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The Effectiveness of the Parent–Child VOC-Focused Environmental Education Program

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Abstract

Environmental education for children is a critical strategy that addresses current environmental threats by encouraging individuals to make positive changes in their daily behaviors. However, existing programs aimed at children often fall short of achieving effective learning outcomes because they do not consider the children's developmental characteristics and the impact of facilitators, fragmented content, ineffective delivery methods, and the lack of actionable knowledge. To resolve these problems, this study's authors created a 5-week online environmental education program with a focus on a socially important topic—volatile organic compounds (VOCs). The program positioned children as primary learners and parents as facilitators, such that the parents' involvement was based on their children's developmental characteristics and the need to make environmental changes within the family unit. Furthermore, the study emphasized the importantce of concrete, actionable knowledge, which has been overlooked in existing programs. For this study, a pretest-posttest design was employed and 55 parent-child pairs were recruited to participate in the online program. Among the response data, eight pairs that did not meet the criteria were excluded from final analysis, so data from 47 parent-child pairs were analyzed. The results indicated that the VOC-focused environmental education program significantly contributed to the increase of both VOC-related knowledge and pro-environmental attitudes in children and parents. Additionally, parents showed improved environmental efficacy after participating in the program. Although this study was limited by the absence of a control group, the findings suggested that for environmental education to be effective, education program should consider the children's developmental characteristics, engage parents as the facilitators of the educational program, provide concrete environmental content, and employ effective delivery methods.

Keywords

environmental education, volatile organic compounds, parental involvement, pro-environmental attitudes, environmental efficacy

The global environment is currently facing an abrupt negative shift caused by human-inflicted damage (Hobbs et al., 2024; Kouppanou, 2020; McMichael, 2015). The exceptional rise in Antarctic temperature to 38.5°C—is a clear example of how the environmental danger has exceeded ecological thresholds (McKie, 2024)

To solve the crisis, scholars have emphasized the need for substantial changes in cultural and social structures. Given that such changes are contingent upon societal stakeholders' collaboration and interconnection, environmental sustainability should be achieved at the individual, collective, and institutional levels (Ardoin & Bowers, 2020; Willis & Schor, 2012). Of these three, individual actions may be the best foundational starting point to create change.

Environmental education works well to change individuals' behavior regarding environmental protection and conservation, expecially when it is aimed at young children (Ardoin & Bowers, 2020; Chawla & Cushing, 2007). This is because children can become crucial

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stakeholders and agents leading to a sustainable future (UN, 2015). In fact, numerous studies have indicated that educational interventions performed during the early years of education can have a profound and persistent effect that lasts into adulthood (Collado et al., 2015; Stern et al., 2014).

In line with worldwide streams, the South Korean government has implemented policies and supported environmental sustainability. However, these policies and education programs have not been effectively translated into environmental education practices. For example, very few teachers specialize in environmental education, which is commonly provided only as an elective subject in schools (B. Kim, 2021). Yang and Song (2022) indicated that very little content about environmental sustainability is included in South Korean elementary school textbooks.In a social studies textbook targeting sixth-grade students, only one chapterfocuses on this topic; moreover, it merely covers global environmental issues in a broad way rather than providing specific information that may facilitate real action. Such apporaches in formal education settings falls short of facilitating actual behavior change.

Meanwhile, for effective children's learning, parental involvement is significant and beneficial (Hornby & Lafaele, 2011). When parents actively participate in their children's learning process, both children and parents can benefit from increased knowledge acquisition and positive attitude development. However, the research in environmental education has primarily focused on assessing children's learning outcomes. It has paid limited attention to the impact on parents, who play the most important role in their children's attitude formation process.

Environmental education must address the key components of pro-environmental actions. For instance, it should deal with environmental knowledge (Schmitz & Da Rocha, 2018; Wetering et al., 2022), pro-environmental attitudes (Schmitz & Da Rocha, 2018), connectedness with nature (Liefländer et al., 2013), and environmental efficacy (Milfont, 2012).

