Cultivating Chinese elementary school children's environmental awareness and protection: Which parents' natural engagement methods are effective?

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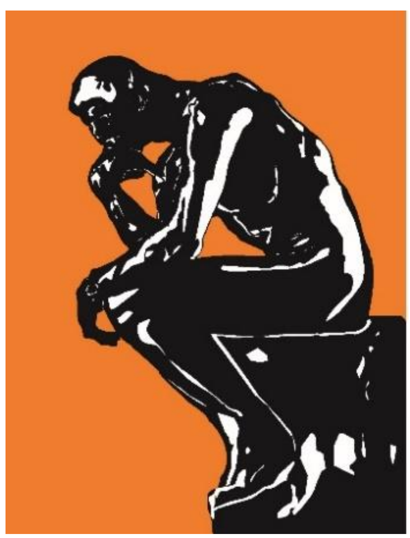

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Abstract

Parental environmental education in early childhood is vital for nurturing environmental awareness and ecological protection. This study investigates how parents' nature engagement methods influence children's environmental awareness and participation in protection activities. Using the Bayesian Mindsponge Framework with data from 516 children and their primary caregivers across 23 elementary summer schools in five urban Chinese cities, the findings reveal varying impacts of parental engagement methods. Raising animals and plants is positively associated with environmental awareness (moderate reliability) and protection activities (high reliability). Visiting museums about endangered and extinct species enhances children's environmental awareness, while learning about insects and their habits improves their participation in protection activities (both high reliability). However, outdoor learning experiences and playing in natural environments (e.g., parks and forests) show ambiguous effects. These results underscore the value of family-centered environmental education, emphasizing the crucial roles of direct nature interactions and providing actionable insights for child-focused environmental policies.

Keywords: parents-child relationship; nature-human nexus; environmental education; pro-environmental behaviors; mindsponge theory

> "At sunset, when the slanting rays of the setting sun heads westward in that same bird village, the sound has taken on a different tone, as though it is also saying goodbye to the passing day.
>
> Kingfisher takes note of such a miraculous occurrence. He marvels at the beauty of nature and the purity of bird vocalization, pitying those who have failed to recognize this."
>
> —In "Conductor"; *Wild Wise Weird* (2024)

1. Introduction

Connecting humans and nature offers a promising avenue for addressing global climate challenges. Recent studies highlight the relationship between connection to nature and environmental-related psychological and behavioral issues. Empirical evidence from the UK reveals that individuals aged 16–24, particularly males, are more likely to feel disconnected from nature, correlating with lower life satisfaction and reduced pro-environmental behavior (Barrable & Booth, 2022). Alternatively, Nguyen, Nguyen, et al. (2023) and Vuong et al. (2024) found that the plant and pet diversity, as well as their aesthetic values in residential dwellings, are associated with the belief in biodiversity loss among urban Vietnamese. However, humanity's relationship with the natural world has grown increasingly decoupled. Enhancing individuals' cognitive and emotional connection with nature through effective environmental education has thus become increasingly crucial (Ives et al., 2018).

Since children will mature into adults with the role of citizens and having responsibility for society and the environment, they need to be equipped with essential knowledge, practical skills, and deep empathy for nature and the environment. Environmental education in early childhood is crucial for developing environmental awareness and fostering ecological protection (Lamanauskas, 2023). The preschool and primary stages of education help children form their personalities by connecting their worldview with nature, environment, and people. This foundational education enhances environmental literacy and develops cognitive, social, and emotional skills (Ardoin & Bowers, 2020). Hence, early environmental education can positively affect children's moral behavior and contribute to sustainable development in the long term (Lamanauskas, 2023). Despite its importance, the effort for sustainable environmental education in schools remains inadequate in many countries, particularly in developing ones (Debrah et al., 2021; Lee, 2023). As the discrepancy between environmental curricula and practical actions still exists, environmental sustainability education should be further incorporated into educational institutions at all levels (preschool, K-12 level, and higher education) in developing countries (Debrah et al., 2021; Lee, 2023).

Beyond educational institutions, the family remains a vital cornerstone of early childhood education. Parents, as children's first teachers, play a critical role in fostering environmental awareness, especially when environmental education at school remains inadequate. Environmental education can be done through many pathways. Parents can support their children by helping them address environmental challenges in daily life (GÃ¼ven, 2017). Alternatively, they serve as role models, demonstrating behaviors for their children to emulate. For instance, children often adopt energy-saving habits observed in their parents, such as turning off lights when leaving a room, turning off taps while brushing teeth, watering plants at night to conserve water, and setting thermostats to moderate temperatures (Zerinou et al., 2020). Such practices guide children toward adopting positive environmental behaviors.

Moreover, parents nowadays often face the challenge of children being drawn to electronic devices and gadgets instead of engaging with nature (Lamanauskas, 2023). To address this, parents can inspire children to spend more time in nature and foster a connection with the natural world (Apdillah et al., 2022). They can also guide their children in the ethical and constructive use of digital platforms to promote pro-environmental awareness and education (Apdillah et al., 2022; Lamanauskas, 2023; Merritt et al., 2022). Integrating technology in educating about nature can enhance environmental learning at home through digital media use (Lin & Ardoin, 2023).

There are growing studies on environmental education in Asian countries, particularly China. Since the 1990s, China has faced the challenge of environmental destruction while exponentially increasing in economic achievements (Iwaniec & Curdt-Christiansen, 2020; Tian & Wang, 2016). Chinese schools have implemented innovative education by incorporating education for sustainable development into the curriculum and getting involved community to enhance environmental awareness (Tian & Wang, 2016). Though Chinese parents, as role models, are more proactively involved in educating their children on environmental literacy, the effectiveness of these interventions is unfavorable. These findings are relatively different from those in Europe and New Zealand because Taoism and Confucianism significantly influence the Chinese culture, particularly the pedagogical methods. For instance, parents desire their children to pursue high academic performance rather than environment-oriented achievement. High socio-economic status parents seem to spend less time tutoring their children (because they are busier) and award their children through toys and electronic devices that are harmful to the environment (Iwaniec & Curdt-Christiansen, 2020). However, few studies have examined how Chinese parents' efforts in connecting children with nature have influenced children's environmental awareness. Moreover, most studies on environmental education in China focus on the perspectives of either parents/caregivers (Iwaniec & Curdt-Christiansen, 2020) or children (Li et al., 2024), which hinders the comprehensive understanding of both parents and children simultaneously and precisely.

Accordingly, we address these research gaps by examining how parents' methods to engage children with nature nourish their environmental awareness and protection in five urban Chinese cities. These methods include raising animals and plants, learning in the wild, learning about insects, going to natural environments, and going to museums. Specifically, we embrace the innovative thinking of mindsponge theory and Bayesian analysis, also named Bayesian Mindsponge Framework (BMF), for answering the following two questions:

- How are Chinese parents' methods of engaging children with nature associated with their environmental awareness?
- How are Chinese parents' methods of engaging children with nature associated with their participation in environmental protection activities?

