sustainability

MDPI

Article

The Psychological Mechanisms of Education for Sustainable Development: Environmental Attitudes, Self-Efficacy, and Social Norms as Mediators of Pro-Environmental Behavior Among University Students

Jianyang Zhang [1] and Aochen Cao [2,*]

[1] Faculty of Arts, University of Auckland, Auckland 1010, New Zealand; ajhz239@aucklanduni.ac.nz
[2] School of Economics, Central University of Finance and Economics, Beijing 102206, China
* Correspondence: cac@email.cufe.edu.cn

Abstract: Education for Sustainable Development (ESD) has been widely promoted as a key strategy for fostering pro-environmental behavior, yet the psychological mechanisms underlying its effectiveness remain inadequately understood. This study investigates how ESD participation influences pro-environmental behavior through the mediating roles of environmental attitudes, environmental self-efficacy, and social norm perceptions. Using structural equation modeling with data from 500 university students, we tested a comprehensive model integrating these psychological pathways. Environmental attitudes, mediating 56% of the effects, emerged as the strongest factor, followed by social norm perceptions (27%) and environmental self-efficacy (17%). These findings demonstrate full mediation through these psychological mechanisms, suggesting that ESD's effectiveness depends on its ability to transform students' environmental attitudes, strengthen their self-efficacy beliefs, and foster supportive social norms. These results contribute to both the theoretical understanding and practical implementation of ESD by highlighting the relative importance of different psychological pathways and suggesting targeted strategies for enhancing educational interventions. This study provides evidence-based insights for educators and policymakers seeking to design more effective sustainability education programs in higher education settings.

Keywords: education for sustainable development (ESD); pro-environmental behavior; environmental attitudes; self-efficacy; social norms; structural equation modeling; psychological mechanisms; higher education; new environmental paradigm (NEP); mediation analysis

Academic Editor: Karmen Erjavec

Received: 24 December 2024
Revised: 17 January 2025
Accepted: 21 January 2025
Published: 23 January 2025

Citation: Zhang, J.; Cao, A. The Psychological Mechanisms of Education for Sustainable Development: Environmental Attitudes, Self-Efficacy, and Social Norms as Mediators of Pro-Environmental Behavior Among University Students. *Sustainability* **2025**, *17*, 933. https://doi.org/10.3390/su17030933

1. Introduction

Education for Sustainable Development (ESD), endorsed in the Berlin Declaration [1], represents a transformative pedagogical approach that integrates critical thinking development with environmental responsibility. This educational paradigm seeks to empower learners with the requisite knowledge, skills, and attitudes necessary for addressing contemporary environmental challenges. However, the psychological mechanisms through which these educational interventions translate into behavioral outcomes remain inadequately understood, particularly in the context of higher education, where students are positioned as future decision-makers and change agents.

Despite the global promotion of ESD, a notable gap persists between environmental awareness and concrete pro-environmental behavior (PEB) among students [2]. Traditional

knowledge-focused education often fails to instill meaningful behavioral change [3], highlighting the critical importance of understanding the underlying psychological mechanisms, such as environmental attitudes [4], self-efficacy, and social norms, in shaping sustainable behaviors. While efforts have been made to explore these factors individually, there remains a lack of integrated frameworks that elucidate how these psychological pathways collectively mediate the relationship between ESD participation and PEB.

While previous studies have examined individual psychological mechanisms in ESD [2,3], they have predominantly focused on singular pathways, examining either attitudes, self-efficacy, or social norms in isolation. This fragmented approach has limited our understanding of how these mechanisms collectively influence pro-environmental behavior. The present study advances the field by proposing and empirically testing an integrated theoretical framework that simultaneously examines multiple psychological pathways, offering a more nuanced understanding of their relative contributions and interactive effects.

In the context of higher education, where students are positioned as future leaders and decision-makers, understanding these mechanisms becomes even more critical. Higher education institutions have incorporated ESD through curriculum design, interdisciplinary learning, and extracurricular activities [5]. However, challenges persist in translating these efforts into measurable behavioral outcomes. The existing research has primarily examined psychological factors such as attitudes, self-efficacy, and social norms in isolation, leaving their collective influence poorly understood. This research seeks to address these gaps by constructing a comprehensive model that examines the psychological pathways underlying ESD's influence on PEB.

Drawing on the New Environmental Paradigm [4] as a theoretical foundation, this study examines how environmental attitudes mediate the relationship between ESD participation and pro-environmental behavior.

Bandura's [6] self-efficacy theory highlights the role of individuals' beliefs in their capacity to execute behaviors that influence desired outcomes. Environmental self-efficacy, an extension of this theory, has been shown to predict behaviors such as recycling and energy conservation [7]. It operates by enhancing individuals' confidence in their ability to contribute to environmental solutions, thereby bridging the gap between awareness and action. This construct not only reflects personal competence but also mediates the relationship between knowledge acquisition and behavioral implementation.

1.1. The Role of Social Norms in Environmental Behavior

Ajzen's [8] Theory of Planned Behavior (TPB) emphasizes social norms as critical determinants of behavioral intentions. Social norms can be classified into descriptive norms (what people typically do) and injunctive norms (what people perceive as socially approved behavior). Research by Saracevic and Schlegelmilch [9] demonstrates the powerful influence of social contexts in shaping sustainable behaviors, particularly through peer influence and community engagement.

While the NEP emphasizes attitudes, self-efficacy theory focuses on individual capacity, and social norm theory highlights collective influence; their integration provides a holistic understanding of ESD's impact on PEB. Together, these frameworks illustrate how cognitive, affective, and social dimensions interact to shape pro-environmental behaviors. Specifically, the NEP provides an overarching cognitive framework for understanding environmental worldviews, self-efficacy operates at the individual level to influence action, and social norms contextualize behavior within a social and cultural setting. This study's theoretical framework synthesizes these perspectives to examine how ESD participation influences students' environmental attitudes, self-efficacy, and social norms, ultimately

fostering PEB. The proposed relationships are illustrated in Figure 1, which presents the integrated theoretical model underpinning this research. The novelty lies in the simultaneous consideration of these pathways, addressing gaps in the existing research and providing a comprehensive explanatory model.

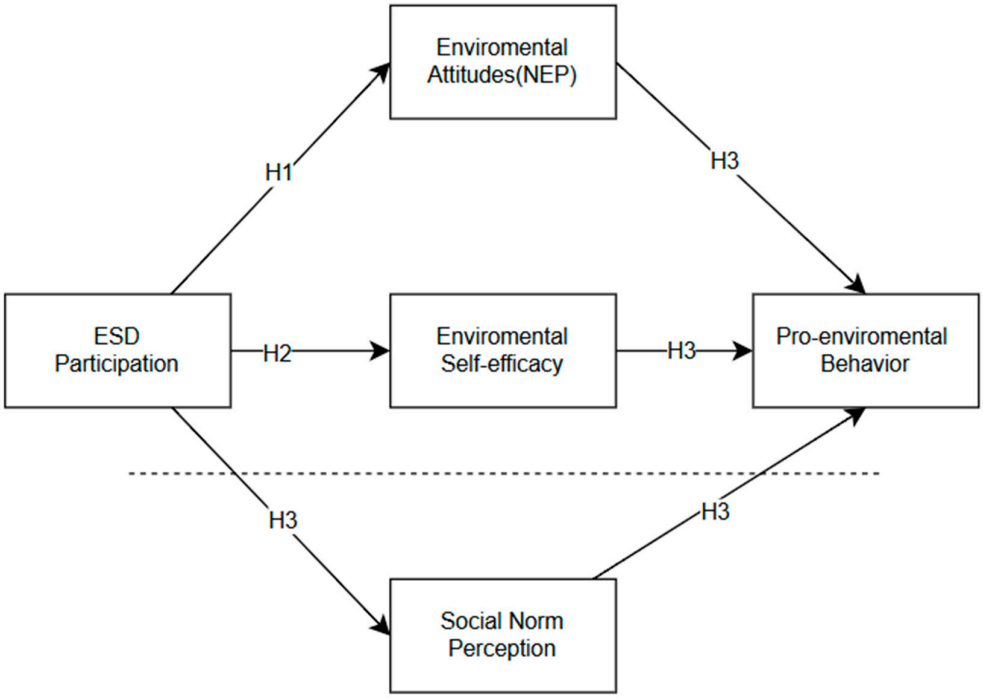

Figure 1. Theoretical model of the study. Note: Solid lines represent hypothesis mediation paths; dashed represents direct effects. ESD = Education for Sustainable Development; NEP = New Environment Paradigm.

The primary objective of this study is to construct and validate an integrated model that explores the psychological mechanisms linking ESD participation with PEB. This objective is grounded in the theoretical insights provided by NEP, self-efficacy, and social norm theories, which collectively emphasize the interplay between attitudes, individual capacity, and social influence. Specifically, the study seeks to accomplish the following:

a. Investigate whether ESD participation enhances students' environmental attitudes and self-efficacy;
b. Examine the role of social norms in shaping the relationship between ESD participation and PEB;
c. Identify the relative contributions of environmental attitudes, self-efficacy, and social norms in mediating the ESD–behavior relationship.

Based on these objectives, the following research questions are proposed:

a. Does ESD participation improve students' environmental attitudes and environmental self-efficacy?
b. In what ways do social norms influence the relationship between ESD participation and PEB?
c. How do environmental attitudes, self-efficacy, and social norms jointly mediate the ESD–behavior relationship?