Of these antecedents, knowledge makes an especially important contribution to behavioral change. Specifically, "action knowledge" that provides specific, actionable information (Wetering et al., 2022, p. 101781) is highly important in that it suggests ways for individualsto practice environmental sustainability. Furthermore, because the environmental field requires practical actions, the content of related education must be specifically applicable in real life. Therefore, the content should be concrete rather than general so that individuals can implement real-life proactices. However, traditional approaches to environmental education often provides broad and fragmented content. Such content is insufficient for generating transformation in daily life.

To identify the unaddressed issuesin the literature, we developed a differentiated environmental education program. First, we specified a concrete topic: volatile organic compounds (VOCs). VOCs, as an emerging pressing concern, refer to hydrocarbon compounds that evaporate into the atmosphere, causing particulate matter pollution with potential effects on both individuals' health and physical environment (T. Y. Kim et al., 2022). Second, we desinged concrete and actional information so that learners could easliy and effectively take actionable steps. Moreover, we primarily targeted children while

fostering a high level of parental involvement as the facilitators of their children's learning, considering that positive change is usually achieved within family units. We also structured the curriculum so that children and parents could actively interact through diverse activities, discussions, and shared learning experiences.

For the study, we recruited 55 parent–child pairs. After obtaining their consent to participate in the 5-week education program, we measured their environmental perception, including knowledge and pro-environmental attitudes, at two time points: before the program's commencement and after its completion.

We have structured this paper as follows. First, we review existing studies on environmental education, parental involvement, environmental perception and attitude as key factors influencing environmental action and VOCs. Next, we describe our research methodology we employed in our study. Subsequently, we present the research results based on the data we collected. Finally, we draw conclusions from the findings and discuss our research implications.

Literature Review

Environmental Education

Scholars have recognized environmental education as an essential tool for empowering individuals to address socio-environmental issues (Díaz-López et al., 2023; Green et al., 2015). As the natural environment continues to deteriorate, the societal need for environmental education is gradually increasing and discussions on various constructs and approaches to environmental education are taking place.

Meanwhile, scholars have emphasized that individuals with concrete, practical information about environmental solutions can easily implement pro-environmental behavior (Frick et al., 2004). This method helps people recognize the relevance of environmental issues to their lives and empowers them to perform pro-environmental actions (Abrahamse et al., 2005).

However, many environmental education programs focus on delivering general information based on an environmental conservation mentality, which may not be

sufficient to influence practical decision-making and behavior change in daily life. In this regard, Blumstein and Saylan (2007) pointed out that environmental education should lead to significant changes in individual lives, particularly in the consumption context; however, existing education programs do not target these changes. Moreover, in Asian countries, such as South Korea and Japan, resources for environmental education are themselves limited. In South Korea, only about 15% of all secondary schools offer environmental education as a subject (Cho, 2023). Similarly, Nagata (2017) identified the "superficial awareness" of environmental issues as one of the reasons that environmental education in Japan is ineffective (p. 4).

Scholars have indicated that most environmental education programs do not make positive changes in individual behavior (Cho, 2023; Yang & Song, 2022). Thus, a new method of educating children should be developed to enable the transformation of their everyday lives, with a shift from broad information to actionable and context-specific knowledge. Only then can environmental education effectively address the complicated socio-environmental risks and threats we face today.

Parental Involvement in Environmental Education

Parental involvement in environmental education is a powerful tool for promoting behavioral change and fostering a sense of environmental responsibility among children (Hornby & Lafaele, 2011). Parents' support for their children through activities such as parenting, communication, and home tutoring allows their children to learn as students at home (Epstein, 1995; So et al., 2022). Such parental support is more vital than ever, particularly in the context of the rise of remote education during COVID-19.

Duvall and Zint (2007) indicated that environmental education, when facilitated through family interaction, enables children and parents to engage in meaningful dialog and share their perspectives on the importance of environmental issues. This means that environmental education affects parents as well as children. Indeed, Damerell et al. (2013) highlighted the transfer of environmental education outcomes from children to their parents. They discovered children who participated in the educational program on wetland-related content showed changes in their knowledge, which then a positive effect on their parents, even when their parents were not directly engaged in the education. This shows the potential for intergenerational learning between children and parents and the broader effects of environmental education programs. However, recent research in the environmental education field has concentrated on assessing children's learning outcomes, paying limited attention to the potential educational impact on parents who are actively involved and who become sustainable helpers in their children's learning process (Vaughan et al., 2003).