2. Methodology

2.1 Theoretical foundation

This study is grounded in Mindsponge Theory (MT), a cognitive framework that explains how individuals process, filter, and internalize information, especially within social and cultural contexts (Vuong, 2023). MT uses the metaphor of a sponge to describe how people selectively absorb or reject cultural values based on their personal beliefs and environmental context (Vuong & Napier, 2015). According to MT, values that align with an individual's needs and environment are "absorbed," while those perceived as irrelevant or costly are "discarded." Over time, MT has integrated principles from information theory and quantum mechanics to offer a deeper understanding of human cognition. Drawing from Shannon's information theory, MT conceptualizes information as a spectrum of potential alternatives, with the mind acting as a dynamic filtering system within the "infosphere," the informational environment surrounding us (Shannon, 1948; Vuong & Nguyen, 2024a, 2024b). This entropy-based approach highlights how core values serve as cognitive anchors, guiding decision-making by weighing the costs and benefits of new information (Vuong & Nguyen, 2024c).

MT is based on several cognitive principles, such as self-balancing, cost-benefit analysis, goal alignment, and energy conservation, all of which support personal growth and adaptation

(Vuong, 2023). At its core, MT relies on the concept of mindsets—structured collection of core values that guide the evaluation of incoming and stored information. Information that aligns with these values and is perceived as beneficial is integrated into the cognitive process, reinforcing the mindset in a self-sustaining cycle. In contrast, information that conflicts with these values is typically rejected. MT has been widely applied in various fields, including environmental psychology and conservation psychology, to explore how individuals adopt sustainable behaviors (Alzahrani et al., 2023; Huang et al., 2023; Nguyen et al., 2024).

2.2. Selected variables for the study

This study utilized data from a survey conducted across 23 elementary summer schools in five major cities in China, aimed at assessing children's and parents' pro-environmental behaviors (PEBs) and their parent-child environmental engagements. The survey included 516 children and their 516 primary caregivers, resulting in a total of 516 of observations made up from both the responses of childen and their caregivers. The data was collected through online questionnaires administered to children during class time and to parents at home. The dataset, titled "Parent-Child Pro-Environmental Engagements in China," includes variables such as children's perceptions of their parents' PEBs, children's reported communication with their parents about environmental issues, and the frequency of parent-child pro-environmental activities (Jia & Yu, 2021).

The data is available on Mendeley Data under the DOI: https://doi.org/10.1016/j.jenvp.2021.101575. The sampling method involved a cluster approach, selecting schools based on personal contacts, and participants were from a range of socio-economic backgrounds in urban cities like Beijing, Harbin, Fuzhou, Guangzhou, and Hangzhou. The dataset provides information about how families engage in environmentally friendly behaviors. It can be used to compare different cultures, study changes over time, and explore the relationship between parents and children in environmental psychology.

For the purposes of this research, several key variables were selected to understand the relationship between children's engagement with nature and their environmental awareness and participation in environmental protection. The outcome variables in this study include *EnvironmentalNewsAwareness*, which captures children's awareness to environmental topics through various media sources, and *EnvironmentalProtectionParticipation*, which assesses their involvement in activities such as recycling, clean-up events, and resource conservation. The predictor variables consist of *RaisingAnimalsandPlants*, which represents parents' engagement of children with nature through raising pets or plants. *TeachingintheWild* represents parents' engagement of children with nature through outdoor learning experiences in the wild (e.g. plant recognition and plants' relationship with human life). *LearningaboutInsects* represents parents' engagement of children with nature through learning about insects in various seasons and their habits. Finally, *Goingto NaturalEnvironments* represents parents' engagement of children with nature through walking and playing in natural environments, like parks, forests, and wildlife reserves, while

GoingtoMuseums represents parents' engagement of children with nature through visiting to museums focused on endangered and extinct species as well as their roles in the environment.

Table 1: Variable Description

Variable's Name	Description	Data Type	Measurement
EnvironmentalNewsAwareness	The level of awareness children have regarding environmental issues through exposure to environmental news and media	Numerical	1 = never; 2 = a little bit; 3 = sometimes; 4 = fairly often; 5 = always
EnvironmentalProtectionParticipation	The extent to which children actively participate in behaviors aimed at protecting the environment (e.g., recycling, conservation).	Numerical	1 = never; 2 = a little bit; 3 = sometimes; 4 = fairly often; 5 = always
RaisingAnimalsandPlants	Parents' engagement of children with nature through raising pets or plants	Numerical	1 = never; 2 = a little bit; 3 = sometimes; 4 = fairly often; 5 = always
TeachingintheWild	Parents' engagement of children with nature through outdoor learning experiences in the wild (e.g. plant recognition and plants'	Numerical	1 = never; 2 = a little bit; 3 = sometimes; 4 = fairly often; 5 = always

	relationship with human life)		
LearningaboutInsects	Parents' engagement of children with nature through learning about insects in various seasons and their habits	Numerical	1 = never; 2 = a little bit; 3 = sometimes; 4 = fairly often; 5 = always
GoingtoNaturalEnvironments	Parents' engagement of children with nature through walking and playing in natural environments, like parks, forests, and wildlife reserves	Numerical	1 = never; 2 = a little bit; 3 = sometimes; 4 = fairly often; 5 = always
GoingtoMuseums	Parents' engagement of children with nature through visiting to museums focused on endangered and extinct species as well as their roles in the environment	Numerical	1 = never; 2 = a little bit; 3 = sometimes; 4 = fairly often; 5 = always

In this study, the Bayesian Mindsponge Framework (BMF) is applied to examine how cognitive processes influence individuals' awareness of environmental issues and their subsequent intentions toward pro-environmental behaviors. The framework helps explain how people understand and make sense of information related to protecting the environment, including issues like climate change, pollution, and conservation. A crucial aspect of this process is how individuals perceive the significance of environmental issues and the potential benefits of engaging in behaviors that promote sustainability. When people view environmental engagement as rewarding—either through a sense of personal satisfaction or the broader societal impact—they are more likely to adopt pro-environmental behaviors and strengthen their intentions to protect the environment. This study further explores how specific activities, such as *RaisingAnimalsandPlants, TeachingintheWild, LearningaboutInsects, GoingtoNaturalEnvironments,* and *GoingtoMuseums*, influence individuals' environmental awareness and their willingness to engage in protective actions.

According to the BMF, these activities enable children to access environmental information, which helps shape their cognitive processes and guide how they internalize subsequent environmental issues. For instance, raising animals and plants offers direct, sensory experiences that deepen ecological understanding, while engaging in activities like teaching in nature or learning about insects provides immersive learning experiences that foster emotional and cognitive connections to environmental problems (Beery & Jørgensen, 2018). Learning environmental topics, like natural history, science, and sustainability, can also offer children the necessary knowledge of the natural world. Participation in these activities improves environmental knowledge, nurtures empathy toward nature, and contributes to the development of positive attitudes toward environmental protection. As individuals experience the natural world through these activities, they are more likely to perceive environmental issues as critical and become more inclined to engage with environmental news, thus strengthening their awareness and participation in pro-environmental behaviors. When these engagements are guided and supported by parents, children are more likely to absorb and internalize environmental information into their mindsets, as parents are considered trustworthy information sources (Vuong et al., 2021).

