Environmental Education in Low-income and Middle-income Countries: A Systematic Review and Meta-Analysis

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Abstract

Behavior change is a critical part of effectively addressing climate change. Environmental education stands out as a sustainable long-term strategy for mitigating its impacts. Despite the growing implementation of environmental education in low- and middle-income countries (LMICs), comprehensive data on its successes or shortcomings remain relatively scarce compared to the wealth of evidence available from non-LMIC contexts. This study performed a robust variance estimation meta-analysis on 187 independent effect sizes, involving 34,283 participants. The results indicated a positive and significant effect of environmental education in LMICs (Hedges' g = 1.11, 95% CI [0.87, 1.35]). Specifically, participation in environmental education programmers was associated with increased environmental knowledge (Hedges' g = 1.35, 95% CI [1.02, 1.69]), environmental attitudes (Hedges' g = 0.94, 95% CI [0.56, 1.32]), and environmental behaviors (Hedges' g = 0.68, 95% CI [0.46, 0.90]). Moderator analyses revealed that outcomes differed by intervention length, measurement time, age, and national development level, while study design, education level, intervention type, and gender did not show significant differences in outcomes. This study underscores the importance of implementing environmental education in LMICs, providing valuable insights for future research and practical applications in these contexts.

Keywords: Environmental education, low-income and middle-income country, environmental behavior, environmental attitude, environmental knowledge, meta-analysis

Introduction

The impacts of climate change on public health and the economy are continuously escalating (Romanello et al., 2023). This overarching crisis has reached the level of a global health emergency (Abbasi et al., 2023). To address these challenges, countries worldwide are actively promoting various measures to effectively mitigate climate change (Lu et al., 2023; Moran et al., 2020). Recognizing anthropogenic factors as the primary contributors to climate change (Masson-Delmotte et al., 2021), researchers advocate for more intervention measures to promote pro-environmental behavior (Creutzig et al., 2016). Environmental education is an essential component in promoting long-term behavioral changes at the individual level and continually gaining attention (Otto et al., 2020; UNESCO, 2021; Varela-Candamio et al., 2018).

In many developed countries, environmental education has become an integral part of the education system. For example, in 1969, the United States passed the National Environmental Policy Act (NEPA). The National Environmental Education Act (NEEA) of 1990 is the only federal legislation solely focused on environmental education (Fasolya, 2016; Potter, 2009), establishing a national framework, directing the EPA to manage environmental education programs, and creating the National Environmental Education Foundation (NEEF) to support these initiatives. The German government has also enacted many laws and regulations on environmental education from the 1970s to the present (Schleicher, 1995; Tapia & Blochmann, 2000). In low- and middle-income countries (LMICs), however, environmental education has yet to gain traction due to a lack of educational resources (Ma & Chen, 2023; Trotter et al., 2022). There is an urgent need for comprehensive evidence to assess the current state of environmental education in LMICs and to provide more effective guidance to mitigate climate change.

Environmental Education

The objective of environmental education, as emphasized by UNESCO (1977), is to cultivate a global population equipped with the knowledge, skills, attitudes, motivations, and commitment necessary to address current challenges and prevent new ones. Consistent with this, the action competence approach emphasizes that climate change mitigation behavior should be experiential and evidence-based knowledge (Jensen & Schnack, 2006). Breiting & Mogensen (1999) introduced three components of action competence: knowledge of action possibilities, confidence in one's influence, and willingness to act. Enhanced action competence involves developing comprehensive and flexible knowledge about action possibilities, possessing self-efficacy and empowerment to act, and being passionate and willing to engage in sustainability transformations at various societal levels. Building on the theory of planned behavior, it's crucial to recognize the influence of external factors on environmental awareness and perceived behavior control, subsequently driving behavioral intentions (Ajzen, 1991; Horvat & Smrekar, 2017). In this context, sustainability-related knowledge is considered a prerequisite for successful action and is a crucial element of environmental education (Frick et al., 2004; Oinonen et al., 2023).

We adopted van de Wetering et al. (2022) definition of environmental education, which encompasses all programs aimed at providing children and adolescents in school settings, with knowledge or training to enhance their environmental outcomes. These interventions should be specifically designed to address environmental issues, rather than being part of regular school activities. They can be implemented in both formal settings, such as classroom instruction, and informal settings, such as outdoor education. In this study, we focused exclusively on interventions within school settings, excluding those targeting community adolescents or brief information dissemination, as they did not meet our criteria for environmental education. We also focused on outdoor education, which is a form of intentional, structured education designed to enhance students' knowledge, attitudes, or behaviors related to environmental issues through outdoor experiences. Single outdoor activities were excluded, as they may simply be part of regular school activities and are not necessarily centered around environmental objectives, such as outdoor activities aimed at physical exercise. Educational programs must be explicitly designed with these environmental objectives in mind.

Existing research has underscored the effectiveness of environmental education in addressing climate change (Nalipay et al., 2023; Varela-Candamio et al., 2018). Van de Wetering et al. (2022) found a significant increase in environmental knowledge among adolescents through environmental education, with comparatively lower improvements in environmental attitude and behavior. Ardoin et al. (2023) found that environmental education programs can impact individual-level outcomes, including civic knowledge and understanding, civic attitudes and dispositions, civic skills, and civic action.

Environmental Education in LMICs

Environmental education is essential for LMICs due to their contributions to and vulnerabilities in the climate crisis (Blicharska et al., 2017; Huq et al., 2013; Vaidyanathan, 2023). LMICs often rely on natural resources such as agriculture and fisheries as their primary economic pillars, and face significant challenges from climate change-induced variations in factors such as temperature and rainfall. These changes can lead to decreased productivity, exacerbating food shortages and livelihood challenges. Furthermore, LMICs frequently face higher risks of natural disasters, such as hurricanes, floods, and droughts. (Aleksandrova, 2020; Borg et al., 2021). Climate change has the potential to escalate the frequency and intensity of these disasters, directly impacting social infrastructure, human settlements, and public health (Martins et al., 2023; Mousavi et al., 2020). The increasing impact of climate change on LMICs is confirmed by existing research (Fuhr, 2021; Fuller et al., 2022).