Each hypothesis is grounded in theoretical insights from NEP, self-efficacy theory, and social norms research. Based on the theoretical framework and existing literature, the study hypothesizes the following:

H1. *ESD participation positively predicts environmental attitudes.*

H2. *ESD participation positively predicts environmental self-efficacy and social norms.*

H3. *Environmental attitudes, self-efficacy, and social norms positively predict PEB.*

H4. *Environmental attitudes, self-efficacy, and social norms mediate the relationship between ESD participation and PEB.*

This study seeks to address the theoretical fragmentation in current ESD research by examining how multiple psychological constructs collectively mediate educational outcomes. While the existing literature has investigated psychological factors in isolation, the need for an integrated theoretical framework remains pressing [10]. By synthesizing environmental attitudes, self-efficacy, and social norms within a unified analytical model, this investigation responds to calls for more comprehensive theoretical approaches in sustainability education research. By testing the combined effects of environmental attitudes, self-efficacy, and social norms, it addresses the theoretical gap identified by Hanisch and Eirdosh [10] regarding the need for comprehensive models in ESD research. The findings are expected to contribute to the refinement of behavioral theories in sustainability education.

The use of structural equation modeling (SEM) represents a methodological advancement, enabling the simultaneous analysis of complex relationships and indirect effects. Unlike traditional regression analyses, SEM allows for the simultaneous testing of complex interrelationships and mediation pathways while accounting for measurement errors. This capability is particularly advantageous for capturing the complex interdependencies among variables and testing multiple mediation effects simultaneously, which are critical for understanding the nuanced psychological impacts of ESD on pro-environmental behavior.

For educators and policymakers, this study provides actionable insights into designing effective ESD programs. By identifying the most influential psychological pathways, it informs the development of targeted interventions that address attitudinal, normative, and efficacy-related barriers to sustainable behavior. Additionally, the findings highlight the importance of creating supportive social environments within educational settings to amplify ESD's impact.

In summary, this study seeks to bridge the theoretical and practical dimensions of ESD, offering a nuanced understanding of how educational interventions can cultivate environmentally responsible behaviors. By addressing the existing research gaps and proposing innovative solutions, it aims to enhance the effectiveness of sustainability education in higher education contexts.

1.2. Theoretical Integration and Hypotheses Development

The theoretical framework underpinning this study synthesizes three distinct yet interconnected psychological mechanisms that mediate the relationship between ESD participation and pro-environmental behavior. This integration addresses the theoretical gap identified in contemporary sustainability education research regarding the psychological pathways through which educational interventions translate into behavioral outcomes. By examining these mechanisms collectively rather than in isolation, this study advances a more nuanced understanding of how ESD influences behavioral change.

The first theoretical pillar draws from the New Environmental Paradigm (NEP), which posits that environmental attitudes form through the internalization of ecological worldviews [4]. Within the context of ESD, the NEP framework suggests that educational interventions can systematically modify students' environmental attitudes by challenging anthropocentric perspectives and fostering eco-centric worldviews. Recent empirical evidence supports this theoretical proposition, demonstrating that structured

educational experiences can significantly alter environmental attitudes [4]. This leads to our first hypothesis:

H5. *ESD participation positively predicts environmental attitudes through the mechanism of ecological worldview transformation.*

The second theoretical strand incorporates Bandura's [6] self-efficacy theory, specifically its application to environmental behavior. Environmental self-efficacy, conceptualized as individuals' beliefs in their capacity to effect environmental change, emerges as a critical mediator in the education–behavior relationship. Contemporary research has demonstrated that educational interventions can enhance environmental self-efficacy by providing mastery experiences and vicarious learning opportunities [11]. This theoretical understanding forms the basis for our second hypothesis:

H6. *ESD participation enhances environmental self-efficacy, which in turn facilitates pro-environmental behavior.*

The third theoretical component draws from social norm theory, particularly its application in environmental contexts as elaborated by Ajzen [8]. Social norms operate through dual mechanisms: descriptive norms that communicate typical behavior patterns and injunctive norms that convey social approval or disapproval [9]. ESD programs, by creating collaborative learning environments and fostering peer interactions, can actively shape these normative perceptions. Recent studies have confirmed the significant role of social norms in environmental behavior modification [5], leading to our third hypothesis:

H7. *Social norm perceptions mediate the relationship between ESD participation and pro-environmental behavior.*

The integration of these theoretical perspectives suggests a complex network of psychological mechanisms through which ESD influences behavior. This comprehensive framework extends beyond traditional single-mediator models by examining how multiple psychological pathways operate simultaneously. The proposed model addresses the theoretical limitation noted by Zainal Abidin et al. (2024) [3] regarding the need for more integrated approaches in sustainability education research. Furthermore, it responds to calls for more sophisticated theoretical frameworks that can account for the multifaceted nature of behavioral change in environmental contexts [11].

This theoretical integration leads to our final hypothesis regarding the collective mediation effect:

H8. *Environmental attitudes, self-efficacy, and social norms collectively mediate the relationship between ESD participation and pro-environmental behavior, with each mechanism contributing uniquely to the overall effect.*

The proposed theoretical framework not only synthesizes existing knowledge but also advances our understanding of how educational interventions can more effectively promote sustainable behavior. By examining these psychological mechanisms simultaneously, this study provides a more nuanced understanding of the pathways through which ESD influences behavioral outcomes. This integrated approach offers both theoretical insights for researchers and practical guidance for educators designing sustainability education programs.

2. Literature Review

2.1. Conceptual Evolution of ESD

The conceptual evolution of Education for Sustainable Development (ESD) reflects a paradigmatic transformation from reductionist environmental education to an integrated framework encompassing psychological mechanisms and behavioral outcomes. This evolution manifests itself through three distinct yet interconnected developmental phases, each characterized by increasingly sophisticated theoretical conceptualizations and methodological approaches.

The initial phase, predominantly focused on environmental awareness, emerged from traditional knowledge dissemination models. During this period, ESD operated primarily through information transfer paradigms, emphasizing ecological knowledge acquisition while largely overlooking the psychological dimensions of behavioral change [2]. This approach, while foundational, demonstrated limited efficacy in fostering sustainable behaviors, as evidenced by the persistent gap between environmental awareness and concrete pro-environmental actions.

The second phase marked a significant theoretical advancement through the integration of sustainability dimensions. This period witnessed the emergence of interdisciplinary approaches that acknowledged the complex interrelationships between environmental, social, and economic factors in sustainability education. McCowan and Chankseliani [5] demonstrate how this integration manifested itself in higher education contexts, where institutions began incorporating sustainability principles across the curriculum design and pedagogical practices. This phase represented a crucial transition from purely environmental concerns to a more comprehensive understanding of sustainability education.

The contemporary phase, characterized by transformative learning approaches, represents the most sophisticated conceptualization of ESD. This current framework, articulated in the Berlin Declaration [12], emphasizes the critical role of psychological mechanisms in mediating the relationship between educational interventions and behavioral outcomes. The declaration explicitly recognizes ESD as a transformative educational process aimed at fostering critical thinking, systems thinking, and pro-environmental behavior through the activation of specific psychological pathways.

Recent theoretical developments have particularly emphasized the role of psychological constructs in ESD's effectiveness. Zainal Abidin et al. [3] identify how contemporary ESD frameworks increasingly incorporate psychological mediators such as environmental attitudes, self-efficacy beliefs, and social norm perceptions. This integration reflects growing recognition that effective sustainability education must address not only cognitive understanding but also the psychological mechanisms that facilitate behavioral change.

The evolution of ESD theoretical frameworks has also revealed significant operational challenges. The current frameworks often struggle with the precise operationalization of psychological constructs within educational contexts. This limitation manifests itself in the difficulty of integrating interdisciplinary approaches and measuring psychological outcomes effectively. As Hanisch and Eirdosh [10] argue, these challenges necessitate more sophisticated theoretical models that can capture the complex interactions between educational interventions and psychological mediators.

Furthermore, the contemporary conceptualization of ESD emphasizes the role of higher education institutions as crucial sites for sustainability transformation. Li et al. [11] demonstrate how universities function as laboratories for testing and refining ESD approaches, particularly in their capacity to integrate psychological mechanisms into educational practice. This institutional context provides unique opportunities for examining how psychological constructs mediate the relationship between educational interventions and behavioral outcomes.

The critical analysis of the existing ESD frameworks reveals several theoretical tensions that warrant further investigation. While contemporary models acknowledge the importance of psychological mechanisms, they often lack systematic frameworks for understanding how these mechanisms interact within educational contexts. This theoretical gap is particularly evident in the limited integration between psychological theories and pedagogical practices, as noted by Xu [13] in their analysis of university-based sustainability education.

The current conceptualization of ESD thus represents a sophisticated theoretical framework that acknowledges the complex interplay between educational interventions, psychological mechanisms, and behavioral outcomes. However, this evolution also highlights the need for more integrated theoretical models that can effectively capture the multifaceted nature of sustainability education. Future theoretical developments must address both the operational challenges of implementing psychological constructs in educational settings and the broader goal of fostering sustainable behavior through targeted educational interventions.

2.2. Environmental Attitudes and Behavioral Foundations

Environmental attitudes serve as fundamental cognitive constructs mediating the relationship between educational interventions and pro-environmental behaviors, with their theoretical conceptualization primarily anchored in the New Environmental Paradigm (NEP). Initially developed by Dunlap and Van Liere [4], the NEP framework has evolved into a sophisticated theoretical apparatus for understanding ecological worldviews and their behavioral manifestations. Contemporary research has substantially extended this foundational framework, revealing increasingly nuanced relationships between attitudinal constructs and behavioral outcomes within educational contexts.