Research suggests that activities involving direct exposure to nature and structured environmental learning experiences can significantly increase individuals' environmental empathy (Salazar et al., 2024). Students or individuals involved in these activities often develop a greater awareness of environmental issues and are more likely to take pro-environmental actions in response to environmental news. Conversely, individuals who lack these experiences or have limited exposure to environmental education may not fully internalize environmental issues or may develop weaker intentions to engage in protective behaviors (Bergman, 2016).

Thus, based on the BMF, we propose that activities that immerse individuals in nature or provide structured learning experiences, especially when parents support their engagement, can enhance their understanding of environmental issues, strengthen their connections to the natural world, form value system regarding nature, improve their likelihood to absorb pro-environmental information, and develop intentions to adopt pro-environmental behaviors. These experiences can serve as key inputs in fostering environmental news awareness, which is a critical step in promoting active participation in environmental protection. Without such activities or educational experiences, individuals may not fully engage with environmental news or adopt the behaviors necessary for sustainability.

2.3. Statistical models

Model 1 was designed to examine the effects of *RaisingAnimalsandPlants, TeachingintheWild, LearningaboutInsects, GoingtoNaturalEnvironment,* and *GoingtoMuseum* on the dependent variable, *EnvironmentalNewsAwareness*. The model is structured as follows:

$$EnvironmentalNewsAwareness \sim normal(\mu, \sigma) \quad (1.1)$$

$$\mu_i = \beta_0 + \beta_1 * RaisingAnimalsandPlants_i + \beta_2 * TeachingintheWild_i + \beta_3 * LearningaboutInsects_i + \beta_4 * GoingtoNaturalEnvironment_i + \beta_5 * GoingtoMuseum_i \quad (1.2)$$

$$\beta \sim normal(M, S) \quad (1.3)$$

In this model, μ_i represents the level of awareness that individual i has regarding environmental issues through exposure to environmental news and media. The coefficients ($\beta_1 - \beta_5$) follow normal distributions with mean *M* and standard deviation *S*. The parameter σ represents unexplained variability.

Model 2 tests the relationship between *RaisingAnimalsandPlants, TeachingintheWild, LearningaboutInsects, GoingtoNaturalEnvironment,* and *GoingtoMuseum* on *EnvironmentalProtectionParticipation.* The model formulation is as follows:

$$EnvironmentalProtectionParticipation \sim normal(\mu, \sigma) \quad (2.1)$$

$$\mu_i = \beta_0 + \beta_1 * RaisingAnimalsandPlants_i + \beta_2 * TeachingintheWild_i + \beta_3 * LearningaboutInsects_i + \beta_4 * GoingtoNaturalEnvironment_i + \beta_5 * GoingtoMuseum_i \quad (2.2)$$

$$\beta \sim normal(M, S) \quad (2.3)$$

In this model, μ_i represents the extent to which individual i actively participates in behaviors aimed at protecting the environment. As in Model 1, the coefficients follow normal distributions with mean *M* and standard deviation *S.*

2.2.4. Analysis and validation

This study employed Bayesian Mindsponge Framework (BMF) analytics, a method selected for its combination of the logical reasoning derived from Mindsponge Theory and the strong inferential capabilities of Bayesian analysis (Nguyen et al., 2022; Vuong et al., 2022). BMF utilizes a Bayesian approach, treating all parameters probabilistically, which enables the creation of streamlined, predictive models (Csilléry et al., 2010; Gill, 2014). Unlike traditional frequentist methods, Bayesian analysis offers credible intervals rather than relying on *p-values*, providing more comprehensive insights (Halsey et al., 2015; Wagenmakers et al., 2018). Moreover, Bayesian methods are well-suited to handle issues like multicollinearity and limited datasets by incorporating informative priors, which help address these challenges more effectively(Adepoju & Ojo, 2018; Jaya et al., 2019; Leamer, 1973).

The selection of priors was crucial in constructing the model (van de Schoot et al., 2021). To reduce subjectivity in this exploratory analysis, uninformative priors were initially applied. Afterward, sensitivity analyses were carried out by re-running the model with informative priors, assuming neutral beliefs, defined by a normal distribution with a mean of 0 and a standard deviation of 0.5. The consistency of results across different types of priors was considered as evidence of the model's robustness. The fit of the model was evaluated using Pareto-smoothed importance sampling leave-one-out (PSIS-LOO) diagnostics, a method that assesses the model's predictive accuracy and stability (Vehtari & Gabry, 2019; Vehtari et al., 2017).

The LOO criterion was calculated as:

$$LOO = -2LPPD_{loo} = -2\sum_{i=1}^{n} \log \int p(y_i|\theta)p_{post(-i)}(\theta)d\theta$$

In the PSIS method, $p_{post(-i)}(\theta)$ represents the posterior distribution without the influence of observation i. The *k*-Pareto values are used to identify influential observations, with values below 0.5 indicating a well-fitting model, while values above 0.7 signal influential points that may distort the leave-one-out (LOO) estimate.

Convergence for well-fitting models was confirmed through both statistical and visual diagnostics. The effective sample size *n_eff* quantifies the adequacy of the sample, where values over 1000 suggest sufficient samples for reliable estimates (McElreath, 2018). The Gelman-Rubin *Rhat* statistic assesses convergence, with values close to 1 indicating that the Markov chains have converged (Brooks & Gelman, 1998). Trace plots were also reviewed to visually verify consistent sampling behavior across the Markov chains.

The Bayesian analysis was carried out in R using the bayesvl package, which is recognized for its advanced visualization capabilities (La & Vuong, 2019). To promote transparency and enable reproducibility, the study's dataset and code were made publicly available on a preprint server, ensuring others could access and reuse the materials (Vuong, 2018). The dataset and code can be accessed at https://zenodo.org/records/13859282.

3. Results

3.1. Model 1: Environmental awareness

It is important to assess the goodness of fit in Model 1 relative to the data. As illustrated in Figure 1, all the estimated *k*-values are below the 0.5 threshold, suggesting a good fit between the model and the observed data.