Public awareness of climate change is low in some LMICs, underscoring the urgent need for environmental education (Lee et al., 2015). Citizens in LMICs may face more problems than environmental issues, such as the need for daily subsistence. However, active engagement and actions within LMICs are essential to effectively mitigate the global impacts of climate change. Current research indicates insufficient attention to environmental education in LMICs, emphasizing the necessity for more in-depth studies to understand the specific challenges and opportunities these nations face (Sharifi, 2021).

Potential Moderator

Several factors, including aspects of curriculum design and student characteristics, have a significant impact on the effectiveness of education (Dignath & Büttner, 2008; Kyriakides et al., 2013). In-depth exploration of the conditions fostering optimal effectiveness becomes imperative, particularly within the constraints of limited resources prevalent in LMICs (Monroe et al., 2019). For study characteristics, we focused on intervention type, intervention length, measurement time, and study design. For subject characteristics, we focused on educational level, gender, age, and country developmental level.

We first focus on the intervention type. Different intervention types yield disparate results. Typical environmental education is classroom and informal settings. The active engagement of learners through participatory methods proves more effective in fostering student involvement than traditional, passive classroom learning (Pellitier et al., 2023; Robelia et al., 2011; Varela-Losada et al., 2016). In order to maximize the impact of environmental education, some studies integrate various types of environmental education into a wide range of activities, which yields better results (Ogelman, 2012; Wayan Sukarjita et al., 2015).

The intervention length emerges as a critical determinant of effectiveness. Longer intervention periods, while implying greater implementation costs, also suggest more substantial intervention effects (Ardoin et al., 2023; Marques et al., 2020). However, an intriguing consideration arises: whether short-term interventions can achieve comparable effects at a lower cost. Examples include environmental communication and climate change-related games (Douglas & Brauer, 2021; Leiserowitz et al., 2021). In the context of LMICs, their value becomes more pronounced. This study distinguishes between intervention length as a short-term intervention that lasts one lesson or one day, and a long-term intervention that lasts multiple lessons or multiple days (van de Wetering et al., 2022).

Measurement time is crucial for the effectiveness of environmental education, which aims to inspire lasting changes in individual knowledge, intentions, and behavior (Nilsson et al., 2017). Despite noteworthy progress, the field remains somewhat underexplored due to a scarcity of longitudinal measurements in most studies (Varela-Losada et al., 2016). Studies revealed that both attitude and knowledge returned to pre-intervention levels during the follow-up period (Hansel et al., 2010; Nates et al., 2012). These findings highlight the need for additional research to understand the long-term effectiveness of environmental education.

Additionally, research quality deserves attention. To obtain more valid results, we included not only ideal intervention settings (pre-post test with control group) but also post-test only with control group and pre-post test only intervention designs. Different intervention designs may influence the outcomes differently, necessitating further analysis of these differences (Efthimiou et al., 2017; Faber et al., 2016). For example, low-quality intervention designs may overestimate the outcomes of environmental education (Świątkowski et al., 2024).

For subject characteristics, there exists a discernible variability in the effectiveness of environmental education across different educational levels. Notably, environmental education appears to be more effective among students at lower educational levels in the Czech context (Cincera et al., 2023). Although these preliminary studies highlight differences related to educational levels, it remains uncertain whether similar trends exist in LMICs (Low- and Middle-Income Countries), which warrants further investigation. This phenomenon could be attributed to the formation of environmentally relevant habits as students age, coupled with an increasing cost associated with behavior change (Chen & Chao, 2011; Verplanken & Whitmarsh, 2021). An intriguing finding by Olsson & Gericke (2016) identified an 'adolescent dip,' indicating a substantial decrease in the 'sustainability consciousness' of 9th graders compared to their 6th-grade counterparts. These findings suggest that different learning stages may result in varying receptiveness to environmental education, and this hypothesis requires further validation. Gender may also influence the effectiveness of environmental education. Carrier (2009) found that males were more effective than females in changing attitudes and behavior after environmental education in the elementary school context. There are also large differences in environmental awareness between genders, with females typically having greater environmental awareness than males, and this gender difference continues to increase with age (Olsson & Gericke, 2017). These findings imply that males and females may exhibit different responses to environmental education, and these differences should be further validated in LMICs.

While our focus was on LMICs, significant differences in development levels persist among them. To uncover these disparities, we categorized countries using the Human Development Index (HDI) (Nations, 2022). The HDI is a composite measure that combines three key dimensions: health (life expectancy), education (years of schooling), and standard of living (GNI per capita). Ranging from 0 to 1, higher HDI values indicate greater levels of human development. This index provides a holistic measure of a country's socioeconomic progress, considering not only economic indicators but also advancements in health and education. Further analysis of the HDI allows us to examine how varying levels of development across LMICs impact environmental education.

The Present Study

Current climate change research predominantly focuses on high-income and northern countries (Monroe et al., 2019; Stern et al., 2014; van de Wetering et al., 2022). Despite the growing importance of environmental education in LMICs, comprehensive evidence of its effectiveness remains relatively scarce compared to non-LMICs, even though a substantial amount of research exists within LMICs. Furthermore, most existing studies emphasize single outcomes, often restricted to specific educational settings such as primary schools or universities (Acosta & Queiruga-Dios, 2021; Ernst et al., 2021), limiting a comprehensive exploration of environmental education's impact across the entire educational spectrum.

Previous related studies, such as Monroe et al. (2019), have not provided a quantitative synthesis of environmental education effectiveness. Van de Wetering et al. (2022) synthesized five decades of research on the effectiveness of environmental education for children and adolescents, including 169 studies across 43 countries. Their meta-analysis found that environmental education significantly improved environmental knowledge ($g = 0.95$), attitudes ($g = 0.38$), intentions ($g = 0.26$), and behaviors ($g = 0.41$), demonstrating the potential of environmental education to positively influence various outcomes. However, their analysis primarily focused on high-income and northern countries, with LMICs underrepresented, resulting in limited comprehensive insights.

To address these gaps, this study conducted a meta-analysis to evaluate the effectiveness of environmental education in LMICs and to provide guidance for future initiatives. Our analysis included nearly half of the new studies in this field, offering a broader representation of LMICs.

We aimed to assess the effects of environmental education on knowledge, attitudes, and behaviors, while also examining the influence of broader moderators in shaping these effects.