The NEP's theoretical architecture encompasses several interconnected dimensions: beliefs in ecological limits, the rejection of anthropocentrism, and acceptance of sustainable practices [14]. These dimensions collectively constitute a comprehensive framework for understanding how individuals conceptualize human–environment relationships. Recent theoretical advancements have particularly emphasized the dynamic nature of these relationships within educational contexts. Tang and Tian [15] demonstrate how the NEP framework effectively captures the transformation of environmental attitudes through educational interventions, particularly in cross-cultural contexts where traditional Western environmental paradigms intersect with local ecological perspectives.

A critical examination of the NEP's application in environmental education reveals both its theoretical robustness and methodological limitations. While the framework provides a sophisticated mechanism for assessing ecological worldviews, its operationalization within educational contexts presents specific challenges. Recent empirical investigations by Wilson and Kaiser [16] highlight how the NEP's general ecological orientation sometimes fails to capture the nuanced behavioral determinants specific to educational interventions. This limitation becomes particularly salient when examining the attitude–behavior relationship within structured educational environments.

The theoretical relationship between environmental attitudes and behavioral outcomes demonstrates considerable complexity, necessitating sophisticated analytical frameworks. Recent research has identified multiple mediating and moderating factors that influence this relationship. Tang and Tian [15] empirically demonstrate how environmental values interact with perceived efficacy to influence behavioral outcomes, suggesting a more complex theoretical model than previously recognized. Their findings indicate that the attitude–behavior relationship is mediated by both cognitive and affective factors, particularly within educational contexts where systematic interventions can target specific psychological mechanisms.

The theoretical relationship between the NEP and self-efficacy constructs represents a critical intersection in environmental education research. While the NEP framework emphasizes cognitive structures and ecological worldviews as fundamental determinants of environmental behavior, self-efficacy theory focuses on behavioral implementation mechanisms and capability beliefs. This theoretical complementarity suggests that environmental attitudes and self-efficacy operate through distinct yet interconnected pathways: NEP-based attitudes provide the cognitive architecture for understanding human–environment relationships, while self-efficacy beliefs facilitate the translation of these understandings into concrete behavioral outcomes. Recent empirical evidence [14,15,17] supports this theoretical integration, demonstrating how the confluence of ecological worldviews and efficacy beliefs creates more robust predictors of pro-environmental behavior than either construct in isolation.

Contemporary theoretical developments have particularly emphasized the role of measurement sophistication in understanding environmental attitudes. The General Ecological Behavior (GEB) scale, as validated by Fan and Chen [18], represents a significant methodological advancement in connecting attitudinal measures to observable behaviors. However, critical analysis reveals persistent challenges in establishing cross-cultural validity and maintaining measurement invariance across diverse educational contexts. These methodological considerations necessitate more nuanced approaches to attitude assessment within ESD frameworks.

The integration of environmental attitudes within broader psychological frameworks has emerged as a crucial theoretical development. Recent empirical work demonstrates how attitudinal constructs interact with self-efficacy beliefs and social norm perceptions to influence behavioral outcomes. This theoretical integration suggests that environmental attitudes function not merely as isolated psychological constructs but as integral components of a broader cognitive architecture that mediates educational effectiveness. The empirical evidence supporting this integration has particular significance for understanding how ESD interventions can effectively target multiple psychological pathways simultaneously.

Furthermore, longitudinal investigations have revealed the dynamic nature of environmental attitudes within educational contexts. Recent studies demonstrate how attitudes evolve through recursive interactions with educational interventions and behavioral experiences. This temporal dimension adds considerable complexity to our understanding of how environmental attitudes mediate the relationship between educational inputs and behavioral outputs. Such findings necessitate more sophisticated theoretical models that can capture these dynamic relationships while maintaining analytical precision [19].

The theoretical exploration of attitude–behavior relationships within ESD contexts has also highlighted the importance of institutional and cultural factors. Educational institutions provide unique contexts where environmental attitudes can be systematically influenced through structured interventions. However, the effectiveness of these interventions depends significantly on their alignment with broader cultural and social frameworks. This contextual dimension suggests the need for more nuanced theoretical models that can account for institutional and cultural variables while maintaining focus on core psychological mechanisms [20].

Contemporary research has particularly emphasized the need for integrated theoretical frameworks that can capture the complex interactions between environmental attitudes and other psychological constructs within educational contexts [19]. Such an integration requires sophisticated methodological approaches that can simultaneously assess multiple psychological pathways while maintaining analytical rigor. This theoretical advancement represents a crucial development in understanding how environmental attitudes mediate the relationship between educational interventions and behavioral outcomes.

2.3. Psychological Mechanisms in Environmental Education

The psychological mechanisms underpinning environmental education, particularly self-efficacy and social norms, have emerged as critical mediators in the relationship between educational interventions and behavioral outcomes. These mechanisms operate through distinct yet interconnected pathways, fundamentally shaping how educational initiatives translate into sustainable behaviors.

Environmental self-efficacy, theoretically grounded in Bandura's [6] framework, represents a crucial psychological mechanism mediating the relationship between environmental knowledge and behavioral implementation. Empirical research by Tabernero and Hernández [7] demonstrates how self-efficacy beliefs significantly predict specific environmental behaviors, including recycling and energy conservation practices. Their findings reveal that individuals with a higher environmental self-efficacy consistently demonstrate greater engagement in pro-environmental behaviors, suggesting the construct's crucial role in behavioral activation.

Social norms, conceptualized within Wu's [21] Theory of Planned Behavior, constitute another critical psychological mechanism in environmental education. Saracevic and Schlegelmilch [9] empirically demonstrate how descriptive and injunctive norms differentially influence environmental behavior, with descriptive norms (what people typically do) and injunctive norms (what people perceive as socially approved) operating through distinct psychological pathways. Their research reveals that social norms significantly shape behavioral intentions and subsequent actions through collective influence mechanisms.

The interaction between these psychological mechanisms has received increasing empirical attention. Recent work by Colombo [22] reveals how self-efficacy and social norms operate synergistically within educational contexts, with normative influences often amplifying individual efficacy beliefs. This interaction suggests that effective environmental education must address both individual capability beliefs and collective normative influences to maximize its behavioral impact.

The measurement and operationalization of these psychological constructs present significant methodological challenges. Estrada et al. [23] demonstrate how structural equation modeling can effectively capture the complex relationships among these psychological mediators, providing empirical support for theoretical models that posit multiple pathways between education and behavior. Their methodological framework enables a sophisticated analysis of how these psychological mechanisms collectively influence behavioral outcomes.

Recent empirical work by Nyborg et al. [24] identifies specific challenges in implementing psychological constructs within educational contexts, particularly regarding the integration of interdisciplinary approaches. Their findings suggest that effective environmental education requires sophisticated frameworks capable of addressing multiple psychological pathways while maintaining theoretical coherence and methodological rigor.

2.4. Methodological Approaches in ESD Research

Contemporary methodological approaches in Education for Sustainable Development (ESD) research reflect an evolving sophistication in empirical investigation, characterized by the integration of advanced quantitative techniques with theoretically grounded analytical frameworks. Structural equation modeling (SEM) has emerged as a particularly robust methodological tool, offering unique capabilities for examining complex mediational relationships within educational contexts [25].

Qin [26] demonstrates SEM's methodological advantages in capturing intricate relationships among latent variables while accounting for measurement error—a critical consideration in psychological research. The analysis reveals how SEM's capacity to si-

multaneously test multiple mediation pathways provides crucial insights into the complex mechanisms through which educational interventions influence behavioral outcomes. This methodological sophistication enables researchers to disentangle direct and indirect effects while maintaining analytical precision.

The application of quantitative methodologies in ESD research presents specific challenges regarding measurement validity and reliability. Chen [27] empirically demonstrates how sophisticated measurement approaches can effectively capture the multidimensional nature of environmental constructs. This research emphasizes the importance of establishing measurement invariance across different educational contexts, particularly when examining psychological mediators such as environmental attitudes and self-efficacy.

Methodological considerations regarding self-reported data warrant particular attention in ESD research. Chen [28] identifies specific challenges related to social desirability bias in environmental behavior measurement, emphasizing the need for sophisticated measurement approaches that can control for response biases while maintaining construct validity. This work underscores the importance of employing multiple measurement methods to enhance the robustness of empirical findings.

The integration of advanced statistical techniques with theoretical frameworks represents a crucial methodological advancement in ESD research. Iyengar [29] demonstrates how sophisticated analytical approaches can effectively capture the dynamic nature of psychological mechanisms while maintaining methodological rigor. This research emphasizes the importance of employing analytical techniques that can account for both measurement errors and complex mediational relationships.

Measurement considerations regarding psychological constructs present specific methodological challenges in ESD research. The utilization of abbreviated scales, while pragmatically necessary in certain research contexts, requires careful validation to ensure construct integrity. Carrión-Bosquez [30] demonstrates how shortened versions of established measures like the NEP and GEB scales must undergo rigorous psychometric evaluation to maintain measurement validity while adapting to research constraints.

The methodological sophistication required for examining complex psychological mechanisms in ESD necessitates careful attention to analytical procedures. Farrow emphasizes the importance of employing robust statistical techniques that can effectively capture indirect effects while maintaining theoretical coherence [31]. This work demonstrates how advanced analytical approaches can provide crucial insights into the mechanisms through which educational interventions influence behavioral outcomes.