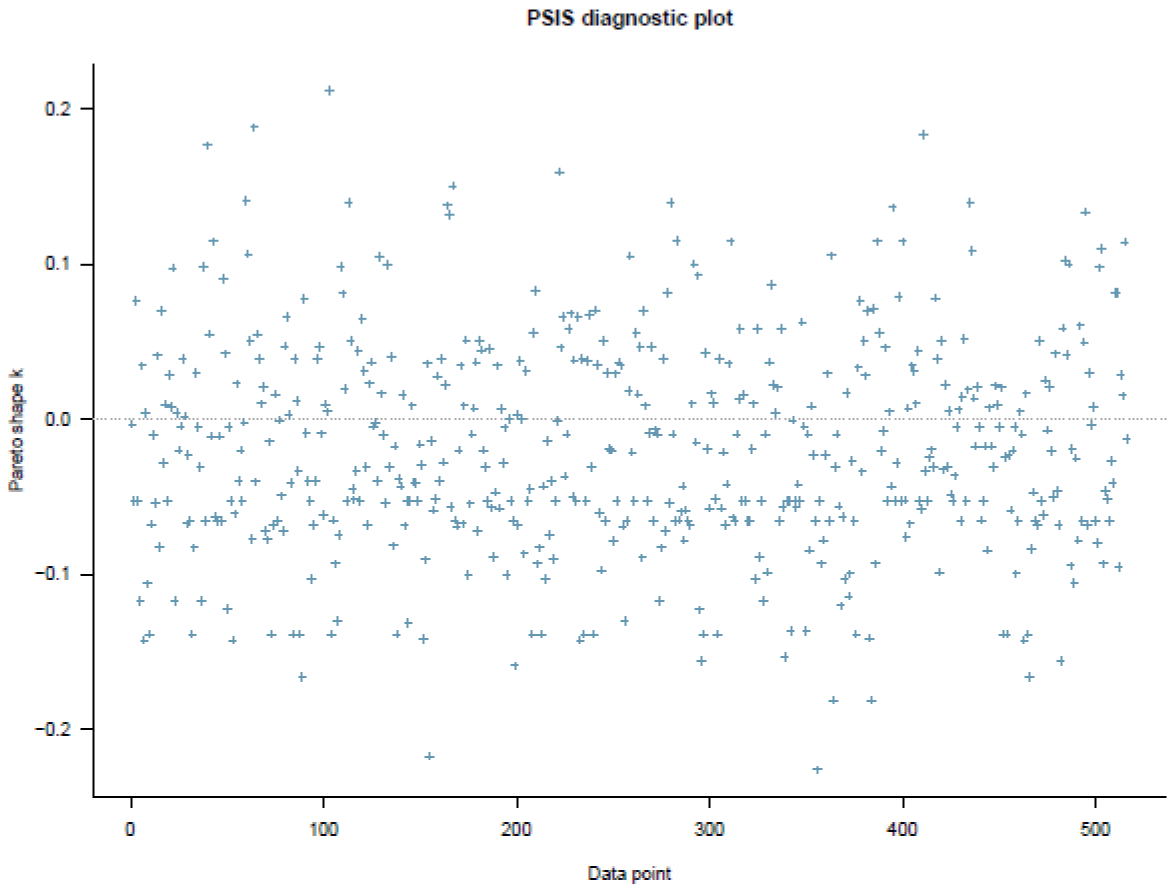

Figure 1: Model 1's PSIS-LOO diagnosis

The estimated posterior distributions for Model 1 are detailed in Table 1. Each *n_eff* value exceeds 1,000, and *Rhat* values are equal to 1, affirming the convergence of the Markov chains in Model 1. This convergence is further corroborated by the trace plots in Figure 2, where all chain values stabilize around a central equilibrium after the 2,000th iteration.

Table 2: Estimated results of Model 1

Parameters	**Uninformative priors**				**Informative priors**			
	Mean	**SD**	***n_eff***	***Rhat***	**Mean**	**SD**	***n_eff***	***Rhat***
Constant	2.12	0.23	11293	1	2.12	0.22	11458	1
RaisingAnimalPlant_ EnvironmentalNewsAwareness	0.06	0.06	11124	1	0.06	0.06	10085	1

TeachingintheWild_ EnvironmentalNewsAwareness	0.06	0.09	11285	1	0.05	0.09	10102	1
LearningaboutInsects_ EnvironmentalNewsAwareness	0.06	0.08	11847	1	0.06	0.08	10652	1
GoingtoNaturalEnvironments_ EnvironmentalNewsAwareness	0.05	0.07	10878	1	0.05	0.07	9715	1
GoingtoMuseums_ EnvironmentalNewsAwareness	0.13	0.07	11873	1	0.13	0.07	11087	1