VOCs

VOCs are among of the most significant environmental issues that have recently received public attention. VOCs are known to come from various indoor and outdoor sources, related to petroleum-based products such as paints, glues, household cleaners, building materials, and transportation. They can persist in the atmosphere for long periods, causing risks to both human health and natural ecosystems (Tsai, 2019). They contribute to the formation of ozone and photochemical smog by combining with nitrogen oxides in the atmosphere, thus making the globe warmer (Jeon et al., 2010). Despite the negative effects of VOCs on environmental preservation and restoration, public awareness and understanding of these chemicals is minimal.

Considering that VOCs are a relatively novel and unfamiliar topic for both children and parents, it is essential to present environmental education on the issue that is detailed, actionable, and easily comprehensible. However, environmental education programs on VOCs that help learners comprehensively understand the issue are lacking. Given this gap, new educational programs must be created to deal with the issue, thereby fostering a sense of environmental responsibility and agency.

Theoretical Orientation About Learning Outcomes: Pro-environmental Attitude, Environmental Concern, Environmental Efficacy, and Environmental Knowledge

The ultimate goal of all environmental education programs is to promote pro-environmental behavior change. However, measuring behavior change is inherently complex and challenging. In this context, Ardoin and Bowers, 2020. (2020) conducted a systematic review of 105 studies and found that the most commonly measured learning outcomes of environmental education programs were behavioral antecedents such as knowledge, attitudes, intention, and awareness. These comprised 87% of the reviewed articles (91 out of 105). Research on the variety of the antecedents implied the difficulty of directly measuring behavior change or influencing behavioral shifts. Accordingly, the present study also aimed to assess learning outcomes using indirect indicators that contribute to behavior change.

Attitudes are considered among the most significant behavioral antecedent factors that play an important role in predicting corresponding behaviors (Fazio & Petty, 2008). Attitudes represent comprehensive evaluations of specific objects held in an individual's memory, ranging

from favorable to unfavorable, and are primarily based on affect or cognition (Breckler, 1984; Fabrigar & Petty, 1999; Fazio, 1995, 2007). Although many studies have highlighted the issue of attitude-behavior inconsistency, modern social psychologists view attitudes as reliable predictors of behavior under certain conditions. For example, robust attitudes are typically more resistant to persuasion and more likely to influence behavior compared to weak attitudes (Petty & Krosnick, 1995).

The Elaboration Likelihood Model (ELM; Petty & Cacioppo, 1984) asserts that attitudes can be formed via the central route or the peripheral route. The central route entails active engagement with logical arguments and comprehensive information processing, whereas the peripheral route depends on superficial cues such as the credibility or attractiveness of the source. Lee and Cheon (2018) found that pro-environmental attitudes—specifically regarding purchasing energy-saving products, organic foods, and recycled products as well as participating in boycotts—were more guided by cognitive elements than affective ones.

In this context, tangible, practical knowledge can augment central route processing, contributing to attitude changes. According to Moradi and Zihagh (2022), precise, actionable information facilitates more enduring attitude modifications through the central route. Likewise, Allum et al. (2008) demonstrateda positive relationship between knowledge and attitudes in a meta-analytic study. Sturgis et al. (2024) also found that higher levels of knowledge are related to better attitudes based on their analysis of cross-national survey data from 144 countries.

Social Cognitive Theory (SCT; Bandura, 1986b) explains how individuals learn and act by emphasizing the dynamic interplay among personal factors, behaviors, and environmental influences. Personal factors include aspects such as self-efficacy and an understanding of related benefits and risks. Self-efficacy can be defined as an individual's assessment of their own abilities and their capacity to utilize them (Bandura, 1977, 1986a). In the context of environmental behavior, environmental efficacy means the extent to which an individual perceives their own capacity to be involved in pro-environmental action (Sellers et al., 2014). For instance, a stronger perception of one's ability to improve the environment is closely linked to positive environmental behavior (Wu & Mweemba, 2010).