Method

Literature search

We searched articles via Web of Science, EBSCO (PsycINFO and ERIC), and Scopus. Search terms included a combination of environmental education and LMICs. This search strategy was developed regarding current studies (Briggs et al., 2018; Fu et al., 2020; Merritt et al., 2022; van de Wetering et al., 2022). The details of the search strategy can be found in the Appendix. Second, we extracted environmental education studies from LMICs in other systematic reviews and meta-analyses (Monroe et al., 2019; van de Wetering et al., 2022). The literature search encompassed articles published before September 27, 2023. The screening process was shown in Figure 1. All articles were screened and data was extracted by two coders using Covidence software (Babineau, 2014). Covidence is an online platform that leverages machine learning algorithms to prioritize relevant articles, accelerating the screening process. Automated systematic review tools allow researchers to set stopping criteria, such as stopping screening when 30% of the selected studies are deemed irrelevant (van de Schoot et al., 2021), but we did not use this feature in our review. To ensure comprehensiveness and minimize the risk of missing relevant studies, we screened all abstracts to include as many relevant articles as possible. In the data extraction process, Covidence did not offer decision-making assistance. We preregistered our research question and inclusion criteria but not our analysis strategy. The Pre-registration and Exploratory Analyses section of the Appendix provides details on deviations from the pre-registered plans and the analysis strategy.

Inclusion criteria

We established literature inclusion criteria based on the PICOS framework (Amir-

Behghadami & Janati, 2020) :

Population: Students, ranging from K12 to university level, with interventions conducted in LMICs (The World Bank, 2023). Details of the included LMICs can be found in the Appendix.

Intervention: Environmental education aimed at enhancing students' environmental knowledge, attitude, or behavior.

Comparison: The study included a blank control group, other unrelated interventions, or pre-post interventions.

Outcome: Quantitative outcomes that can be converted to effect sizes (Hedges' g), including environmental knowledge, environmental attitude, or environmental behavior. Environmental knowledge refers to an individual's understanding of environmental issues, their causes, consequences, and potential actions that can be taken. Environmental attitudes refer to an individual's favorable beliefs, emotions, or values regarding environmental issues, but do not include concepts such as environmental identity, inclusion of nature in oneself, connectedness to nature, or implicit attitudes. Environmental behaviors involve actual actions or habits aimed at improving or protecting the environment (van de Wetering et al., 2022).

Study design: Randomized controlled trial, pre-post intervention trial, or post-only intervention trial was included.

The exclusion criteria were as follows:

a) Reviews, theoretical, and qualitative studies.

b) The starting point for the publication search was set in 1987 because it marks the introduction of the theory of sustainable development (Acosta & Queiruga-Dios, 2021).

c) Studies that used the same data as previous research were excluded, with only the earliest published study being included.

d) Studies not in the English language.

e) We excluded unpublished papers, such as preprints and unpublished data.

Coding

The literature included in the meta-analysis was coded. The coding included details such as literature information (author name & publish time), sample size, country (extract the HDI index of the country as moderator), gender composition (female), age, educational level (primary school, secondary school, and university), intervention type (indoor course, outdoor activity, and multi), intervention length (more than one day and less than one day), measurement time (immediately and delay), outcome (environmental behavior, environmental attitude, and environmental knowledge), intervention design (pre-post test with control group, post-test only with control group, pre-post test only), and effect size. If a study reported multiple conditions (e.g., different intervention strategies or measurement times), each condition was coded as a separate effect size. For studies that only reported an age range, we used the mean of the minimum and maximum values for further analysis.

Literature effect sizes were coded by different independent samples. In cases where a single article reported multiple independent samples simultaneously, each was coded separately to generate various unique effect sizes. Within a single study, if multiple measures (e.g., different items assessing attitudes, knowledge, or behavior) were used to evaluate a single outcome, we combined the effect sizes for the corresponding variable. If a study met the inclusion criteria but lacked data to calculate effect sizes, we contacted the corresponding author to request the missing data. The data extraction process was conducted independently by two coders, and any discrepancies were addressed by correcting coding inconsistencies through a review of the original literature and subsequent discussion. The categorization of the moderator variables was conducted by two raters (Cohens κ ranging from 0.66 to 1.00; see Table S2).

Data Analysis

In this study, the effectiveness of environmental education was assessed by comparing the standardized difference between the intervention and control groups. Hedges' g was employed as the effect size to evaluate the effectiveness, which represents the standardized mean difference between two group means and is considered a more accurate estimate of the effect size than Cohen's d (Grissom & Kim, 2005; Rosenthal, 1998). Typically, Hedges' g values of 0.2, 0.5, and 0.8 indicate small, intermediate, and large effect sizes, respectively.

All data were initially computed using Cohen's d according to the method outlined by Lenhard & Lenhard (2017) and subsequently converted to Hedges' g with 95% confidence intervals using Comprehensive Meta-Analysis (CMA) 3.0 software (Borenstein, 2022). CMA 3.0 offers an efficient method for batch conversion of effect sizes. The meta-analysis was conducted using the *metafor* (version 3.8-1) R package (Viechtbauer, 2010). We employed hierarchical random‑effects models with robust variance estimation (RVE) using the *clubSandwich* (version 0.5.11) R package (Pustejovsky & Tipton, 2022). Because each study contributed multiple effect sizes without reporting within study covariances, we assumed a constant within study correlation of ρ=0.60 to capture study level heterogeneity. We anticipated substantial heterogeneity within studies and employed the correlated hierarchical effects (CHE) working model for our analyses. To supplement the pooled effects, we also used a Bayesian random-effects model meta-analysis with the *brms* (version 2.22.0) R package (Bürkner, 2017) and three-level meta-analyses (Assink & Wibbelink, 2016). Bayesian meta-analysis serves as a complementary approach, providing a more comprehensive interpretation when intervention outcomes may not be significant (Geiger et al., 2021).

