Carbon Neutrality Education Promotes Parents' Pro-environmental Behavior by Children's Information Communication

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Abstract. Climate change is a global problem, and the Chinese government has put forward the goal of carbon neutrality. Carbon neutrality is increasingly embedded in the field of education. However, few researchers have explored its effects. In particular, previous researchers have found that education may have a spillover effect on parents. Therefore, this study examines the effect of carbon-neutral education on parents' pro-environment behaviors and examines the indirect effect of children's information communication. Based on matched and longitudinal family-level data, this study found that carbon neutrality education can effectively increase children's participation in carbon-neutral information communication. In addition, children's information communication significantly increased their parents' pro-environment behaviors. Furthermore, carbon neutrality education can increase parents' pro-environment behaviors by increasing children's information communication. The findings of this study not only demonstrate the effectiveness of carbon neutral education in China, but also provide new insights into how carbon neutrality education promotes parents' pro-environment behaviors from an intergenerational learning perspective.

Keywords: carbon neutrality education · information communication · children · parents · pro-environmental behavior

1 Introduction

Climate change is a global issue that needs to be addressed by all countries in the world, as it is already having a serious impact on human survival, economic and social development. The Intergovernmental Panel on Climate Change report identified carbon neutrality as an important tool to address and mitigate climate change, and that carbon neutrality needs to be achieved by around 2050 to meet the Paris Agreement's 1.5 °C target. To address the challenge of climate change, the Chinese government proposed in September 2020 to achieve carbon neutrality by 2030. As a result, Chinese cities have been implementing carbon neutral education in primary, secondary and tertiary schools. However, to date, very limited research has tested the impact of carbon neutrality education.

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Education is considered to be one of the effective interventions to promote behavior change [1]. For example, previous research has found that primary and middle school students who participated in environmental education programs self-reported higher levels of pro-environmental attitudes and behaviors [2–4]. More importantly, empirical studies have found that environmental education programs not only work on children's pro-environmental behaviors, but also spillover to parental behaviors [5–7]. Thus, researchers suggest that the cause of this phenomenon may be that children influence their parents through intergenerational learning [8]. Researchers believed that intergenerational learning occurs because children communicate environmental information from school education with their parents. However, there is limited research explored the indirect effect of children's information communication between carbon neutrality education and parents' pro-environmental behaviors from the perspective of intergenerational learning.

1.1 Education Influences Children's Information Communication

Applied in the context of climate change, carbon neutrality education aims to provide students with knowledge and skills about low-carbon lifestyles. For example, education increases students' understanding of the relationship between climate change and carbon emissions, as well as their awareness of climate change solutions. Previous studies have shown that climate change education can increase students' understanding of climate science. For example, Swim et al. found that visitors reported more knowledge about climate change after visiting a nature museum with an educational theme on climate change, compared to non-visitors.

Researchers of climate change communication believe that knowledge of climate change is an important factor in breaking the climate silence. Because those who don't have knowledge about climate change, they don't have the ability or fear to express their opinions to avoid being disliked by their peers. In addition, other evidence also shows that climate change education contributes to the increase of self-efficacy and the hope for information dissemination [9, 10], thus increasing climate change communication. However, Chinese cities have only gradually introduced carbon-neutral education in recent years, and the effectiveness of carbon-neutral education has been tested by limited research. Therefore, it is necessary to examine the impact of carbon-neutral education on children's information communication.

1.2 Intergenerational Learning—Children's Information Communication Influences Parents' Pro-environmental Behavior

Previous studies have used socialization theory to explain intergenerational learning between parents and children. Researchers believe there is a transfer of skills, values and behavior patterns between parents and children. Most studies are based on the assumption that parents are social factors for children, and emphasize children's learning outcomes. These learning outcomes are often attributed to information communication. However, according to the bidirectional theory of parent-child relationship, socialization is a bidirectional process. Therefore, previous studies have ignored the intergenerational

learning process between parents and children. In other words, children's information communication helps parents learn from children.