Environmental concern, an awareness of ecological issues coupled with a commitment to protecting valued natural environments (Dunlap & Hefferman, 1975), can also be considered as a significant motivator within both the SCT and the ELM. Numerous scholars have argued that environmental concern serves as a primary motivator for pro-environmental attitudes and is closely linked to attitudes toward green products (Hanson, 2013; Maichum et al., 2016; Yadav & Pathak, 2016). In the context of environmental education, environmental efficacy and environmental concern can serve as significant motivators and meaningful outcomes of learning and achievement.

In this sense, we attempted to empirically evaluate the efficacy of the VOC-focused environmental education program for cultivating the environmental perceptions and pro-environmental attitudes of parents and children. To address this research question, we sought to measure knowledge of VOCs, environmental concern, environmental efficacy, and pro-environmental attitudes as learning outcomes of the newly developed VOC-focused environmental education program. Given that parents and children have different capacities and developmental contexts, we formulated the following hypothesis for parents:

H1: Parents' learning outcomes will increase after the environmental program.
H1-1: Parents' environmental knowledge will increase after the environmental education program.
H1-2: Parents' environmental concern will increase after the environmental education program.
H1-3: Parents' environmental efficacy will increase after the environmental education program.
H1-4: Parents' environmental attitudes will increase after the environmental education program.

Because of the challenges young children face in independently understanding and responding to survey questions, numerous studies have focused solely on measuring environmental perceptions or attitudes,. For example, Biber et al. (2023) evaluated the effectiveness of environmental education programs for children by assessing only environmental awareness and attitudes, given the developmental limitations of children. In this study, we aimed to accommodate the ability of children to respond to questions and, therefore, measured children's VOCs-related knowledge, as a type of environmental perception, along with their pro-environmental attitudes. The hypotheses are as follows:

H2: Children's learning outcomes will increase after the environmental education program.
H2-1: Children's environmental knowledge will increase after the environmental education program.
H2-2: Children's pro-environmental attitudes will increase after the environmental education program.

Meanwhile, both the ELM and the SCT highlight correlations among individual personal factors, suggesting the existence of an underlying mechanism that influences the formation of strong attitudes. For example, Mosler and Martens (2008) used the ELM to analyze environmental campaign strategies and found that strong arguments were more effective at changing attitudes among individuals with high environmental concern, whereas peripheral cues had a greater influence on those with low concern. Similarly, Mensah et al. (2023) applied SCT and demonstrated that research self-efficacy positively impacted attitudes toward research among university students in Ghana.

In this sense, we hypothesized that the regression model of environmental perception factors (knowledge, concern, and efficacy) on pro-environmental attitudes would have greater explanatory power after participation in the program than before. Accordingly, we propose the following hypothesis:

H3: The regression model of environmental perception factors (knowledge, concern, and efficacy) on pro-environmental attitudes will have greater explanatory power after participation in the program than before.

The Present Study

Most environmental education programs for children showed limitations in inducing actionable outcomes. This result may be due to the ineffectiveness of designing targets, topics, content, and delivery methods. Meanwhile, some programs often presume the essential involvement and assistance of adults, such as parents; however, they tend to overlook the effects of adult-children interactions and possible learning outcomes of adults.

Given the limitations discovered in the literature, we designed an environmental educational curriculum centered on VOCs, which have recently emergeredas a critical social concern. We made attempted to develop a differentiated curriculum that provides tangible, concrete content, fostering active parental involvement that encourages children and parents to actively collaborate, thus facilitating children as primary learners and amplifying the positive effect on their parents. Accordingly, we attempted to evaluate the educational effectiveness of the VOC-focused environmental education program for children and parents.

For this study, we implemented a 5-week program targeting 55 parent–child pairs. A one-group pretest-posttest design, and a quasi-experimental approach were employed. Owing to practical constraints, we chose not to include a control group. Instead, we measured a single group consisting exclusively of parent–child pairs. However, to ensure that the analysis was robust and improve external validity, we conducted a longitudinal analysis. After obtaining the informed consent of the participants in the program, we assessed their environmental perceptions and pro-environmental attitudes at two time points: before the commencement of the program and following its completion.