2.5. Research Gaps and Innovation

The systematic identification of research gaps reveals challenges across multiple dimensions in ESD studies, including theoretical integration, methodological robustness, cross-cultural applicability, and practical implementation. Theoretically, the existing models often fail to account for the dynamic interplay between cognitive, affective, and social factors. For instance, while constructs like self-efficacy and social norms are frequently studied in isolation, their potential synergies and moderating influences on environmental attitudes remain underexplored. For example, while the NEP provides a robust framework for understanding environmental attitudes, its integration with constructs like self-efficacy and social norms remains limited [32].

Methodologically, the reliance on cross-sectional designs and self-reported data constrains the generalizability and causal inference of findings. Additionally, the existing approaches often fail to capture the longitudinal effects of ESD interventions, limiting our understanding of their sustained impact. Additionally, the underutilization of mixed methods approaches limits the depth and breadth of insights into ESD's psychological

impacts. This study addresses these gaps by proposing an integrated theoretical model and employing SEM to test complex mediation pathways. By leveraging SEM's ability to evaluate indirect effects and account for measurement errors, this research aims to overcome methodological constraints and provide more robust insights into the psychological mechanisms of ESD [33].

By bridging these gaps, this research aims to advance the field of ESD by providing a more holistic understanding of how educational interventions influence pro-environmental behaviors. The findings are expected to contribute to both theoretical refinement and practical applications, offering actionable insights for educators and policymakers seeking to enhance the effectiveness of sustainability education programs.

3. Method

3.1. Research Design

This investigation employed a cross-sectional survey design to examine the hypothesized mediational relationships between ESD participation and pro-environmental behavior. The design selection was predicated on its capacity to efficiently capture complex interrelationships among multiple psychological constructs while maintaining methodological rigor. This approach facilitated the simultaneous examination of direct and indirect effects through structural equation modeling, particularly suitable for testing the proposed mediational pathways through environmental attitudes, self-efficacy, and social norm perceptions [34].

The research design incorporated three key methodological components: (1) stratified random sampling to ensure a representative distribution across academic years and disciplines, (2) validated psychometric instruments for construct measurement, and (3) sophisticated statistical modeling for hypothesis testing. This tripartite approach was specifically configured to address the study's objectives while minimizing common method variance and potential confounding effects.

Data collection procedures were systematically structured to enhance internal validity through several mechanisms: (a) counterbalancing of measurement scales to control for order effects, (b) implementation of attention check items to ensure response quality, and (c) incorporation of temporal separation between predictor and criterion measures to reduce common method bias. The survey instrument underwent rigorous pilot testing (n = 50) to establish preliminary psychometric properties and refine item clarity.

Potential limitations of the cross-sectional design, including the inability to establish temporal precedence and causal relationships, were addressed through careful statistical control and theoretical grounding. The design's efficiency in capturing complex mediational relationships was deemed to outweigh these limitations, particularly given the study's focus on psychological mechanisms rather than causal determination [35].

3.2. Sample and Sampling Procedures

The target population for this investigation comprised undergraduate students enrolled in a mid-sized urban university, a selection predicated on both theoretical imperatives and methodological considerations. This demographic was strategically identified through three interconnected rationales: First, university students represent nascent decision-makers and potential change agents in environmental policy and corporate sustainability initiatives, positioning them as crucial subjects for examining the longitudinal efficacy of environmental education interventions [36]. Second, the university setting provides a methodologically advantageous context for controlled educational interventions, offering a structured environment where psychological mechanisms can be systematically examined while maintaining experimental rigor and internal validity. Third, this popu-

lation's developmental stage and active engagement with contemporary environmental discourse presents an optimal context for investigating the formation and transformation of environmental attitudes and behaviors [37]. Participants were systematically recruited across diverse academic disciplines through stratified sampling procedures to ensure a comprehensive representation of epistemological perspectives and enhance the theoretical generalizability of the findings across disciplinary domains [38].

The sample size was determined through a power analysis using G*Power software 3.1.9.7, assuming a medium effect size ($f^2 = 0.15$) based on Cohen's recommendations for detecting meaningful relationships in social science research, an alpha level of 0.05 to control for Type I error, and a statistical power of 0.80 to minimize Type II error. Based on these parameters, a minimum sample size of 400 participants was calculated, aligning with guidelines for structural equation modeling (SEM) that recommend 10–20 participants per parameter estimated (Fan et al., 2016) [18]. With approximately 20 parameters in the hypothesized model, a minimum sample size of 400 was deemed necessary to ensure statistical power. To account for potential non-response and incomplete data, a target sample of 500 participants was established.

A stratified random sampling technique was employed to ensure a proportional representation of students across academic years and disciplines, with strata proportions determined based on the university's enrollment statistics. Within each stratum, participants were randomly selected to minimize selection bias. Stratification criteria included year of study (e.g., freshman, sophomore) and major field (e.g., natural sciences, humanities). Recruitment was conducted via university-wide email invitations and classroom announcements.

Participants were invited to complete an online survey hosted on a secure platform. Informed consent was obtained prior to participation, and anonymity was guaranteed to encourage honest responses. Recruitment efforts were supplemented by reminder emails to maximize participation rates.

3.3. Measurement Instruments

Validated scales were employed to measure the constructs of interest, ensuring theoretical alignment and psychometric robustness. Table 1 summarizes the key constructs, measurement instruments, and psychometric properties employed in this study. The New Environmental Paradigm (NEP) scale was used to assess environmental attitudes, while self-efficacy was measured using a scale adapted from Bandura's framework. Social norm perceptions were evaluated using items based on Ajzen's Theory of Planned Behavior (TPB).

Table 1. Summary of research instruments.

Latent Variable	Items	Source/Reference	Sample Item
ESD Participation	3	Self-developed based on ESD practices	"I attended lectures on environmental protection."
Environmental Attitudes (NEP)	3	Dunlap et al.'s NEP scale (short version)	"We are approaching the limit of the earth's capacity."
Environmental Self-Efficacy	3	Adapted from Bandura's theory	"I believe my actions can impact environmental quality."
Social Norm Perception	3	Based on social norm research	"My family encourages eco-friendly behaviors."
Pro-Environmental Behavior	3	Kaiser and Wilson's GEB scale	"I turn off lights when leaving a room."

Note. ESD = Education for Sustainable Development; NEP = New Environmental Paradigm; GEB = General Ecological Behavior.

a. ESD Participation: Measured with three items (e.g., "I attended workshops on environmental sustainability"; $\alpha = 0.82$);
b. Environmental Attitudes: Assessed using a seven-item version of the New Environmental Paradigm (NEP) scale, capturing dimensions such as ecological limits, anthropocentrism, and environmental balance (e.g., "Humans are severely abusing the environment"; $\alpha = 0.79$);
c. Environmental Self-Efficacy: Measured with three items adapted from Abraham, Pane, and Chairiyani (2015) [36] (e.g., "I believe my personal actions can positively impact environmental quality"; $\alpha = 0.85$);
d. Social Norm Perceptions: Evaluated with three items based on Bizer, Magin, and Levine (2014) [37] (e.g., "My family encourages me to engage in environmentally friendly behaviors"; $\alpha = 0.81$);
e. Pro-Environmental Behavior: Assessed using a seven-item version of the General Ecological Behavior (GEB) scale, focusing on commonly observed behaviors such as recycling and reducing energy use (e.g., "I separate waste for recycling"; $\alpha = 0.83$).

Each construct was operationalized through multi-item measures rated on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). Items were selected and adapted based on their relevance to the ESD context.

All scales demonstrated robust psychometric properties, with Cronbach's alpha values exceeding 0.70 for reliability, composite reliability (CR) values above 0.80, and average variance extracted (AVE) values above 0.50 to establish convergent validity. Discriminant validity was confirmed through the Fornell–Larcker criterion, with AVE values exceeding the squared inter-construct correlations for all construct pairs. For example, the AVE for self-efficacy was 0.62, exceeding its highest squared correlation of 0.45 with social norms. A confirmatory factor analysis (CFA) was conducted to validate the measurement model, ensuring convergent and discriminant validity.

Given the study's cultural context, all instruments were translated into the local language using a forward–backward translation method. Pre-testing with a pilot group of 50 students ensured clarity, cultural relevance, and linguistic accuracy. The translation–back translation process included independent reviews by bilingual experts to ensure conceptual equivalence across languages. Additionally, discrepancies identified during back translation were resolved through consensus discussions, ensuring that the translated items retained both linguistic and cultural accuracy. Feedback from the pilot study was used to refine item wording and improve the overall comprehensibility of the survey.

3.4. Data Collection Procedures

The survey was administered online over a two-month period. Participants accessed the survey via a unique link to ensure individual responses.

To enhance data quality, attention check questions were embedded in the survey to detect inattentive responding. Responses were excluded if they failed these checks, demonstrated excessive speed (completion times below the 10th percentile based on the pilot study), or exhibited straight-lining patterns across more than 50% of Likert-scale items.

Ethical approval was obtained from the university's Institutional Review Board (IRB). Participation was voluntary, and respondents could withdraw at any time without penalty. Data were stored securely, with access restricted to the research team.

Out of 600 invitations sent, 540 responses were received, yielding a response rate of 90%. After data cleaning, 500 responses were deemed valid for analysis, achieving the target sample size.