Recent studies have found that information transmission within families helps family members adopt pro-environmental behaviors, such as facilitation between couples [11, 12], parents' promotion of children's pro-environment behaviors [13]. Climate change communication studies agree that climate change discussions within families are an information exchange process that helps to increase family members' scientific knowledge of climate change, increase their climate change beliefs, and change their attitudes towards climate change. Consider that climate change has long been a controversial topic, and that parents' perceptions of climate change are often shaped by mature values and political ideologies. As a result, climate change communication remains inadequate for adults. However, the relationship between children and parents is very close, and the child is a trusted source for parents. As a result, parents as adults are more susceptible to the influence of children. In a word, the process of intergenerational learning is caused by children's information communication. Children's information communication changes parents' pro-environment behavior.

In conclusion, this study aims to explore the effect of carbon neutrality education on parental environmental behavior and examine the interpretation of children's communication on this effect from the perspective of intergenerational learning.

2 Methods

2.1 Data Collection

In November 2021, we investigated children (216 males and 218 females, six children did not report their gender; Mean $_{age} = 12.71$, Standard deviation $_{age} = 0.705$) in middle schools ($n_{School\ a} = 126$, $n_{School\ b} = 33$, $n_{School\ c} = 281$) in Beijing. After nine months, we also investigated their father ($n = 95$) and mother ($n = 345$), and collected a total of 440 matched family-level data. In terms of education level, junior high school education and below accounted for 5.9%, high school/junior college education accounted for 16.1%, bachelor's degree/college education accounted for 63.6%, and graduate education accounted for 14.3%; In terms of monthly income, under 3000 RMB/month accounted for 8.0%, 3000–5999 RMB/month accounted for 16.8%, 6000–9999 RMB/month accounted for 28%, 10000–29999 RMB/month accounted for 34.5%, and 30000 RMB/month and above accounted for 12.7%.

Children were asked to report how carbon neutrality education in carried out in their school, whether they engage in environmental information communication, and their socio-demographic information. In addition, we also asked their parents (one parent in each household) about their pro-environmental behavior. Finally, the matched family-level data were collected and recorded in SPSS26.0. After multiple linear regressions analysis, the statistical results were obtained to test the relationship among carbon neutrality education, children's information communication and parents' pro-environmental behavior.

2.2 Measures

Carbon Neutrality Education
Carbon neutrality education was measured by four questions. "Has your school carried out handwritten newspaper production activities on energy conservation, low-carbon environmental protection, etc."; "Has your school organized donation activities for used items"; "Has your school provided the opportunity to participate in science fairs on carbon neutrality, low carbon environmental protection and other themes?"; "Has your school organized lectures in popularizing knowledge on carbon neutrality, energy conservation, emission reduction, low-carbon environmental protection and so on?". Students were asked to answer "yes", "no" or "don't know". Only items with a "yes" answer were scored as 1 point. The sum of the four questions represented carbon neutrality education. The validity of four questions has been tested by existing research [14].

Children's Information Communication
Children's information communication was measured by three statements, adapted from the study by Tian et al. [15]. "I would proactively discuss low-carbon environmental knowledge with my classmates, teachers, or family."; "while I am at home or on vacation, I will actively browse through various channels (e.g., Weibo, WeChat, Shake, BiliBili, newspapers, books, etc.) for information about low-carbon environmental protection or carbon neutrality."; "When I am at home or on vacation, I will comment on my personal social media about low-carbon knowledge or carbon neutrality topics." Students were asked to reported whether these statements matched their situation with a 11-point scale (0 = very unlikely, 10 = very likely). The Cronbach's alpha coefficient for these four questions was 0.862, indicating that the four questions had a good reliability.