We defined outliers as those with Hedges' g values greater than 3 standard deviations from the mean and a Cook's distance greater than 4/N. We also performed leave-one-out analyses to examine the influence on pooled effect size after excluding individual studies (Harrer et al., 2021). Three approaches, namely Funnel Plot (Trim and Fill method), Egger's test, and PET-PEESE were used to investigate publication bias (Duval & Tweedie, 2000; Egger et al., 1997; Stanley & Doucouliagos, 2014). The Egger test and the PET-PEESE test were adjusted for the RVE model. To explore possible sources of research heterogeneity, moderator effects were analyzed (Jackson & Turner, 2017), and educational level, intervention type, intervention length, measurement time, gender, and age were identified as the primary moderators in this study. Subgroup analyses were used to validate the moderator effects of categorical variables, and meta-regression was used to validate the moderator effects of continuous variables. Tau-squared were pooled across subgroups. The robust standard errors were reported, and the robust F-test was used for the subgroup analyses.

Result

We initially identified 11,451 articles. After the title and full-text screening, 90 articles with 187 independent studies were included, involving a total of 34,283 participants (with an average age was 12.28 and a percentage of females was 54%). A total of 67 articles with 96 independent studies focused on environmental knowledge (n = 26,144), 47 articles with 58 independent studies on environmental attitude (n = 13,832), and 28 articles with 33 independent studies on environmental behavior (n = 16,103). The details of the included studies can be found in Table S1. The geographic distribution of all studies was shown in Figure 2. Turkey (22%) and China (17%) had the highest representation. For study design, 23% of studies adopted pre-post design with the control group, and 52% of studies employed pre-post design with only the intervention group. In studies with pre-post designs and control groups, seven studies (37%) reported random assignment (four randomly assigned schools, two randomly assigned students or classes, and one randomly assigned students and classes), of which only two studies provided details on the randomization process they employed. The most prevalent educational levels and types were primary school (49%) and indoor courses (50%).

Main Effect of Environmental Education

Figure 2 illustrated the distribution of environmental education effects across different outcomes. Environmental education demonstrated a significant effect in LMICs ($g = 1.11$, 95% CI [0.87, 1.35], $p < .001$; see forest plot in Figure S1). Leave-one-out analyses showed that the effect size ranged from $g = 1.07$ to $g = 1.14$. After excluding outliers ($n = 6$), the effect size remained relatively stable ($g = 0.95$).

This study primarily focused on the effects of interventions across different outcomes. Specifically, participation in environmental education was associated with increased environmental knowledge ($g = 1.35$, 95% CI [1.02, 1.69], $p < .001$; see forest plot in Figure S2). Leave-one-out analyses showed that the effect size ranged from $g = 1.28$ to $g = 1.37$. After excluding outliers ($n = 3$), the effect size slightly decreased ($g = 1.18$). Participation in environmental education was associated with increased environmental attitudes ($g = 0.94$, 95% CI [0.56, 1.32], $p < .001$; see forest plot in Figure S3). Leave-one-out analyses indicated that the effect size ranged from $g = 0.79$ to $g = 0.96$. After excluding outliers ($n = 3$), the effect size slightly decreased ($g = 0.58$). Furthermore, participation in environmental education was associated with increased environmental behavior ($g = 0.68$, 95% CI [0.46, 0.90], $p < .001$; see forest plot in Figure S4). Leave-one-out analyses, excluding individual studies, revealed that the effect size ranged from $g = 0.60$ to $g = 0.71$. After excluding outliers ($n = 1$), the effect size remained relatively stable ($g = 0.63$).

The results of the three-level meta-analysis were similar to the current results (full outcome: g = 1.12 95%CI [0.87; 1.36]; environmental knowledge: g = 1.35, 95%CI [1.03; 1.68]; environmental attitude: g = 0.93, 95%CI [0.56; 1.30]; environmental behavior: g = 0.67, 95%CI [0.47; 0.88]; detail was shown Figures S5-S8). The results of the Bayesian meta-analysis were also similar to the current results (full outcome: g = 1.01 95%CI [0.83; 1.18]; environmental knowledge: g = 1.25, 95%CI [0.98; 1.51]; environmental attitude: g = 0.78, 95%CI [0.48; 1.07]; environmental behavior: g = 0.68, 95%CI [0.48; 0.89]; detail was shown Figures S9-S13).

Table 1 showed the moderator effect of full outcomes. The effect of environmental education showed no significant differences across different levels of study design ($p = .134$), educational level ($p = .874$), intervention type ($p = .848$), and gender ($p = .541$). Environmental education lasting more than one day had a higher effect size compared to those lasting less than one day ($p = .045$). The effect of environmental education at the delayed test phase was lower than post-test phase ($p = .031$). Additionally, age was negatively associated with the effect of environmental education ($p = .041$). HDI was positively associated with the effect of environmental education ($p = .066$, approached significance). The effectiveness of environmental education varied significantly across different outcomes ($p = .007$), underscoring the necessity of separately reporting the effects for each outcome.

Tables S3 to S5 present the moderators of environmental knowledge, environmental attitudes, and environmental behavior. Regarding environmental behavior, we further examined whether there were differences between self-reported behavior and self-reported behavior intentions in response to environmental education. The results indicated no significant differences between the two measurement approaches ($p = .855$). Notably, almost all behavioral measures were assessed using self-report measures, with the exception of one study that used carbon footprint as a measure.

Publication Bias

This study employed the Funnel Plot, Egger's test, and PET-PEESE to assess the publication bias in the included studies. Firstly, the funnel plot revealed most studies concentrated in the upper-middle region with an asymmetrical pattern, indicating a potential publication bias (Figure 4). The trim and fill method also identify additional studies (full outcome: 23 studies, environmental knowledge: 10 studies, environmental attitude: five studies, environmental behavior: four studies). Secondly, Egger's test showed significant results for the full outcome (b = 1.16, $p < .001$), environmental knowledge (b = 1.41, $p < .001$), environmental attitude (b = 1.41, $p < .001$), and environmental behavior (b = 0.85, $p < .001$). The significant results in Egger's test for all outcomes suggested that there is a systematic tendency for studies with significant or positive results to be published more frequently than those with non-significant results, leading to potential publication bias. Lastly, effect size correction was conducted using PET-PEESE for bias correction. For environmental attitude, the corrected effect size was $g = 0.17$ ($p = .265$), indicating that the result was not significant. For full outcome, environmental knowledge, and environmental behavior, the PET was not significant, indicating insufficient evidence of publication bias.