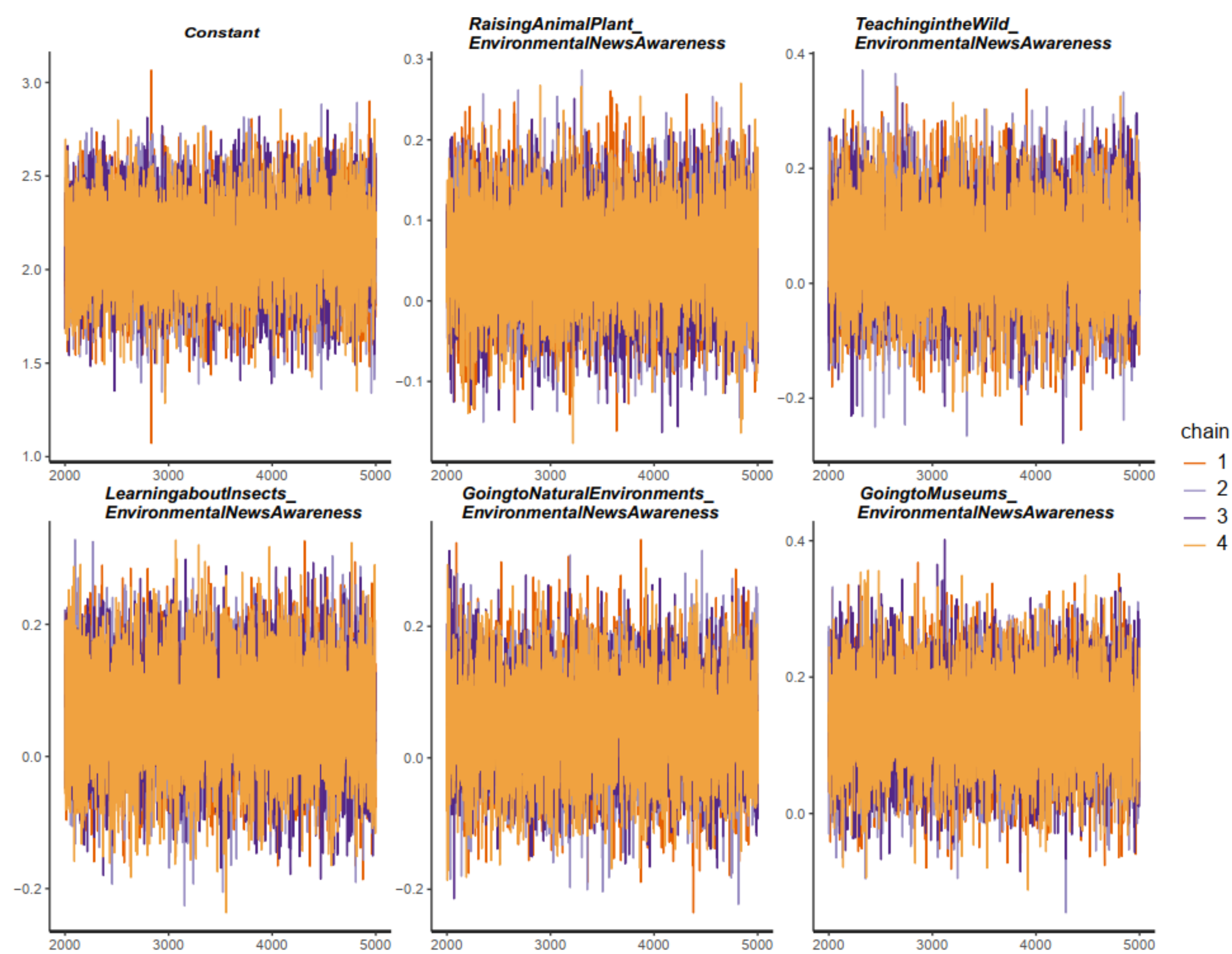

Figure 2: Model 1's trace plots estimated using uninformative priors

As all diagnostics confirm the convergence of the Markov chains, the simulated results of Model 1 are eligible for interpretation. The estimated results indicate that *GoingtoMuseums* ($M_{GoingtoMuseums\_EnvironmentalNewsAwareness}$ = 0.13 and $S_{GoingtoMuseums\_EnvironmentalNewsAwareness}$ = 0.07) and *RaisingAnimalPlant* ($M_{RaisingAnimalPlant\_EnvironmentalNewsAwareness}$ = 0.13 and $S_{RaisingAnimalPlant\_EnvironmentalNewsAwareness}$ = 0.07) are positively associated with *EnvironmentalNewsAwareness*, while other methods of parents to engage children with nature have ambiguous effects on their environmental awareness. The estimated using informative priors also indicates similar results, implying that the findings are robust against the modifying prior belief.

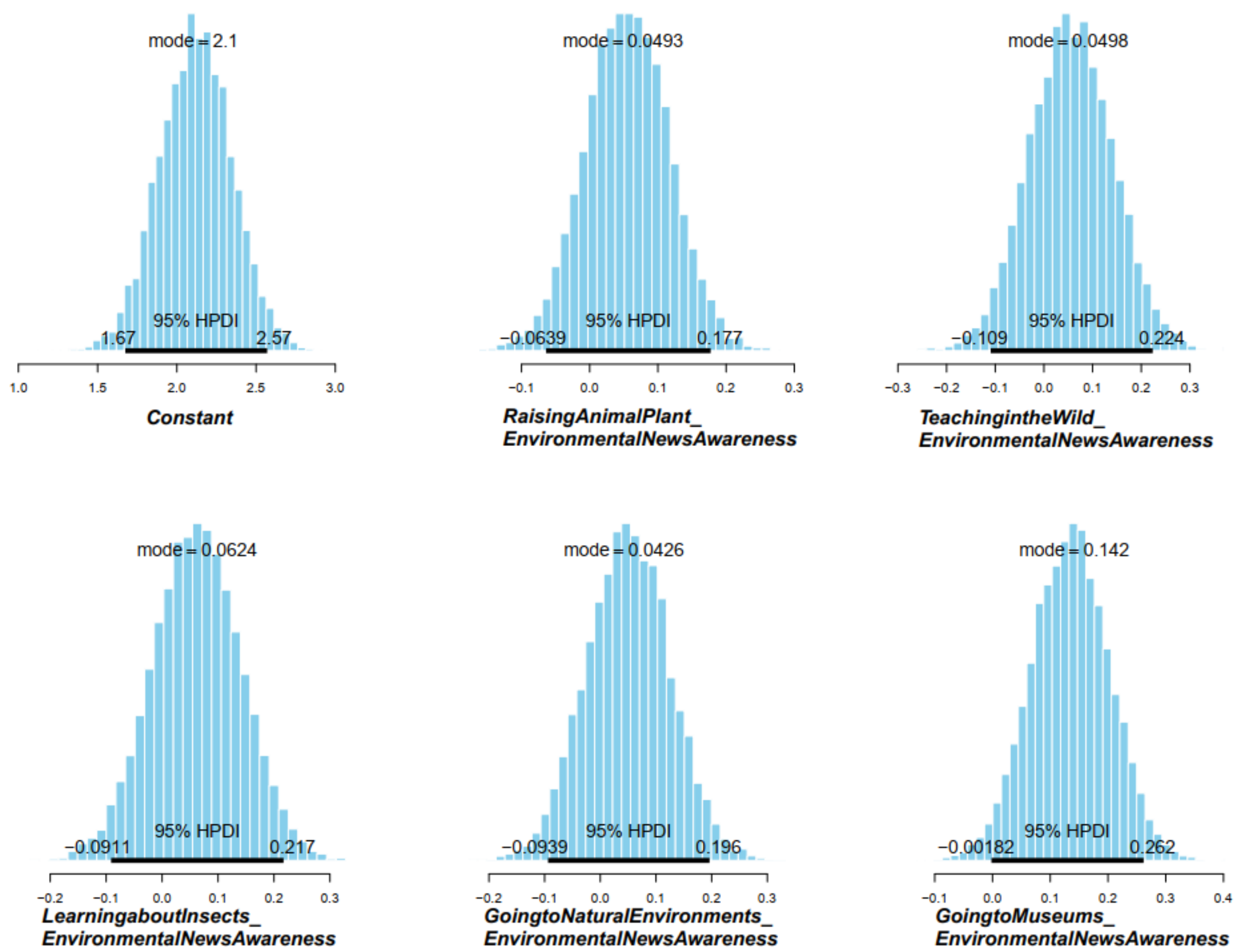

Figure 3: Posterior distributions of Model 1's coefficients estimated using uninformative priors

As can be seen from Figure 3, 95% of the Highest Posterior Density Intervals (HPDIs) of the coefficient $GoingtoMuseums\_EnvironmentalNewsAwareness$, depicted by the black line in the middle, is located entirely on the positive side of the *x*-axis, highlighting the high reliability.

A proportion of the coefficient $RaisingAnimalPlant\_EnvironmentalNewsAwareness$ is still located on the negative side, and its mean value is equal its standard deviation, so we can consider the positive association between $RaisingAnimalPlant$ and $EnvironmentalNewsAwareness$ is moderately reliable.

3.2. Model 2: Participation in environmental protection activities

The PSIS-LOO test for Model 2 is presented in Figure 4. All the calculated *k*-values fall below the 0.5 threshold, indicating that the model demonstrates an acceptable level of goodness of fit with the dataset.