Pro-environmental Behavior
The measure of pro-environmental behavior was adapted from the study by Han et al. [16]. Parents were asked to reported whether four descriptions matched their own situation, including "Every time I leave a room, I turn off the lights", "I save electricity by removing the plug from the plugboard immediately after charging my phone or other electronics while at home", "I can use air conditioners or heaters in an energy-conserving way, for example, the temperature of air conditioners is not set lower than 26 °C in summer, and windows are not opened frequently in winter to reduce unnecessary energy waste" and "I manage to reduce water consumption when taking a shower (e.g. turning off the showerhead when applying the shampoo)". The Cronbach's alpha coefficient for these four questions was 0.778, indicating that the four questions had a good reliability.

3 Results

3.1 The Descriptive Statistics and Correlation of Key Variables

The correlation analysis was performed on carbon neutrality education, children's information communication, and parents' pro-environmental behavior, as shown in Table 1.

Table 1. The descriptive statistics and correlation of key variable

	M(SD)	1	2	3
1. Carbon neutrality education	1.51(1.31)	1		
2. Children's information communication	6.02(3.44)	.227**	1	
3. Parent's pro-environmental behavior	8.92(1.36)	.101**	.134*	1

Note: M presents mean, SD presents standard deviation; * $p < 0.05$, ** $p < 0.01$

From the data analysis results in the table, it can be concluded that carbon neutrality education, children's information communication, and parents' pro-environmental behavior are positively correlated.

3.2 The Effect of Carbon Neutrality Education on Parents' Pro-environmental Behavior by the Mediation of Children's Information Communication

First, we examine the influence of carbon neutrality education on children's information communication by multiple linear regressions analysis, and the results are shown in Table 2.

From the data analysis results in the table, it can be concluded that carbon neutrality education has a positive effect on children's information communication (standardized $\beta = 0.235$, $SE = 0.111$, $p < 0.001$), even after controlling for gender, age and school. The result suggest that students engage in more carbon neutrality education, they are more likely to engage in information communication.

Next, we test the effect of children's information communication on parents' pro-environmental behavior by multiple linear regressions analysis, and the results are shown in Table 3.

Table 2. The effect of carbon neutrality education on children's information communication

Predictive variable	Model 1		
	Standardized β	SE	t
Gender	−0.016	0.289	−0.348
Age	−0.07	0.226	−1.345
School a	−0.09	0.607	−0.993
School b	0.037	0.586	0.404
Carbon neutrality education	0.235	0.111	4.974***
R^2	0.073		
F	6.608***		
VIF_{max}	3.827		

Note: Outcome variable: Children's information communication; *** $p < 0.001$; Children gender: 0 = female, 1 = male. School a: 0 = no, 1 = yes. School b: 0 = no, 1 = yes.

Table 3. Emotion scores of positive emotion picture

Predictive variable	Model 2		
	Standardized β	SE	t
Children gender	0.045	0.133	0.924
Children age	−0.059	0.104	−1.105
School a	0.104	0.279	1.113
School b	−0.001	0.273	−0.011
Parent gender	0.016	0.163	0.323
Parent age	0.01	0.014	0.187
Income a	−0.143	0.215	−1.905
Income b	−0.055	0.262	−0.755
Income c	0.007	0.336	0.107
Income d	−0.084	0.233	−1.094
Education a	−0.086	0.392	−1.319
Education b	0.01	0.209	0.13
Education c	0.019	0.281	0.25
Carbon neutrality education	0.084	0.053	1.667
Children's information communication	0.114	0.022	2.272**
R^2	0.055		
F	1.574		
VIF_{max}	4.031		

Note: Outcome variable: Parent's pro-environmental behavior; F indicates a marginal significant, $p = 0.07$; ** $p < 0.01$. Parent gender: 0 = female, 1 = male. Income a: 0 = no, 1 = under 3000 RMB/Month. Income b: 0 = no, 1 = 3000–5999 RMB/Month. Income c: 0 = no, 1 = 6000–9999 RMB/Month. Income d: 0 = no, 1 = 10000–29999 RMB/Month. Education a: 0 = no, 1 = junior high school and below. Education b: 0 = no, high school/junior college. Education c: 0 = no, 1 = bachelor's degree/college. Children gender: 0 = female, 1 = male. School a: 0 = no, 1 = yes. School b: 0 = no, 1 = yes.