Discussion

How effective is environmental education in LMICs? This study employed a meta-analysis to examine the effect of environmental education in LMICs on environmental knowledge, attitude, and behavior. We further explore the moderator effects of educational level, intervention type, intervention length, measurement time, gender, and age.

Effectiveness of Environmental Education in LMICs

This meta-analysis found a significant overall positive association for environmental education programmers in LMICs ($g = 1.11$). Specifically, participation in environmental education was associated with increased environmental knowledge (g = 1.35), environmental attitude (g = 0.94), and environmental behavior (g = 0.68). This suggests that environmental education yielded positive outcomes, both in preparing individuals for pro-environmental behavior and in implementing actual pro-environmental behavior. When compared to existing results (van de Wetering et al., 2022), where environmental knowledge had an effect size of g = 0.95, environmental attitude g = 0.38, and environmental behavior g = 0.41, our study found that environmental education may have a higher effect size in LMICs. There are many reasons for this phenomenon. On the one hand, in LMICs, where the level of education is relatively lower, the environmental knowledge of the general public is limited (Matlack et al., 2023). Targeted environmental education programs can rapidly increase environmental awareness and understanding among residents. Once a foundational awareness of environmental issues is established, it is more likely to stimulate positive changes in environmental behavior, laying a solid foundation for sustainable development (Svarstad et al., 2023). On the other hand, residents of LMICs are more directly affected by the impacts of climate change and environmental degradation (Li et al., 2024). Frequent extreme weather events and natural disasters directly threaten residents' livelihoods and living environments (Rüttenauer, 2023). This first-hand experience makes residents more willing to engage in environmental education, as they deeply understand the interconnectedness of environmental protection and their well-being (Rüttenauer, 2023). In this context, conducting environmental education activities can more effectively respond to urgent social demand, inspire more people to participate in environmental protection efforts, and promote a broader social consensus. Therefore, the implementation of environmental education in LMICs can more easily lead to profound societal impacts. Policymakers in LMICs should integrate environmental education into key climate change mitigation strategies.

Despite the positive relationship in environmental education, knowledge-attitude, and knowledge-behavior gaps persist. Behavioral change is often more challenging than changing knowledge or attitudes (Colombo et al., 2023; Kollmuss & Agyeman, 2002; Park & Lin, 2020). Environmental education is unlikely to lead to environmental behavior if there are barriers preventing behavior adoption or if the conditions for behavioral implementation are absent (Kaaronen & Strelkovskii, 2020; Kukowski et al., 2023). On the other hand, individuals may possess knowledge about environmental issues, but if this knowledge conflicts with their existing beliefs or habits, they may experience cognitive dissonance (Festinger, 1954; Szmigin et al., 2009). The discomfort associated with conflicting information may lead individuals to resist changing their attitudes or behaviors (Leeuwis et al., 2022). This suggests that environmental education should not only focus on schools but also address how societal structures can reduce barriers to the implementation of environmental behaviors. It's worth noting that this study exhibits significant publication bias. After correction, the improvement in environmental attitude was not significant. This implies a potential risk of overestimating the intervention effects in LMICs.

Moderator Associated with Effectiveness of Environmental Education

This study examines the different levels of moderators in environmental education to offer more effective guidelines for LMICs.

First, there was no significant difference in the effectiveness of environmental education across different types of interventions. This implies that different intervention types may be associated with positive outcomes in LMICs. When designing environmental education programs, there is flexibility in selecting different types to suit various educational contexts and learning needs. Low-cost interventions may have more potential based on limited resource investment in LMICs. Notably, combining multiple intervention methods did not yield significantly different outcomes compared to single-method interventions, suggesting a potential negative synergy (Alt et al., 2024).

Second, consistent with previous research, environmental education interventions lasting more than one day tended to show higher effect sizes compared to those lasting less than one day (Marchini & Macdonald, 2020). However, the effect size for environmental education measured at the delayed test phase was lower than that at the post-test phase, suggesting that the impact of environmental education may diminish over time. These findings suggest that environmental education should not be viewed as a singular or sporadic intervention, but rather as an ongoing process that requires iterative course cycles. This underscores the importance of incorporating regular reviews, updates, and interactive content within educational programs to sustain and enhance learners' environmental awareness and motivation for action.

Third, the effect of environmental education showed a declining trend as student age increased. It is suggested that environmental education be introduced at a younger age for a more positive impact, underscoring the importance of implementing environmental education early in students' development. Given that students across different grades exhibited significantly different levels of environmental awareness, the effectiveness of the intervention may not be influenced by their educational level. For example, there was a notable difference in environmental awareness between freshmen and seniors (Cogut et al., 2019).

Finally, the study found no significant differences in the effects of environmental education across different gender groups. This suggests that in LMICs, environmental education may be equally effective across genders, likely because environmental issues are widespread and commonly shared in these regions (Li et al., 2024).

Challenges and Recommendations for Future Research

This study can provide valuable guidance for future research in environmental education in LMICs. The challenges associated with implementing effective environmental education in LMICs are multifaceted. Economic constraints are often a significant barrier, limiting the financial resources available for educational initiatives (den Elzen et al., 2022; Humpenöder et al., 2022). Allocating funds for necessities may take precedence over investment in environmental education programs in LMICs (UNEP, 2023), exacerbating existing disparities in educational infrastructure and making it difficult to develop comprehensive and accessible curricula (Ma & Chen, 2023). In addition, political instability in regions where governance is uncertain or prone to frequent changes can undermine long-term planning and sustained efforts in environmental education (Lamb et al., 2020; Shrikhande et al., 2023; Supran & Oreskes, 2017). Political priorities, often focused on immediate concerns, may overshadow the need to address climate-related issues. Finally, social injustice exacerbates the challenges faced by LMICs in their pursuit of environmental education (Malerba, 2022). Vulnerable populations, who are often disproportionately affected by the impacts of climate change, may also experience inequalities in access to education (Apollo & Mbah, 2021; Engle et al., 2011).