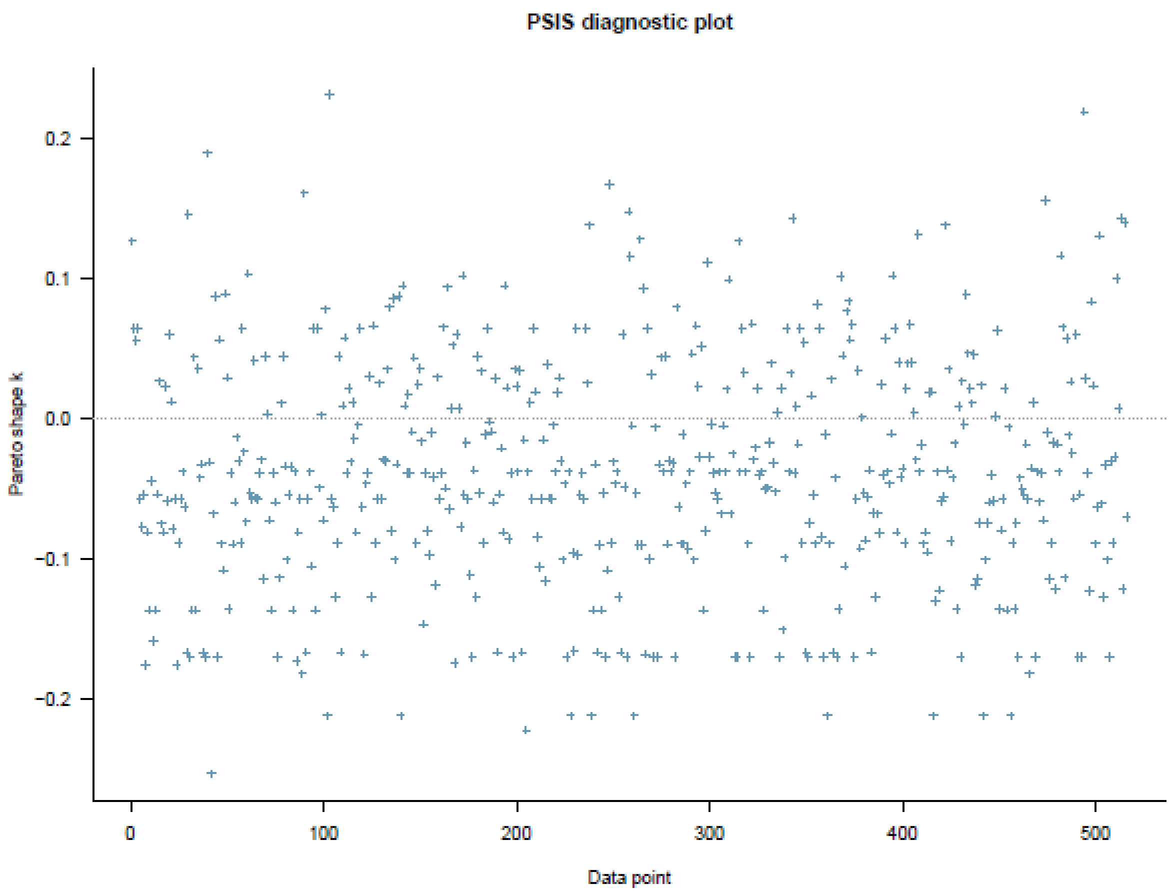

Figure 4: Model 2's PSIS-LOO diagnosis estimated using uninformative priors

The posterior distribution statistics of Model 2 are shown in Table 3. All *n_eff* values are greater than 1000, and *Rhat* values are equal to 1, so the models' Markov chains are well-convergent. The convergence of Markov chains of Model 2 is also reflected in the trace plots of Figure 5. In particular, after the 2000th iteration, all chains' values fluctuate around the central equilibrium.

Table 3: Estimated results of Model 2

Parameters	Uninformative priors	Informative priors

	Mean	SD	*n_eff*	*Rhat*	Mean	SD	*n_eff*	*Rhat*
Constant	1.82	0.21	10518	1	1.82	0.21	12150	1
RaisingAnimalPlant_ EnvironmentalProtectionParticipation	0.10	0.06	10147	1	0.10	0.06	12817	1
TeachingintheWild_ EnvironmentalProtectionParticipation	0.08	0.08	9120	1	0.08	0.08	10487	1
LearningaboutInsects_ EnvironmentalProtectionParticipation	0.19	0.07	10812	1	0.18	0.07	10149	1
GoingtoNaturalEnvironments_ EnvironmentalProtectionParticipation	0.03	0.07	10807	1	0.03	0.07	11512	1
GoingtoMuseums_ EnvironmentalProtectionParticipation	-0.03	0.06	10325	1	-0.02	0.06	11504	1