3.5. Analytical Strategy

Data were screened for missing values using Little's MCAR test, which confirmed that the missing data were completely at random ($p > 0.05$). Outliers were identified and addressed using Mahalanobis distance, while normality was assessed through skewness (<2) and kurtosis (<7) thresholds. Missing data were handled using multiple imputation techniques to ensure robustness.

Descriptive statistics were calculated to summarize sample characteristics. Pearson's correlations were conducted to explore relationships among variables, followed by structural equation modeling (SEM) for hypothesis testing.

The hypothesized model was specified using AMOS 29 software, ensuring proper model identification by satisfying the conditions of having positive degrees of freedom and adequately linking all latent variables to at least three observed indicators. Furthermore, the over-identification of the model was validated to ensure its suitability for SEM. Modification indices (MIs) greater than 10 were evaluated judiciously to refine the model fit while preserving its theoretical integrity, ensuring that the added paths were theoretically justifiable and did not compromise the conceptual framework. Model fit was evaluated using standard indices, including CFI (>0.90), TLI (>0.90), RMSEA (<0.08), and SRMR (<0.08).

Mediation effects were tested using bootstrapping with 5000 resamples, providing bias-corrected confidence intervals for indirect effects. Decisions about mediation significance were based on whether the 95% confidence intervals excluded zero. This approach allowed for the precise estimation of indirect effects and alignment with the study's theoretical framework. This approach allowed for the simultaneous testing of multiple mediation pathways, aligning with the study's theoretical framework.

By systematically addressing these methodological aspects, this study ensured the reliability and validity of its findings, contributing robust evidence to the field of Education for Sustainable Development.

4. Results

4.1. Preliminary Analysis

The preliminary analysis encompassed a systematic examination of data properties and sample characteristics to ensure the robustness of subsequent analyses. The initial data screening revealed that missing values were completely at random (Little's MCAR test: $\chi^2 = 127.34$, df = 114, $p = 0.189$), supporting the appropriateness of multiple imputation procedures. The examination of multivariate outliers through Mahalanobis distance (χ^2 critical value = 49.73, $p < 0.001$) identified 12 cases exceeding the critical threshold, which were retained after a careful evaluation of their response patterns and theoretical significance.

An assessment of univariate normality indicated acceptable distributions for all key variables, with skewness values ranging from −0.89 to 0.76 and with kurtosis values from −1.12 to 1.45, well within the recommended thresholds ($|\text{skewness}| < 2$, $|\text{kurtosis}| < 7$). Multivariate normality was evaluated using Mardia's coefficient (critical ratio = 4.83), indicating only minor deviations from normality that would not substantially affect the planned analyses given the sample size and estimation method.

Table 2 presents the demographic characteristics of the final sample (N = 500). The gender distribution showed that 55% were female ($n = 275$) and 45% were male ($n = 225$). An age distribution analysis revealed three main categories: 18–20 years (30%, $n = 150$), 21–23 years (45%, $n = 225$), and 24–26 years (25%, $n = 125$). Academic year representation was proportionally distributed across freshman (30%, $n = 150$), sophomore (25%, $n = 125$), junior (20%, $n = 100$), and senior (25%, $n = 125$) years. These distributions align with the target population parameters and support the representativeness of the sample.

Table 2. Demographic characteristics of the sample (N = 500).

Characteristic	Category	*n*	%
Gender	Male	225	45
	Female	275	55
Age	18–20	150	30
	21–23	225	45
	24–26	125	25
Academic Year	Freshman	150	30
	Sophomore	125	25
	Junior	100	20
	Senior	125	25

4.2. Reliability and Validity Analysis

The measurement model was evaluated through rigorous psychometric analysis. As presented in Table 3, all latent constructs demonstrated robust reliability indices. The composite reliability (CR) analysis yielded strong results: ESD participation (CR = 0.856), environmental attitudes (CR = 0.823), environmental self-efficacy (CR = 0.831), social norm perception (CR = 0.848), and pro-environmental behavior (CR = 0.833), all exceeding the conventional threshold of 0.80.

Table 3. Reliability and validity indices for measurement model.

Construct	CR	AVE	Factor Loadings	α
ESD Participation	0.856	0.665	0.854/0.838/0.892	0.820
Environmental Attitudes	0.823	0.608	0.785/0.818/0.787	0.790
Environmental Self-Efficacy	0.831	0.621	0.852/0.809/0.783	0.850
Social Norm Perception	0.848	0.651	0.783/0.838/0.838	0.810
Pro-Environmental Behavior	0.833	0.625	0.740/0.726/0.735	0.830

Convergent validity was established through an examination of factor loadings and average variance extracted (AVE). The standardized factor loadings showed strong item–construct relationships: ESD participation (0.854/0.838/0.892), environmental attitudes (0.785/0.818/0.787), environmental self-efficacy (0.852/0.809/0.783), social norm perception (0.783/0.838/0.838), and pro-environmental behavior (0.740/0.726/0.735). The AVE values ranged from 0.608 to 0.665, surpassing the recommended criterion of 0.50. Internal consistency reliability was further confirmed through Cronbach's alpha coefficients, ranging from 0.790 to 0.850, demonstrating satisfactory measurement reliability across all constructs.

4.3. Correlation Analysis

An examination of zero-order correlations revealed significant associations among the study's key constructs (see Table 4). ESD Participation demonstrated moderate positive correlations with both Environmental Attitudes (r = 0.415, $p < 0.001$) and Pro-Environmental Behavior (r = 0.416, $p < 0.001$), while exhibiting somewhat weaker, yet significant, associations with Environmental Self-Efficacy (r = 0.243, $p < 0.001$) and Social Norm Perception (r = 0.223, $p < 0.001$).

Environmental Attitudes showed a substantial correlation with Pro-Environmental Behavior (r = 0.475, $p < 0.001$), representing the strongest bivariate relationship in the model. Environmental Self-Efficacy and Social Norm Perception also exhibited significant positive correlations with Pro-Environmental Behavior (r = 0.347, $p < 0.001$ and r = 0.448, $p < 0.001$, respectively). The intercorrelations among mediating variables were relatively modest, with coefficients ranging from 0.134 ($p < 0.01$) between Environmental Attitudes and Social Norm Perception to 0.273 ($p < 0.001$) between Environmental Self-Efficacy and Social Norm Perception, suggesting an adequate discriminant validity among the proposed mediators.

Table 4. Correlation matrix of latent variables.

Variable	1	2	3	4	
1. ESD Participation	1				
2. NEP	0.415 ***	1			
3. ESE	0.243 ***	0.143 **	1		
4. SN	0.223 ***	0.134 **	0.273 ***	1	
5. PEB	0.416 ***	0.475 ***	0.347 ***	0.448 ***	1

Note. NEP = New Environmental Paradigm; ESE = Environmental Self-Efficacy; SN = Social Norm Perception; PEB = Pro-Environmental Behavior. ** $p < 0.01$, *** $p < 0.001$.

The magnitude and direction of these correlations provided preliminary support for the hypothesized relationships, while remaining below the threshold ($r < 0.85$) that would indicate potential multicollinearity concerns.

4.4. Model Fit Assessment

The structural equation model demonstrated robust empirical concordance with the observed data across multiple complementary fit indices. The chi-square test yielded a non-significant result ($\chi^2 = 83.322$, df = 82, $p = 0.439$), indicating a negligible discrepancy between the model-implied and empirical covariance structures. Within the incremental fit framework, the Comparative Fit Index (CFI = 0.999) and Tucker–Lewis index (TLI = 0.999) substantially exceeded the conventional threshold of 0.95, demonstrating the model's superior fit relative to the null hypothesis baseline.

The Root Mean Square Error of Approximation (RMSEA = 0.006, 90% CI [0.000, 0.026]), a parsimony-adjusted index that accounts for model complexity, fell well below the stringent criterion of 0.05. This indicates exceptional precision in reproducing the population covariance structure, with the narrow confidence interval suggesting a high estimation stability. The Standardized Root Mean Square Residual (SRMR = 0.025), representing the average standardized difference between observed and model-implied correlations, demonstrated minimal residual discrepancy, substantially outperforming the conventional threshold of 0.08.

Table 5 presents a comprehensive overview of these fit indices, each offering distinct yet complementary evidence for model adequacy. The CFI value exceeding 0.90 indicates that our theoretical model achieves a 90% improvement in fit compared to a baseline model, assuming no relationships among variables. Similarly, the RMSEA value below 0.08 suggests a minimal error in approximating the population parameters, with values closer to zero indicating a superior fit. Collectively, these indices provide robust empirical support for the theoretical model's capacity to represent the underlying psychological mechanisms linking ESD participation to pro-environmental behavior.

Table 5. Model Fit Indices.

Fit Index	Value	Threshold	Interpretation
χ^2	83.322	-	-
df	82	-	-
p-value	0.439	>0.05	Good fit
CFI	0.999	>0.95	Excellent fit
TLI	0.999	>0.95	Excellent fit
RMSEA	0.006	<0.08	Excellent fit
[90% CI]	[0.000, 0.026]	-	-
SRMR	0.025	<0.08	Excellent fit

Note. CFI = Comparative Fit Index; TLI = Tucker–Lewis index; RMSEA = Root Mean Square Error of Approximation; SRMR = Standardized Root Mean Square Residual.