First, the assessment of environmental education outcomes should move beyond self-reports and prioritize evaluating the effectiveness of environmental education through direct observation of actual behavior. Previous research has found a discrepancy between self-reported and actual pro-environmental behavior (Kormos & Gifford, 2014; Lange et al., 2023). In the behavioral outcomes included in this meta-analysis, nearly all used self-reported measures, with only one study reporting carbon footprint (Lin, 2016). Presently, the spillover effects of environmental education are often overlooked, such as positive spillover promoting other pro-environmental behavior or negative spillover hindering such behavior (Maki et al., 2019). Research should pay attention to the impact of environmental education on secondary behavior, which is crucial for intervention effectiveness (Nilsson et al., 2017). The effectiveness of environmental education also should be assessed from a cost-effectiveness perspective. LMICs often need to balance resource investment with optimal implementation success (Chausson et al., 2020). By improving these aspects, future research can provide more comprehensive guidance for policy development related to environmental education in LMICs.

Secondly, environmental issues are complex and multi-layered (Pruneau et al., 2015). The implementation of environmental education demands interdisciplinary involvement to assist students in developing a comprehensive understanding of complex environmental issues. Future research should aim to integrate environmental education into daily education, incorporating disciplines like STEM (McCright et al., 2013). According to the results of the study, the implementation of environmental education in LMICs should take place as early as possible to achieve the most positive results. Focusing on the shift from environmental knowledge to environmental attitude and behavior also needs more attention.

Finally, concerning the goals of environmental education. Intervention planners need to emphasize the importance of agents in environmental education: environmental education teachers (Nalipay et al., 2023; Sass et al., 2022). Clear and accurate teacher training programs are imperative to lay the foundation for the successful promotion of environmental education. Education planners also should expand their focus to include additional targets. For example, household behavior directly or indirectly contributes to 70% of CO_2 emissions (Niamir et al., 2020). Future research should explore leveraging students as entry points for environmental targeting household behavior.

Limitation

There are some limitations to this study. Firstly, it is possible that some of the studies from LMICs were published in native-language journals. Given that this study exclusively considered papers in English, there is a potential for language bias, potentially leading to the omission of relevant research published in non-English journals. Secondly, this meta-analysis included a large number of single groups with pre-post studies, which have limitations for inferring causality. For example, the knowledge level of young participants may naturally improve over time, which in turn affects their attitudes and behaviors. When only studies with pre-post comparison groups were included, the effect sizes were g = 1.56 (95% CI [0.99, 2.14]) for environmental knowledge, g = 0.38 (95% CI [0.12, 0.63]) for environmental attitudes, and g = 0.53 (95% CI [-0.03, 0.83]) for environmental behavior. Except for the results of environmental knowledge, which were relatively stable, the results of both environmental attitudes and environmental behavior were further reduced. Additionally, this meta-analysis is the exclusion of unpublished data, which may affect the comprehensiveness of the findings. Finally, the presence of outliers, particularly in the environmental attitude data, influenced effect sizes. The exclusion of three outliers led to a notable decrease in the effect size from 0.94 to 0.58 and obtained non-significant results in the PEESE analysis. This variation may be attributed to differences in the specific indicators used to measure environmental attitudes (McIntyre & Milfont, 2016). These limitations should be considered when interpreting the findings of this study, and future research could aim to address these gaps for a more comprehensive understanding of the impact of environmental education in LMICs.

Conclusion

LMICs require effective climate change mitigation measures. This study demonstrates the effectiveness of environmental education in these countries. Participation in environmental education was associated with positive outcomes in LMICs, spanning environmental knowledge, attitude, and behavior. Policymakers should consider promoting environmental education to mitigate climate change in LMICs.

Data Availability Statement

This study was pre-registered: https://osf.io/bc9v8. Details of the analysis script are available via: https://osf.io/4cy9q.

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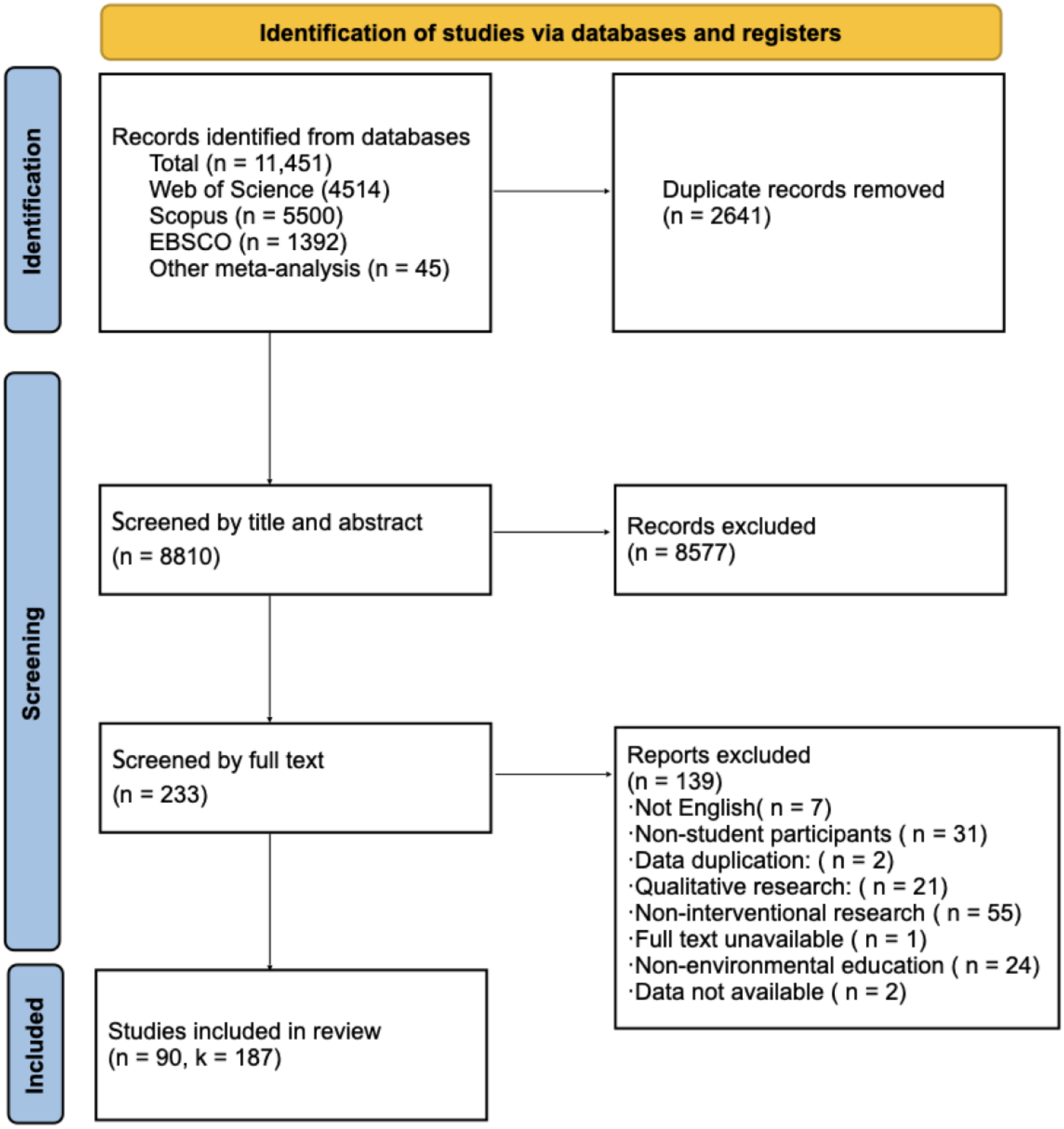
Figure 1