Methods

Participants

The IRB of the university employing the authors approved this study. We recruited parents and children as participants from five kindergarten classes in South Korea via promotion materials. We recruited 110 participants (55 parents and 55 children from 55 households) to participate in this study. As a reward for completing the survey, we provided the parents with financial compensation of about KRW 20,000 (about USD 14.5). After excluding seven cases in which only the father participated, we analyzed the data of 47 sets of mothers and children.

Table 1 shows the participants' characteristics. They consisted of 47 parents and 47 children, and all the parents were mothers. The mothers' mean age was 41.53 years (SD = 3.316) and 7.85 years (SD = 0.93) for the children. Of the children, 25 (53.2%) were girls, and 22 (46.8%) were boys. Of the mothers, 76.5% had a university education. Of the children, 24 (i.e., more than half the total) were 7 years old. About 63% of the participants had no previous experience with any other form of environmental participation.

Measures

Parents

Environmental. Knowledge

To measure environmental knowledge, we created five questions items to be included in the survey. Participants had to answer questions on their environmental knowledge, measured by their awareness of certain factors such as VOCs, microplastics, and the problematic use of plastics. We dichotomously coded the responses as 1 for yes and 0 for no and summed and averaged them (Yes = 1, No = 0).

Environmental. Concern

To measure environmental concern, we adapted and revised the items from Hansla et al. (2008) and Schultz

Table 1. Participant Characteristics.

Background variables	Parents		Children	
Gender	Female	47	Female	25
	Male	0	Male	22
Age[a]	30s	9	5–6 years	9
	40s	37	7 years	24
	50s	1	8–9 years	14
Education[b]	Undergraduate	36		
	Graduate	11		
Other environment educations	Yes	17		16
	No	30		31

[a]Born in 2014, considered 5 years old as of 2023.
[b]One participant responded as an undergraduate at T1 and then as a graduate at T2. We reported based on T1 results.

(2001). We measured all eight items on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Environmental Efficacy. We adapted and revised the environmental-efficacy variable from Wu and Mweemba (2010) and Abraham et al. (2015). We measured four items on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Pro-Environmental Attitude. We adapted and revised the affective and cognitive items of the measure developed by Quoquab and Mohammad (2020). Finally, we employed 14items on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Children

Environmental Knowledge. To measure the children's environmental knowledge, participants responded to four questions about their knowledge of environmental factors such as VOCs and microplastics. All four items had dichotomous measurements of yes or no, and the sum of all answers yielded a scale and average.

Pro-Environmental Attitude. We adapted the items measuring pro-environmental attitude from Musser and Diamond (1999) and Lee (2016). We showed participants 11 questions about two pictures, one of a child with a nature-friendly attitude, the other of a child with a non-nature-friendly attitude. We asked them to identify which one they felt closer to. We coded scores as 1 if the participants chose the nature-friendly picture and 0 otherwise, then we summed and averaged the scores.

The final versions of questionnaires used in the study for both parents and children are presented in Appendix 1. In addition, as recommended by Hosseini et al. (2023), we reveal that we employed, to some degree, ChatGPT (http://chat.openai.com/) and Quillbot (https://quillbot.com/grammar-check) to refine the academic language and proofread our manuscript. However, the authors of the study attempted to write and proofread sentences on the whole as much as possible.

Procedures. The program involves virtual classes using educational videos and online platforms. Each parent-child pair received two sets of experimental equipment to employ during the classes. In this procedure, parents were required to help their children participate in the experiment. Educational videos including online science experiment sessions were distributed via social networking services during the program. The interactive Q&A channel used for the online class performed seamlessly.

The VOC-focused Environmental Education Program comprised four stages. The first involved gathering information, and the second consisted of conducting preliminary experiments and developing content tailored to the selected topics. The third stage corporated two rounds of revisions and enhancements through internal and external advisory boards. The fourth and final stage included professional design work and proofreading. We subjected the textbooks to validity checks through expert consultations and further refined them through instructor workshops and program validation processes to achieve the final version. Table 2 shows the program's key contents.