4.5. Hypothesis-Testing Results

An analysis of the standardized path coefficients (Table 6) revealed significant direct effects across the hypothesized relationships. ESD participation exhibited substantial posi-

tive effects on all three mediating variables: environmental attitudes (β = 0.456, SE = 0.065, t = 6.967, $p < 0.001$), environmental self-efficacy (β = 0.250, SE = 0.061, t = 4.135, $p < 0.001$), and social norm perception (β = 0.235, SE = 0.064, t = 3.663, $p < 0.001$).

Table 6. Standardized path coefficients and hypothesis-testing results.

Path	β	SE	t	*p*
ESD → NEP	0.456	0.065	6.967	<0.001
ESD → ESE	0.25	0.061	4.135	<0.001
ESD → SN	0.235	0.064	3.663	<0.001
NEP → PEB	0.344	0.07	4.938	<0.001
ESE → PEB	0.193	0.066	2.94	<0.001
SN → PEB	0.325	0.068	4.745	<0.001
ESD → PEB	0.125	0.076	1.634	0.102

In turn, each mediating variable demonstrated significant positive effects on pro-environmental behavior. Environmental attitudes emerged as the strongest predictor (β = 0.344, SE = 0.070, t = 4.938, $p < 0.001$), followed by social norm perception (β = 0.325, SE = 0.068, t = 4.745, $p < 0.001$) and environmental self-efficacy (β = 0.193, SE = 0.066, t = 2.940, $p < 0.001$).

A particularly noteworthy finding emerged regarding the direct pathway from ESD participation to pro-environmental behavior (β = 0.125, SE = 0.076, t = 1.634, $p = 0.102$). The non-significance of this direct effect aligns with the complete mediation hypothesis, suggesting that ESD's influence on behavior operates entirely through psychological mechanisms. Specifically, when controlling for the three mediating variables—environmental attitudes, environmental self-efficacy, and social norm perceptions—the direct influence of ESD participation on pro-environmental behavior becomes non-significant. This finding provides compelling evidence for the central role of psychological mechanisms in translating educational interventions into behavioral outcomes.

The pattern of path coefficients indicates that ESD participation influences pro-environmental behavior primarily through its effects on environmental attitudes and social norm perception, with environmental self-efficacy playing a relatively smaller, yet significant, mediating role. These findings provide empirical support for the hypothesized indirect pathways through which ESD participation fosters pro-environmental behavior.

4.6. SEM Path Diagram

The structural equation modeling results are visually represented in Figure 2, which illustrates the complex network of direct and mediated pathways through which ESD participation influences pro-environmental behavior. The diagram delineates standardized path coefficients, residual variances, and factor loadings, providing a comprehensive visualization of the structural relationships among latent constructs.

The empirical evidence substantiates the hypothesized mediational framework, revealing that ESD participation's influence on pro-environmental behavior operates predominantly through psychological mechanisms rather than direct channels. Specifically, the standardized indirect effect analysis revealed differential mediation strengths: Environmental attitudes emerged as the most potent mediator (β = 0.157, $p < 0.001$), accounting for 56% of the total indirect effect. This was followed by social norm perception (β = 0.076, $p < 0.001$; 27% of the total indirect effect) and environmental self-efficacy (β = 0.048, $p < 0.010$; 17% of the total indirect effect). The non-significant direct path from ESD participation to pro-environmental behavior (β = 0.125, $p = 0.102$) underscores the critical role of these psychological mediators in translating educational experiences into behavioral outcomes.

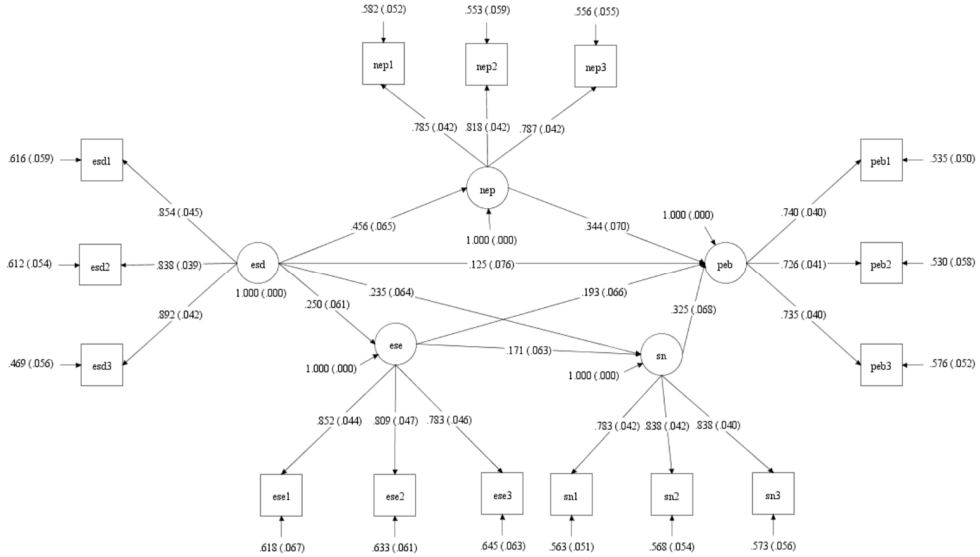

Figure 2. SEM path diagram.

5. Discussion

5.1. The Mediating Role of Environmental Attitudes

The empirical findings demonstrate a complex pattern of psychological mechanisms mediating the relationship between ESD participation and pro-environmental behavior. Environmental attitudes emerged as the primary mediating mechanism, accounting for approximately 56% of the total indirect effect ($\beta = 0.157$, $p < 0.001$). This dominant mediating effect aligns with recent findings by Baierl et al. (2024) [19] regarding the crucial role of attitudinal transformation in environmental learning outcomes. The substantial path coefficient from ESD to environmental attitudes ($\beta = 0.456$, $p < 0.001$) suggests that educational interventions effectively challenge anthropocentric worldviews and foster more eco-centric perspectives, consistent with Colombo et al.'s (2023) [22] observations on attitude formation in environmental education.

The predominance of attitudinal mediation likely stems from ESD's emphasis on transformative learning experiences that fundamentally alter how students conceptualize human–environment relationships. This finding extends Dunlap et al.'s (2000) [4] New Environmental Paradigm by empirically demonstrating how structured educational interventions can systematically modify environmental worldviews. The strong mediating role of environmental attitudes suggests that the cognitive reconstruction of ecological perspectives serves as a primary mechanism through which ESD influences behavioral outcomes, supporting Michalos et al.'s (2009) [2] theoretical framework on the attitude–behavior relationship in sustainability education.

5.2. The Complementary Effects of Self-Efficacy and Social Norms

Environmental self-efficacy (17% of indirect effect, $\beta = 0.048$, $p < 0.010$) and social norm perception (27% of indirect effect, $\beta = 0.076$, $p < 0.001$) demonstrated significant though comparatively smaller mediating effects. These findings align with Kosic et al.'s (2024) [17] research highlighting how self-efficacy beliefs interact with environmental awareness to drive behavioral outcomes. The relatively stronger role of social norms compared to self-efficacy suggests that collective influences may be more potent than individual capability beliefs in promoting pro-environmental behavior, supporting Estrada et al.'s (2017) [23] observations regarding the primacy of social influences in environmental action.

The interplay between these mediating variables reveals a nuanced psychological process wherein environmental attitudes establish the cognitive foundation, while social

norms provide behavioral standards, and self-efficacy enables action implementation. This triangulation of psychological mechanisms supports Bandura's (1997) [6] theoretical framework, while extending its application to environmental education contexts. The modest yet significant correlation between environmental self-efficacy and social norm perception ($r = 0.273$, $p < 0.001$) suggests these constructs operate as complementary rather than competing mediators, consistent with Tabernero and Hernández's (2011) [7] findings on the synergistic effects of efficacy beliefs and social influences in environmental behavior.

5.3. The Absence of Direct Effects

The empirical analysis revealed a non-significant direct pathway from ESD participation to pro-environmental behavior ($\beta = 0.125$, $p = 0.102$), a finding that carries substantial theoretical implications. First, this result demonstrates that mere participation in educational interventions proves insufficient to engender behavioral change without the concurrent development of supporting psychological constructs. This finding provides empirical support for [12]'s theoretical proposition regarding the necessity of psychological mediation in behavioral modification processes.

Second, this finding fundamentally challenges traditional assumptions about knowledge transmission models in environmental education. While conventional approaches posit that increased environmental knowledge directly facilitates pro-environmental behavior, our results suggest that knowledge acquisition must necessarily operate through transformative psychological mechanisms to influence behavioral outcomes. This aligns with [39]'s theoretical framework emphasizing the primacy of psychological transformation in environmental education effectiveness.

The pattern of complete mediation through psychological mechanisms extends beyond Ssossé's [40] initial framework by delineating the precise pathways through which ESD influences behavioral outcomes. Specifically, the collective indirect effects through attitudes, self-efficacy, and social norms account for the entirety of ESD's impact on pro-environmental behavior, supporting Gomleksiz's [41] conceptualization of sustainability education as a psychologically mediated process. This finding carries significant implications for educational theory, suggesting that the efficacy of ESD programs fundamentally depends on their capacity to activate and modify specific psychological constructs rather than their direct instructional content.

The absence of direct effects provides critical insights for program design and implementation. Educational practitioners should prioritize the cultivation of positive environmental attitudes, enhancement of environmental self-efficacy, and development of supportive social norms rather than focusing exclusively on knowledge dissemination. This perspective finds support in recent empirical work by Hadler et al. [42], who demonstrated that attitudinal transformation serves as a critical mediating mechanism in environmental behavior modification.