PRISMA Flowchart.



Note: n refers to the number of articles, while k refers to the number of studies independently sampled in these articles.

Figure 2

Distribution of Include Study in Different Countries and regions.

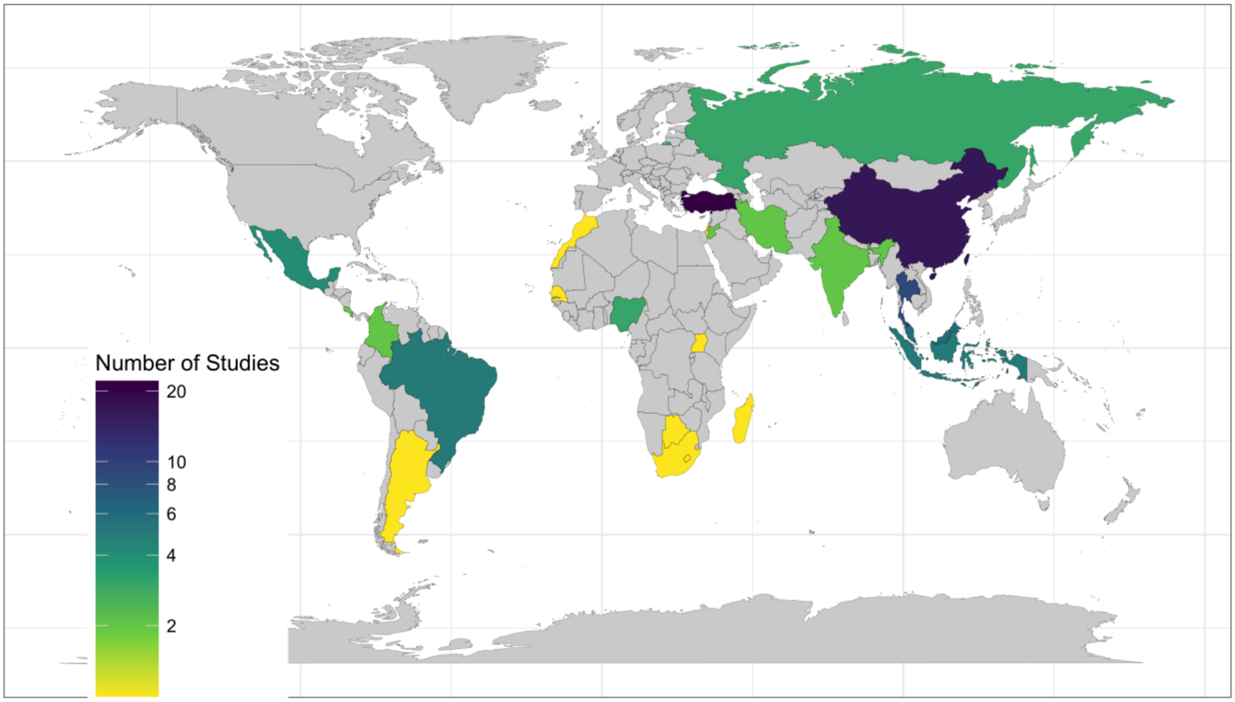
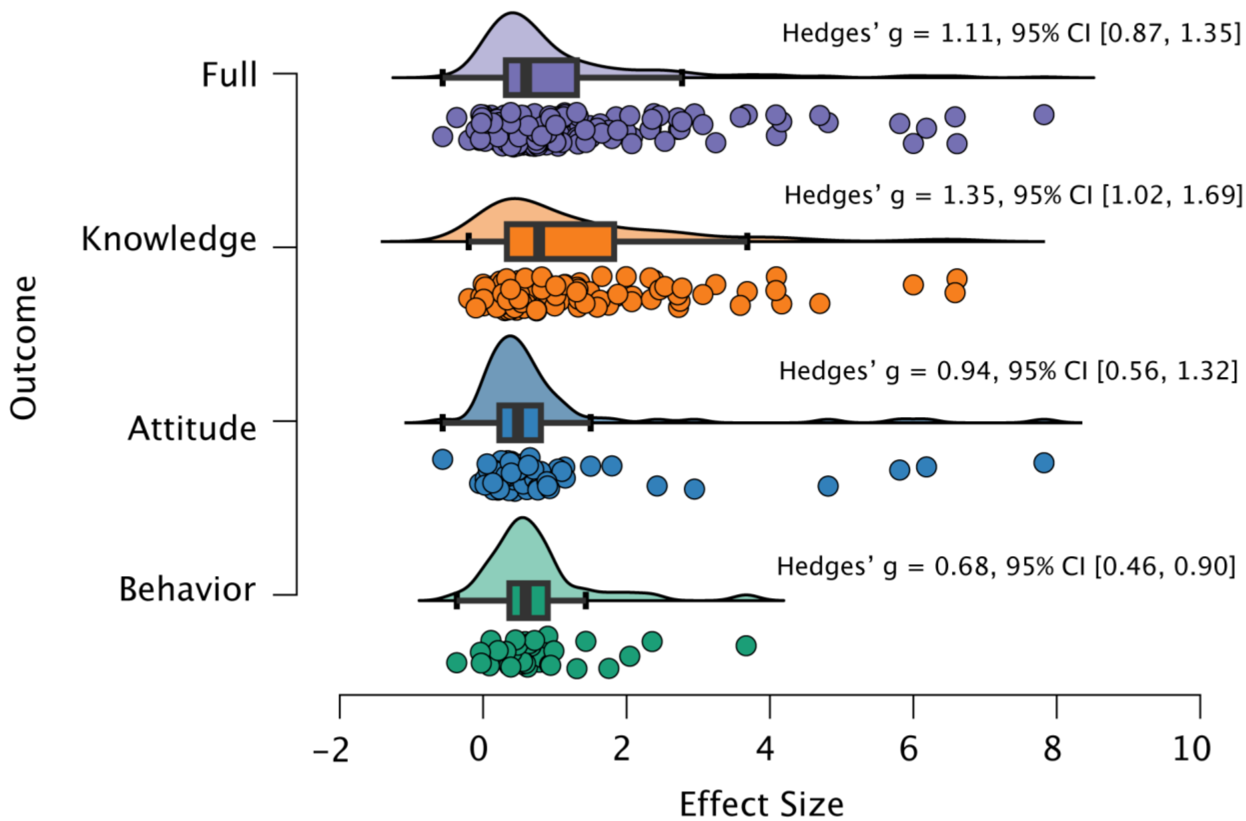


