynamic changes over time. Subsequent studies may adopt a longitudinal framework to obtain comprehensive insight through comparative analysis based on different time periods. Meanwhile, given the possible self-report bias, we also recommend mixed-method data collection for future research, for example, combining objective campus carbon consumption records and real observed low-carbon behaviors. Third, in order to ensure balanced disciplinary representation within the sample, we restricted recruitment to one university that offered balanced disciplinary coverage. To improve the generalizability of the findings, we recommend multi-university sampling as a vital direction for future investigation.

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Informed Consent Statement: Informed consent was obtained from all participants involved in this study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to confidentiality reasons.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Variables and Corresponding Items.

Variables	Measurement Items
Teacher-led environmental education (TEDU)	1. We have specialized courses related to environmental protection. 2. In some courses, our teachers have talked about topics of green low-carbon lifestyles. 3. During expert lectures, teachers have discussed topics of green low-carbon lifestyles. 4. Through practical course activities, I am exposed to green and low-carbon lifestyles.
low-carbon knowledge (LCK)	1. I know some consequences of global warming on human health, economy and agriculture. 2. Individuals' daily activities are also contributors to global warming. 3. I know what constitutes green and low-carbon lifestyles, like electricity saving. 4. I know where to get related knowledge of green and low-carbon lifestyles.
Attitude (ATT)	1. Individuals' green and low-carbon lifestyle is beneficial for carbon reduction. 2. Individuals' green and low-carbon lifestyle is wisdom for carbon reduction. 3. To achieve carbon reduction, I am willing to spend more money or time on adopting green and low-carbon lifestyle. 4. Adopting green and low-carbon lifestyle goes along with my values.
Campus low-carbon climate (CLC)	1. It propagandizes related national policy: We should promote its formation of green and low-carbon lifestyle. 2. It propagandizes related national policy: We can promote green and low-carbon lifestyle via environmental education. 3. School administration strongly encourages students to adopt a green and low-carbon lifestyle. 4. The school conducts publicity campaigns of green and low-carbon concepts.
Students' green and low-carbon intention (GINT)	1. I like to adopt green and low-carbon lifestyle. 2. I plan to adopt green and low-carbon lifestyle. 3. I try to adopt green and low-carbon lifestyle. 4. I encourage my family and classmates to adopt green and low-carbon lifestyle.
Students' green and low-carbon behavior (GLB)	1. I usually set my air conditioner with suitable temperature (≤ 20 °C in winter, ≥ 26 °C in summer). 2. I always turn off computers or lights when leaving the room. 3. I choose public transportation instead of personal car on long journeys. 4. I prefer to purchase products with low-carbon label.

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