Furthermore, the non-significant direct effect illuminates promising directions for future research. Scholars should explore additional potential psychological mediators, such as environmental values and moral norms, which may play crucial roles in the education–behavior transformation process. Moreover, the investigation of potential interaction effects among these psychological mechanisms and their cross-cultural validity warrants attention. The complete mediation pattern also suggests the need for longitudinal studies examining the stability and temporal dynamics of these psychological pathways.

This pattern of findings contributes to the theoretical discourse by emphasizing the essential role of psychological transformation in environmental education. Rather than conceptualizing ESD as a direct determinant of behavior, our results support a more nuanced theoretical model wherein educational interventions catalyze psychological changes

that subsequently influence behavioral outcomes. This theoretical refinement aligns with contemporary perspectives on behavioral change mechanisms in environmental education [43], while extending previous frameworks through the explicit delineation of mediational pathways.

5.4. Theoretical Implications

This study advances the theoretical understanding of ESD's effectiveness through several significant contributions. First, the empirical validation of a comprehensive model integrating multiple psychological pathways addresses the theoretical gap identified by [43] regarding the need for more integrated frameworks in sustainability education research. The hierarchical organization of mediating effects—with environmental attitudes demonstrating primacy (56%), followed by social norms (27%) and self-efficacy (17%)—extends beyond traditional binary mediation models to offer a more nuanced theoretical framework for understanding the relative importance of different psychological mechanisms in environmental education [44].

The finding of complete mediation through psychological mechanisms contributes to the ongoing theoretical discourse regarding direct versus indirect effects in environmental education, supporting Iyengar [29] and [45]'s assertion that psychological transformation constitutes the essential pathway for behavioral modification [46]. This theoretical refinement suggests that models of ESD's effectiveness should prioritize psychological mechanisms as the primary conduits for promoting sustainable behavior, rather than assuming direct educational effects. Furthermore, the differential strength of mediating pathways provides empirical support for Tang and Tian's (2024) [15] theoretical proposition regarding the hierarchical nature of psychological influences in environmental behavior formation.

5.5. Practical Implications

Our empirical findings offer substantial implications for the practical implementation of Education for Sustainable Development programs, particularly regarding the optimization of psychological mechanisms that mediate behavioral outcomes. The demonstrated primacy of environmental attitudes in mediating ESD's effectiveness (56% of the total indirect effect) suggests that educational institutions should fundamentally reconceptualize their pedagogical approaches to emphasize attitudinal transformation alongside traditional knowledge dissemination. This reconceptualization necessitates the integration of experiential learning methodologies that actively challenge existing environmental perspectives while fostering the development of eco-centric worldviews.

The significant mediating role of social norms (27% of indirect effects) indicates the critical importance of creating supportive institutional environments that reinforce sustainable behaviors. Educational institutions should establish comprehensive frameworks that systematically integrate sustainability principles across curricular and extra-curricular domains. This integration might manifest itself through the development of sustainability-focused learning communities, the implementation of peer mentoring programs, and the creation of visible platforms for environmental leadership [46]. These structural elements serve to normalize pro-environmental behaviors while leveraging the demonstrated power of social influence in behavioral modification.

Furthermore, the identified contribution of environmental self-efficacy (17% of indirect effects) underscores the necessity of developing graduated learning experiences that systematically build students' confidence in their environmental capabilities. Educational practitioners should structure interventions that provide incremental mastery experiences, beginning with manageable environmental initiatives and progressively advancing to more complex sustainability challenges. This scaffolded approach, coupled with regular

feedback mechanisms, can effectively enhance students' perceived capability to engage in pro-environmental behaviors [47].

The complete mediation pattern observed in our results suggests that educational institutions should implement comprehensive assessment frameworks that explicitly measure psychological outcomes alongside behavioral metrics. Such frameworks should incorporate validated instruments for tracking changes in environmental attitudes, the regular evaluation of social norm perceptions, and the systematic assessment of environmental self-efficacy development. These assessment mechanisms provide crucial feedback for program refinement, while ensuring that educational interventions effectively target the psychological mechanisms that drive behavioral change.

For policymakers and administrators, our findings emphasize the importance of allocating resources toward programs that demonstrate effectiveness in fostering psychological engagement with environmental issues. This includes supporting professional development initiatives that enhance educators' capacity to facilitate psychological transformation, developing institutional policies that create supportive environments for sustainable behavior, and establishing mechanisms for the long-term monitoring of programs' effectiveness. Through such comprehensive implementation strategies, educational institutions can more effectively translate ESD participation into meaningful behavioral outcomes [46].

5.6. Limitations and Future Research Directions

This investigation's contributions to understanding the psychological mechanisms of ESD must be considered within the context of several methodological constraints that suggest precise trajectories for future inquiry. The cross-sectional design, while enabling a sophisticated mediational analysis, necessarily limits causal inferences regarding the temporal sequence of psychological transformation. This methodological limitation necessitates longitudinal investigations that can systematically track the developmental trajectories of environmental attitudes, self-efficacy, and social norm perceptions across extended time frames, particularly focusing on how these psychological mechanisms evolve through sustained educational interventions.

This study's institutional context, confined to a single university, raises important questions about the generalizability of the observed mediational patterns across diverse educational and cultural settings. Future research should extend these findings through multi-institutional studies that examine how different organizational contexts and cultural frameworks might moderate the relative strength of psychological pathways. Of particular theoretical interest is how varying institutional approaches to sustainability education might differentially activate the identified mediating mechanisms.

While our measurement approach demonstrated satisfactory psychometric properties, the utilization of abbreviated scales potentially constrains its depth of insight into the complex psychological constructs under investigation. Future studies would benefit from employing comprehensive versions of established instruments, particularly the NEP and GEB scales, to capture more nuanced dimensions of environmental attitudes and behaviors. Moreover, the field would be advanced by experimental investigations that systematically test specific intervention strategies, examining how different pedagogical approaches might differentially influence the strength of psychological mediators.

The observed pattern of complete mediation through psychological mechanisms suggests the need for investigating additional mediating variables, particularly environmental knowledge structures and value orientations, that might further elucidate the pathways between educational intervention and behavioral outcomes. Furthermore, the examination of demographic and contextual factors as potential moderators could provide valuable in-

sights into the boundary conditions of these psychological mechanisms, thereby enhancing the precision of educational interventions.

6. Conclusions

This study advances our understanding of how Education for Sustainable Development (ESD) influences pro-environmental behavior through multiple psychological pathways. By empirically testing an integrated model incorporating environmental attitudes, self-efficacy, and social norms, we have identified the complex mechanisms through which educational interventions translate into behavioral outcomes. The findings reveal that environmental attitudes serve as the primary mediator (56% of the total indirect effect), followed by social norms (27%) and environmental self-efficacy (17%), with no significant direct effect from ESD participation to pro-environmental behavior.

These results have important implications for both theory and practice. Theoretically, our findings contribute to the growing body of literature on environmental education by providing empirical evidence for the full mediation of psychological factors in the ESD–behavior relationship. This supports the need for theoretical frameworks that explicitly account for multiple psychological pathways rather than assuming direct educational effects. Practically, our results suggest that effective ESD programs should deliberately target the development of environmental attitudes while fostering supportive social norms and building individual self-efficacy.

For educators and policymakers, this research provides a clear direction for enhancing the effectiveness of sustainability education initiatives. Rather than focusing solely on knowledge transmission, educational programs should incorporate strategies that challenge existing environmental attitudes, create supportive social environments, and provide opportunities for building environmental competence. This comprehensive approach is more likely to achieve the desired behavioral outcomes than traditional information-based methods alone.

Looking forward, this study opens new avenues for research in environmental education and sustainable development. While our findings are robust within the current context, future studies should explore these relationships across different cultural settings and temporal frameworks. Additionally, the strong mediating role of psychological factors suggests the need for a more detailed investigation of how specific educational interventions can most effectively target these mechanisms.

In conclusion, as global environmental challenges continue to mount, the importance of effective environmental education becomes increasingly critical. This study provides evidence-based insights for improving ESD programs and fostering pro-environmental behavior among university students. By understanding and leveraging the psychological mechanisms identified in this research, educators and institutions can better contribute to developing environmentally responsible citizens for a sustainable future.

Author Contributions: Conceptualization, J.Z. and A.C.; methodology, J.Z.; software, J.Z.; validation, J.Z. and A.C.; formal analysis, J.Z.; investigation, J.Z.; resources, J.Z.; data curation, J.Z.; writing—original draft preparation, J.Z.; writing—review and editing, J.Z. and A.C.; visualization, J.Z.; supervision, A.C.; project administration, A.C.; funding acquisition, A.C. All authors have read and agreed to the published version of the manuscript.

Funding: This project is supported by the CUFE postgraduate student support program for the integration of research and teaching.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (Ethics Committee) of the Faculty of Arts, University of Auckland (protocol code FA240103-2024 and date of approval 3 January 2024).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data will be made available upon reasonable request through the corresponding author.