Figure 3

Distribution of Effect Sizes with Different Outcomes.



Note: the raincloud plot includes a representation of the overall distribution of observations, the actual observations, and measures of central tendency.

Figure 4

Funnel Plot with Different Outcomes.

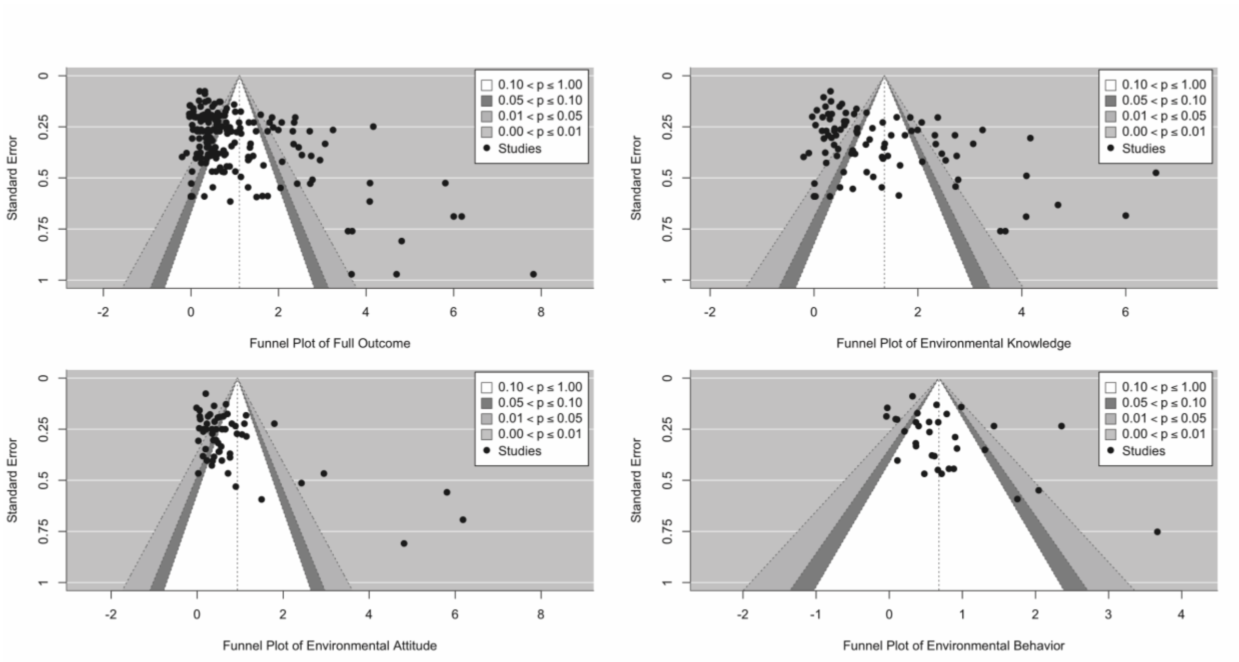


Table 1

Moderator Analysis of Full Outcome.

Moderator		*n*	*k*	*g*	95%CI	*Qm*
Main effect		34,283	187	1.11	0.87; 1.35	
Educational level	Primary school	18,352	83	1.18	0.73; 1.64	0.14
	Secondary school	9,485	60	1.07	0.61; 1.54	
	University	2,663	29	1.32	0.43; 2.22	
Intervention type	Indoor course	14,306	90	1.14	0.82; 1.45	0.17
	Outdoor activity	3,396	39	1.00	0.68; 1.78	
	Multi	18,114	52	1.23	0.35; 1.65	
Intervention length	> 1 day	28,810	151	0.63	0.11; 1.14	612*
	< 1 day	5,466	27	1.23	0.95; 1.50	
Measurement time	Immediately	31,999	154	1.17	0.91; 1.43	6.83*
	Delay	4,557	33	0.69	0.33; 1.05	
Intervention design	Pre-post test with control group	4,298	42	1.04	0.69; 1.38	2.10
	Post-test only with control group	10,637	48	0.77	0.43; 1.11	
	Pre-post test only	21,621	97	1.31	0.90; 1.72	
Outcome	Environmental knowledge	26,144	96	1.33	1.03; 1.64	5.80**
	Environmental attitude	13,832	58	0.86	0.65; 1.07	
	Environmental Behavior	16,103	33	0.86	0.52; 1.20	
Gender		9,795	93	0.01	-0.02; 0.04	0.41
Age		28,661	132	-0.08	-0.16; -0.01	5.23*
HDI		34,283	187	1.80	-0.13; 3.72	3.93^{+}

Note: $^{+}$ p<0.1, * = p < .05, ** = p < .01, *** = p < .001; HDI means Human development indices, Qm means the Wald test of Moderators, 95% CIs were based on RVE standard errors, n means independent sample size and k means independent effect sizes.