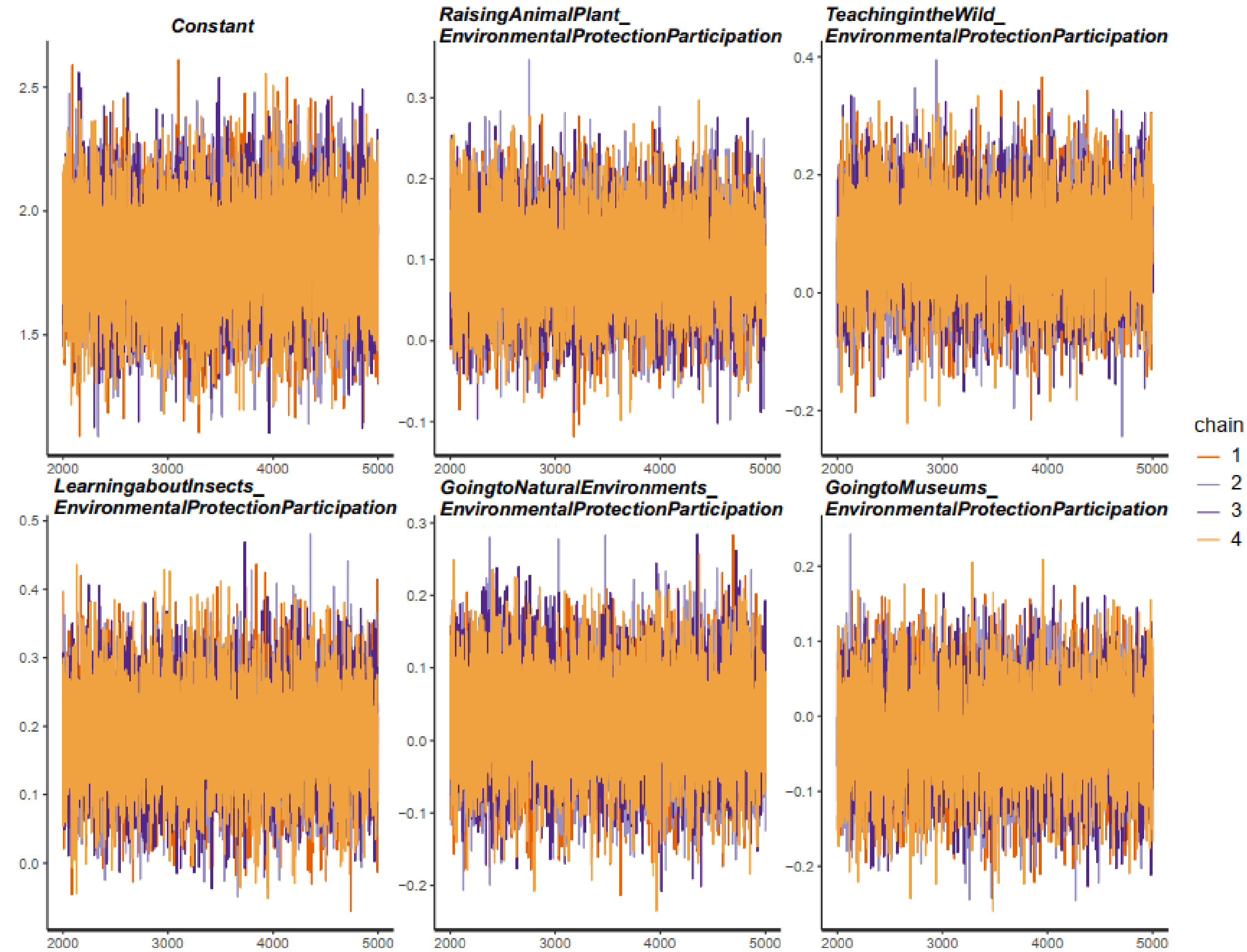

Figure 5: Model 2's trace plots estimated using uninformative priors

The simulated results in Table 3 indicate that engagement in certain activities can positively influence participation in environmental protection activities. Specifically, activities such as raising animals and pants ($M_{RaisingAnimalPlant\_EnvironmentalProtectionParticipation}$ = 0.10 and $S_{RaisingAnimalPlant\_EnvironmentalProtectionParticipation}$ = 0.06), teaching in the wild ($M_{TeachingintheWild\_EnvironmentalProtectionParticipation}$ = 0.10 and $S_{TeachingintheWild\_EnvironmentalProtectionParticipation}$ = 0.06), and helping children learn about insects ($M_{LearningaboutInsects\_EnvironmentalProtectionParticipation}$ = 0.10 and $S_{LearningaboutInsects\_EnvironmentalProtectionParticipation}$ = 0.06) are positively associated with *EnvironmentalProtectionParticipation*. Among these, learning about insects shows the strongest positive effect, followed by raising animals/plants and teaching in the wild. On the other hand, going to natural environments and going to museums have ambiguous associations with *EnvironmentalProtectionParticipation*. The estimated results using informative priors also

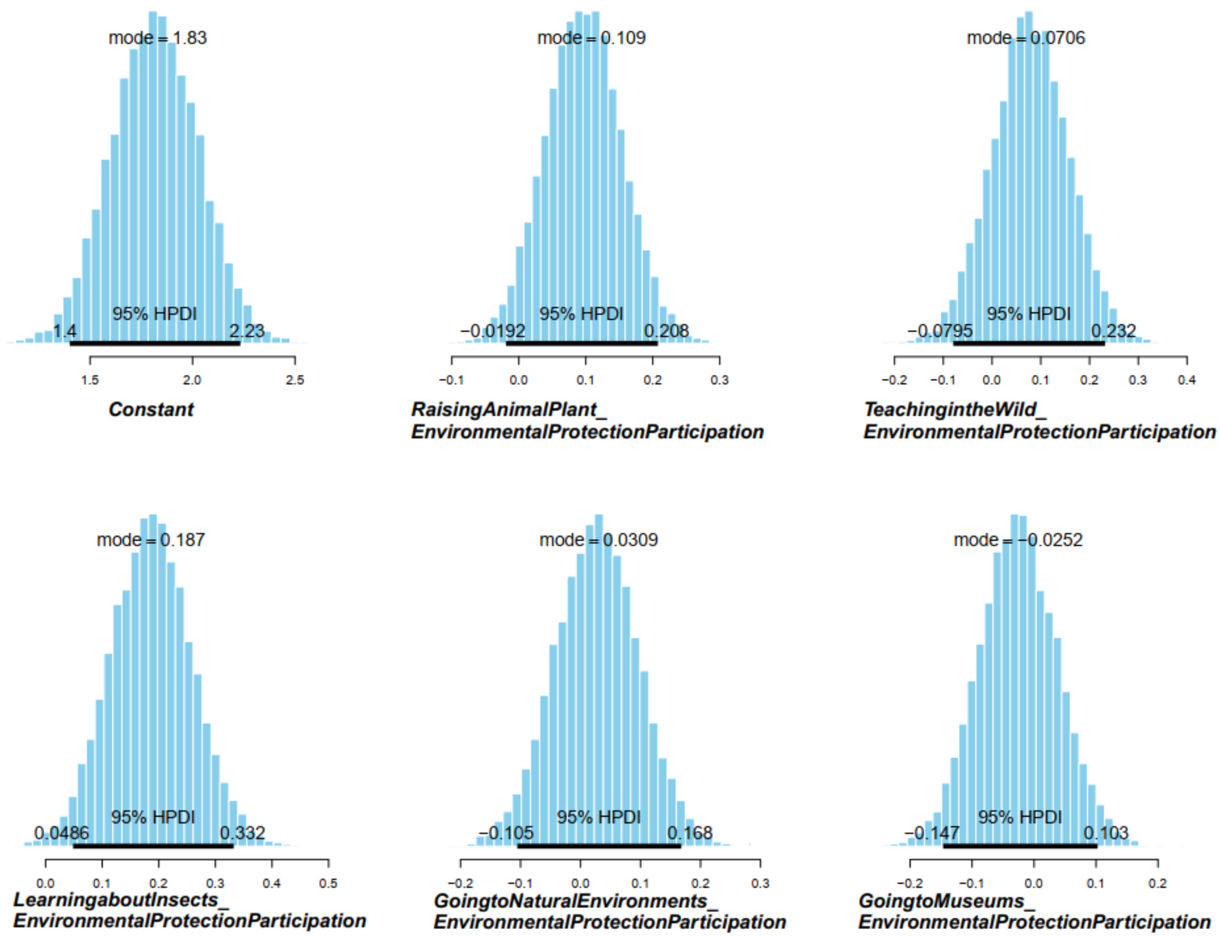

Figure 6: Posterior distributions of Model 2's coefficients estimated using uninformative priors

Figure 6 shows the posterior distribution with Highest Posterior Density Intervals (HPDIs) at 95% of Model 2's coefficients. The 95% HPDIs of *LearningaboutInsects_EnvironmentalProtectionParticipation* is located entirely on the positive side of the *x*-axis, suggesting the high reliability of the positive association. A proportion of *TeachingintheWild_EnvironmentalProtectionParticipation*'s 95% HPDIs is still located on the negative side, and its mean value is equal to its standard deviation; we can say that the positive association between *TeachingintheWild* and *EnvironmentalProtectionParticipation* is moderately reliable. Meanwhile, although a proportion of *RaisingAnimalPlant_EnvironmentalProtectionParticipation*'s 95% HPDIs is also located on the negative side of the *x*-axis, the proportion is negligible, and its mean value is much higher than its standard deviation. Therefore, we can consider the association between *RaisingAnimalPlant* and *EnvironmentalProtectionParticipation* highly reliable.

4. Discussion

Using Bayesian analysis on the dataset of children's nature engagement, our study found some parents' methods of engaging children with nature are positively associated with enhanced environmental awareness and participation in environmental protection activities. These positive associations support our assumption that accessibility to environmental information sources (e.g., hands-on nature experiences and environmental knowledge in the museums) with the support of parents can contribute significantly to cultivating children's environmental information processing and value formation. The finding aligns with previous research demonstrating the importance of direct nature contact in fostering pro-environmental attitudes (Aota & Soga, 2024; Tanja-Dijkstra et al., 2018; Whitburn et al., 2020). The importance of family-mediated nature experiences is further supported by Nmar-Kendöl and Fekete (2024), who found that children's early experiences with natural elements in home environments significantly influenced their cognitive, affective, and behavioral attitudes towards nature.