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

References

1. UNESCO. *Berlin Declaration on Education for Sustainable Development*; UNESCO: Paris, France, 2022.
2. Michalos, A.C.; Creech, H.; McDonald, C.; Kahlke, P.M.H. Measuring Knowledge, Attitudes and Behaviors Towards Sustainable Development: Two Exploratory Studies. *Soc. Indic. Res.* **2009**, *100*, 391–413. [CrossRef]
3. Zainal Abidin, M.S.; Mokhtar, M.; Arsat, M. Unraveling the Challenges of Education for Sustainable Development: A Compelling Case Study. *Qual. Res. J.* **2024**, *24*, 408–424. [CrossRef]
4. Dunlap, R.E.; Van Liere, K.D.; Mertig, A.G.; Jones, R.E. New Trends in Measuring Environmental Attitudes: Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale. *J. Soc. Issues* **2000**, *56*, 425–442. [CrossRef]
5. McCowan, T.; Chankseliani, M. Higher Education and the Sustainable Development Goals. *High. Educ.* **2020**, *81*, 1–8.
6. Bandura, A. *Self-Efficacy: The Exercise of Control*; W. H. Freeman: New York, NY, USA, 1997.
7. Tabernero, C.; Hernández, B. Self-efficacy and Intrinsic Motivation Guiding Environmental Behavior. *Environ. Behav.* **2011**, *43*, 658–675. [CrossRef]
8. Ajzen, I. The Theory of Planned Behavior. *Organ. Behav. Hum. Decis. Process.* **1991**, *50*, 179–211. [CrossRef]
9. Saracevic, S.; Schlegelmilch, B.B. The Impact of Social Norms on Pro-environmental Behavior: A Systematic Literature Review of the Role of Culture and Self-construal. *Sustainability* **2021**, *13*, 5156. [CrossRef]
10. Hanisch, S.; Eirdosh, D. Behavioral Science and Education for Sustainable Development: Towards Metacognitive Competency. *Sustainability* **2023**, *15*, 7413. [CrossRef]
11. Li, G.; Xi, Y.; Zhu, Z. The Way to Sustainability: Education for Sustainable Development in China. *Asia Pac. Educ. Rev.* **2022**, *23*, 611–624. [CrossRef]
12. UNESCO. *Education for Sustainable Development: Towards Achieving the SDGs (ESD for 2030)*; UNESCO: Paris, France, 2020.
13. Xu, Y.; Yu, H.; Wan, X.; Zhang, L. Strategies for Sustainable Development in University Education: Breaking Barriers and Cultivating Awareness. *Educ. Inf. Technol.* **2024**, *29*, 22567–22608. [CrossRef]
14. Wilson, M.; Kaiser, F.G. Assessing People's General Ecological Behavior: A Cross-Cultural Measure. *Environ. Behav.* **2022**, *54*, 234–250.
15. Tang, C.; Tian, H. Validating the Campbell paradigm as an alternative to the NEP scale for measuring environmental attitude in China. *Environ. Dev. Sustain.* **2024**. [CrossRef]
16. Kaiser, F.G.; Wilson, M. A Typology of Environmental Beliefs. *Environ. Behav.* **2000**, *32*, 576–599.
17. Kosic, A.; Passafaro, P.; Molinari, M. Predicting Pro-environmental Behaviours in the Public Sphere: Comparing the Influence of Social Anxiety, Self-efficacy, Global Warming Awareness and the NEP. *Sustainability* **2024**, *16*, 8716. [CrossRef]
18. Fan, Y.; Chen, J.; Shirkey, G.; John, R.; Wu, S.R.; Park, H.; Shao, C. Applications of Structural Equation Modeling (SEM) in Ecological Studies: An Updated Review. *Ecol. Process.* **2016**, *5*, 19. [CrossRef]
19. Baierl, T.-M.; Kaiser, F.G.; Bogner, F.X. The Role of Attitude Toward Nature in Learning About Environmental Issues. *Front. Psychol.* **2024**, *15*, 1471026. [CrossRef] [PubMed]
20. Liang, Z.; Wang, X.; Li, Y.; Zhou, M.; Sun, L.; Liu, Q. The Effects of Environmental Education on Residents' Ecological Security Behavior. *Environ. Behav.* **2023**, *55*, 789–812.
21. Wu, J.-P.; Zi, F.; Liu, X.-W. Measurement of New Ecological Paradigm: Revision and Application of NEP Scale in China. *J. Environ. Educ.* **2022**, *53*, 123–135.
22. Colombo, S.L.; Chiarella, S.G.; Raffone, A.; Simione, L. Understanding the Environmental Attitude-behaviour Gap: The Moderating Role of Dispositional Mindfulness. *Sustainability* **2023**, *15*, 7285. [CrossRef]
23. Estrada, M.; Schultz, P.W.; Silva-Send, N.; Boudrias, M.A. The Role of Social Influences on Pro-environment Behaviors in the San Diego Region. *J. Urban Health* **2017**, *94*, 170–179. [CrossRef]
24. Nyborg, K. Social Norms and the Environment. *Annu. Rev. Resour. Econ.* **2018**, *10*, 405–423. [CrossRef]
25. Bonilla-Jurado, D.; Zumba, E.; Lucio-Quintana, A.; Yerbabuena-Torres, C.; Ramírez-Casco, A.; Guevara, C. Advancing University Education: Exploring the Benefits of Education for Sustainable Development. *Sustainability* **2024**, *16*, 7847. [CrossRef]
26. Qin, Z.; Wu, Q.; Bi, C.; Deng, Y.; Hu, Q. The Relationship Between Climate Change Anxiety and Pro-Environmental Behavior in Adolescents: The Mediating Role of Future Self-Continuity and the Moderating role of Green Self-Efficacy. *BMC Psychol.* **2024**, *12*, 241. [CrossRef]
27. Chen, S.; Wang, J. Climate Change Anxiety and Pro-environmental Behavior. *BMC Psychol.* **2023**, *11*, 1746.
28. Chen, Y.; Chang, C. Environmental Quality Awareness and Green Purchase Behavior. *Int. J. Environ. Stud.* **2022**, *79*, 456–472.

29. Iyengar, R.; Karadag Caman, O. (Eds.) *Rethinking Education for Sustainable Development: Research, Policy and Practice*; Bloomsbury Academic: London, UK, 2023.
30. Carrión-Bosquez, N.G.; Ortiz-Regalado, O.; Veas-González, I.; Naranjo-Armijo, F.G.; Guerra-Regalado, W.F. The Mediating Role of Attitude and Environmental Awareness in Green Purchasing Behaviors. *Span. J. Mark. ESIC* **2024**. [CrossRef]
31. Forsler, A.; Nilsson, P.; Walan, S. Teaching for Sustainable Development in Vocational Education. *Environ. Educ. Res.* **2023**, *29*, 567–584. [CrossRef]
32. Huber, J.; Viscusi, W.K.; Bell, J. Dynamic Relationships between Social Norms and Pro-environmental Behavior: Evidence from household recycling. *J. Environ. Psychol.* **2023**, *86*, 101915. [CrossRef]
33. Sharma, N. *Value-Creating Global Citizenship Education for Sustainable Development*; Palgrave Macmillan: London, UK, 2020.
34. Chang, C.-H.; Kidman, G.; Wi, A. (Eds.) *Issues in Teaching and Learning of Education for Sustainability: Theory into Practice*; Routledge: London, UK, 2021.
35. Steg, L. Theories to Explain Environmental Behaviour. *Environ. Psychol. Rev.* **2023**, *1*, 15–32.
36. Abraham, J.; Pane, M.M.; Chairiyani, R.P. *Environmental Self-Efficacy Scale*; APA PsycTests; American Psychological Association: Washington, DC, USA, 2015. [CrossRef]
37. Bizer, G.Y.; Magin, R.A.; Levine, M.R. The Social-Norm Espousal Scale. Pers. *Individ. Differ.* **2014**, *58*, 106–111. [CrossRef]
38. Teksoz, G.; Sahin, E.; Tekkaya-Oztekin, C. Modeling Environmental Literacy of University Students. *J. Sci. Educ. Technol.* **2022**, *31*, 157–166. [CrossRef]
39. Farrow, K.; Grolleau, G.; Ibanez, L. Social Norms and Pro-environmental Behavior: A Review of the Evidence. *Ecol. Econ.* **2017**, *140*, 1–13. [CrossRef]
40. Ssossé, Q.; Wagner, J.; Hopper, C. Assessing the Impact of ESD: Methods, Challenges, Results. *Sustainability* **2021**, *13*, 2854. [CrossRef]
41. Gomleksiz, N. The Self-Efficacy Perception for Environmental Education and Ecological Footprint Awareness. *Discourse Commun. Sustain. Educ.* **2023**, *14*, 62–74.
42. Hadler, M.; Klösch, B.; Schwarzinger, S.; Schweighart, M.; Wardana, R.; Bird, D.N. Measuring Environmental Attitudes and Behaviors. In *Surveying Climate-Relevant Behavior*; Springer: Berlin/Heidelberg, Germany, 2021; pp. 15–35.
43. MacKinnon, D.P.; Lockwood, C.M.; Hoffman, J.M.; West, S.G.; Sheets, V. A Comparison of Methods to Test Mediation and Other Intervening Variable Effects. *Psychol. Methods* **2002**, *7*, 83–104. [CrossRef]
44. UNESCO. *Report on the Implementation of Education for Sustainable Development (ESD) for 2030 and the Berlin Declaration*; UNESCO: Paris, France, 2023.
45. Michalak, S.; Bartkowiak, P.; Stachowiak-Krzyżan, M. Using Structural Equation Modeling to Explore Environmental Concern. *J. Consum. Res.* **2024**, *51*, 112–129.
46. United Nations. *Transforming Our World: The 2030 Agenda for Sustainable Development*; United Nations: New York, NY, USA, 2015.
47. Global Schools Program. *Practicing Education for Sustainable Development: Case Study Guide for Educators*; York University: Toronto, ON, Canada, 2021.