As shown in the table, children's information communication has a positive and long-term effect on parents' pro-environmental behavior (standardized $\beta = 0.114$, SE $= 0.022$, $p < 0.01$), even after controlling for children's gender, age and school, and parents' gender, age, income and education level. The result indicates that children engage in more information communication, their parents are more likely to engage in pro-environmental behavior.

Finally, based on Baron and Kenny [17], the indirect effect of children's information communication is significant (indirect effect = 0.027), as shown in Fig. 1. The result means that carbon neutrality education has an impact on parents' pro-environmental behavior by the mediation of children's information communication. That is, the more

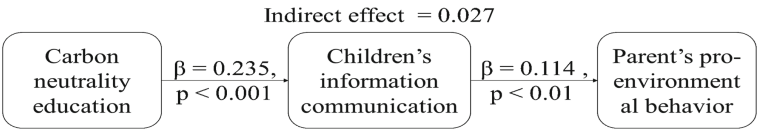

Fig. 1. The indirect effect of children's information communication

carbon neutral education children receive, the more their information communication will increase and thus their parents will be more likely to actively engage in pro-environmental behavior.

4 Discussion

In this study, we collected 440 matched family-level data and examined the effects of carbon neutrality education on parents' pro-environment behaviors through child information communication. First, we found that carbon-neutrality education helps increase children's participation in communication. In other words, children participate in more carbon neutrality education, such as popular science exhibitions, lectures and other activities, and they are more willing to discuss and share knowledge and information about carbon neutrality with classmates, teachers and parents. These findings, consistent with previous research, suggesting that education is an effective means of promoting children's participation in the communication of climate change information. Secondly, we also found that children's participation in information communication helped to increase parents' pro-environment behaviors. We believe that this information comes mainly from schools and that parents are one of the primary communicators for children. Given that there is a process of information exchange between children and parents, information can change parents' understanding of climate change and thus increase their pro-environmental behavior.

4.1 Implications for Carbon Neutrality Education

The findings of this study contribute to practical implications. First, our findings demonstrate that carbon neutrality education in China has worked, as both children's information communication and parents' pro-environment behaviors have increased. These findings suggest that carbon-neutral education is beginning to meet educators' goals. Therefore, we encourage educators to include topics related to climate change, solutions to climate change, and carbon neutrality in the curriculum guide. In addition, we encourage educators to design diversified teaching methods and contents, such as popular science lectures, popular science exhibitions, hand-copied newspapers and other activities. These diverse contents and forms contribute to the increase of students' knowledge and skills.

Finally, our findings also highlight the spillover effects of carbon neutrality education. Even though parents are not the original target of education, they are still influenced by carbon neutrality education. We found that carbon neutrality education helps to increase children's participation in communication, and therefore influences parents. Therefore,

educators can also focus on how to train students to participate in climate change information communication. For example, in the current era of the Internet, children can also acquire knowledge through various online media. Therefore, educators or communicators can use Internet media to develop videos aimed at children about carbon neutrality, which can help children engage in climate change communication and have a broad and far-reaching impact on peers, teachers and parents.

4.2 Limitations and Future Research

The current study still has some limitations. First of all, the current study found for the first time that carbon neutrality education can promote children's information communication, but this study did not further explore how carbon neutrality education in the Chinese context affects children's information communication. Therefore, future studies can further explore the mechanism by which carbon neutrality education affects children's information communication. In addition, the current study did not explore how children's information communication affects parents' pro-environmental behaviors. Therefore, future research can further enrich the relationship between children's information communication and parents' pro-environment behavior. Finally, this study focuses on the effects of carbon neutrality education on parents' pro-environment behaviors, and future research could also focus on how carbon-neutral education affects children's peers and others around them.

5 Conclusions

This study explores the spillover effects of carbon neutrality education on parental environmental behavior, based on matched and longitudinal household-level data. The results show that carbon neutrality education can increase parents' pro-environment behaviors by increasing children's information communication.

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