Animal care and plant cultivation showed a moderately reliable association with environmental awareness and a highly reliable association with participation in environmental protection activities. These relationships can be understood through the lens of emotional connection and empathy development. Burke et al. (2024) demonstrated through their study of primary school students that integrating positive psychology with environmental education led to significant improvements in both well-being and pro-environmental attitudes. Ding et al. (2024) found that positive parent-child environmental interactions enhanced family well-being and nature connectedness, which in turn promoted pro-environmental behaviors. These emotional connections are critical in shaping the pro-environmental values that underpin eco-surplus culture. Wang et al. (2023)'s findings illustrate that empathy with nature, especially developed through early family experiences, significantly influences pro-environmental behavior by fostering connection and responsibility. Emotional engagement appears particularly effective when combined with hands-on experiences, as evidenced by Li et al. (2024), who found that nature-focused emotional learning experiences led to significantly higher levels of environmental concern among preschool children. Freund et al. (2020)'s study of orangutan conservation education programs in Indonesia showed significant improvements in both knowledge and attitudes among participants who had direct interactions with wildlife. Eco-surplus culture, where pro-environmental attitudes, values, beliefs, and behaviors coalesce to mitigate human impacts on the environment (Vuong & Nguyen, 2024a), can flourish through collective action. Initiatives such as community gardening, local conservation projects, or wildlife observation programs provide children with opportunities to engage with their peers in nature-based activities, fostering a sense of shared responsibility (Soga & Gaston, 2023; Walker-Bolton, 2023). By engaging children in pro-environmental activities early in life, we lay the groundwork for eco-surplus values to become embedded in societal norms.

Museums offer interactive and immersive experiences that parents can use as tools to convey complex environmental concepts (e.g., biodiversity, climate change, and conservation practices) in relatable ways. The effectiveness of parent-guided museum visits in fostering environmental awareness shows a positive relation. This finding aligns with Iwaniec and Curdt-Christiansen (2020)'s research, highlighting parents as crucial agents in fostering environmental literacy, particularly when they actively engage in educational experiences with their children. Furthermore, greater learning took place when children engaged with adults rather than exploring independently. This learning was enhanced when parents talked about the exhibit's content with their children after the visit, linked the exhibits to the child's own life experiences, and when parents were metacognitively aware that their understanding of their children's learning processes shaped their interactions with them (Song et al., 2017). By accompanying children to museums, parents act as facilitators who contextualize knowledge, ensuring it resonates with the child's values and everyday experiences.

Interestingly, the weaker statistical reliability of the associations between wilderness learning experiences, environmental awareness, and participation in environmental protection in our analysis differs from our expectation of a high correlation. The effectiveness of nature experiences appears to be influenced by cultural context and socio-economic factors. Jensen et al. (2024)'s study of 14 schools demonstrated that while urbanization itself may not significantly impact nature intervention effectiveness, local access to nature and socio-economic context play crucial roles. This finding is reinforced by the concept of Satoumi, as explored by Uehara et al. (2019), which emphasizes that frameworks re-connecting people to nature often require tailored approaches addressing cultural and socio-economic factors. Yusmaliana et al. (2024) also highlighted the importance of integrating cultural and religious perspectives in environmental education. These findings suggest that effective nature engagement programs must consider and address broader societal contexts. Additionally, unexamined factors such as parental attitudes or school curricula might contribute to these patterns. Jia and Yu (2021) research on parent-child pro-environmental engagement in five Chinese cities highlights the complex interplay of family dynamics in environmental education outcomes. Thus, further studies examining the relationship between wilderness learning experiences, environmental awareness, and participation in environmental protection and incorporating other socio-cultural and economic contexts should be conducted.

The strongest association emerged between insect observation and participation in environmental protection activities, suggesting that even small-scale nature interactions, with the guidance of parents, can substantially impact children's environmental pro-environmental behaviors. This finding supports the "nature benefit hypothesis" proposed by Soga and Gaston (2023), who demonstrated through their study of 6400 adults that direct childhood nature experiences significantly predict pro-environmental behaviors. The mechanism can be explained through the mindsponge theory (Vuong, 2023), which suggests that individuals are more inclined to absorb information that resonates with their existing core values. When children engage in direct observation of insects, they develop positive associations that make them more receptive to broader environmental information. This is also oriented to pro-environment attitudes in the older ages (Chawla, 2020) and promotes eco-surplus culture (Vuong & Nguyen, 2024a; Vuong, 2021). The development of this culture appears particularly crucial in urban environments, where Nguyen, Nguyen, et al. (2023) found that residents' connection to nature significantly influenced their belief in the significance of biodiversity loss, while Akakpo et al. (2024) demonstrated through their study of 265 Ghanaian students that information literacy self-efficacy and climate knowledge significantly influence pro-environmental behaviors.

The findings from our study offer several theoretical and practical implications for environmental education and childhood development. It helps advance understanding of environmental education and child development by demonstrating the differential impacts of various parents' nature engagement methods. The particularly strong correlation between insect observation and participation in environmental protection activities suggests that specific forms of nature interaction may be more effective at certain developmental stages. The study also offers new insights into how exposure to nature shapes environmental beliefs, emotions, and behaviors in children. Building on Li et al. (2024)'s findings regarding empathy with nature in preschool children, our results suggest that emotional connections formed through direct nature experiences serve as fundamental building blocks for environmental awareness. This understanding contributes to the broader theoretical framework of eco-surplus culture development (Nguyen, Duong, et al., 2023; Nguyen & Jones, 2022; Vuong & Nguyen, 2024a), demonstrating how early nature experiences can foster enduring pro-environmental values.

Regarding practical implications, our findings highlight the importance of integrating family-centered approaches into environmental education to prioritize direct nature interactions. The success of structured activities, particularly insect observation, raising animals and plants, and visiting museums, indicates that environmental education should move beyond traditional classroom-based approaches. For urban educational settings, our results specifically suggest encouraging families to create small-scale gardens, care for pets, or explore nearby museums, which can cultivate a collaborative learning environment where parents model pro-environmental behaviors, making the learning process both practical and meaningful for children. This approach becomes particularly crucial given the increasing urbanization and diminishing nature access highlighted by Nguyen, Nguyen, et al. (2023) and Nguyen (2024). The study also provides evidence-based guidance for policymakers designing child-focused environmental initiatives. Following Činčera et al. (2023)'s recommendations on outdoor environmental education, policies should support the development of green spaces and nature interaction opportunities in educational settings and around residential areas to encourage family participation in structured environmental education initiatives.

These implications suggest a fundamental shift in how we conceptualize environmental awareness development in children, moving from knowledge-based approaches toward experiential learning that engages both cognitive and emotional processing pathways. This shift aligns with emerging research on the importance of early nature experiences in shaping lifelong environmental attitudes and behaviors.

The study has limitations that warrant acknowledgment. The cross-sectional nature of our data collection limits our ability to establish causal relationships between variables. Additionally, our focus on specific geographic regions may restrict the findings' applicability to other contexts. Despite these limitations, our findings suggest that enhancing children's direct interactions with nature, particularly through structured activities involving insects, animals, and plants, can be a crucial pathway for developing environmental awareness. When children recognize the value of biodiversity through direct experience, they become more likely to absorb and integrate pro-environmental information, gradually building an eco-surplus culture that supports conservation efforts. This understanding can inform more effective approaches to environmental education and conservation, particularly in increasingly urbanized contexts where connection to nature faces growing challenges.

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