Analyses

We used IBM Statistics SPSS 21.0 and AMOS 21.0 to perform statistical analyses to assess the hypotheses. In addition, we conducted paired sample t tests and hierarchical multiple regression analyses.

Table 2. Contents of the Environmental Education Living Lab Program.

Session	Subject	Contents
1	Microplastics NO! Kitchen detergent made from coffee grounds	To investigate the harmful effects of microplastics and prevent water pollution caused by their influx, we are conducting experiments to create kitchen detergent using coffee grounds as an alternative to microplastic particles.
2	Victory is certain for those who persevere to the end! endocrine disrupter	We explore the types and functions of human hormones and investigate the environmental hormones induced by microplastics.
3	Reduce VOC emissions! Dry flower plaster air freshener	We investigate VOCs and substances that deteriorate indoor air quality, and we explore methods to reduce their impact by creating gypsum air fresheners using eco-friendly products such as dried flowers.
4	Remove VOCs! air cleaner	We research the types of VOCs and methods for their removal and then explore the principles of removing fine dust and VOCs by creating a basic air purifier.
5	Eco-friendly cosmetics and containers	We investigate recyclable or waste-reducing cosmetic containers and vegan cosmetics.

Table 3. Results of Paired Sample *T* tests.

Participants	Variables		Pre (T1)	Post (T2)	Change	
			Mean (*SD*)	Mean (*SD*)	Mean (*SD*)	*t*-Value
Mom	Environmental perception	Environmental knowledge	0.634 (0.244)	0.983 (0.056)	−0.349 (0.241)	−9.915***
		Environmental concern	4.899 (0.269)	4.931 (0.231)	−0.032 (0.269)	−0.814
		Environmental efficacy	4.005 (0.652)	4.521 (0.423)	−0.516 (0.535)	−6.609***
	Pro-environmental attitude		4.287 (0.331)	4.535 (0.294)	−0.248 (0.311)	−5.462***
Child	Environmental perception	Environmental Knowledge	0.537 (0.280)	0.904 (0.142)	−0.367 (0.260)	−9.683***
	Pro-environmental attitude		0.874 (0.136)	0.915 (0.090)	−0.041 (0.130)	−2.147*

*$p < .05$. **$p < .01$. ***$p < .001$.

Results

Mean Comparison Between Before and After the Program

To test H1 and H2, we conducted paired sample t tests to examine the differences among all variables between before (T1) and after (T2) in the environmental education program (see Table 3). For mothers, environmental knowledge and environmental efficacy among environmental perceptions showed significant differences between T1 and T2. Environmental knowledge showed a statistically significant increase ($t = -9.915$, $p < .001$) from the T1 mean of 0.634 ($SD = 0.244$) to the T2 mean of 0.983 ($SD = 0.056$). We also found that environmental efficacy significantly increased after the educational program ($t = -6.609$, $p < .001$). In addition, pro-environmental attitudes also showed a significant difference from T1 to T2 ($t = -5.462$, $p < .001$), showing more positive attitudes at T2 ($M = 4.535$). These results suggest that the environmental education program was effective in improving mothers' environmental knowledge, environmental efficacy, and pro-environmental attitudes.

For children, both environmental knowledge and pro-environmental attitudes showed significant differences between pre-education and post-education. Specifically, the level of environmental knowledge indicated a significant increase after the program ($t = -9.683$, $p < .001$); pro-environmental attitudes also showed a significant increase after the program ($t = -2.147$, $p < .05$). This suggests that the environmental education program was effective in improving children's environmental knowledge and pro-environmental attitudes.

The level of all variables pertaining to mothers and children, except for environmental concern, significantly increased after the environmental education program.

The Regression Model: Cross-Sectional Results

To test H3, we conducted a hierarchical multiple regression analysis to examine the influence of demographic variables, other environmental education experiences, and environmental perceptions on attitudes for mothers and children at T1 and T2, respectively.

Table 4. Results of the Hierarchical Regression Model for Mothers.

	Attitudes											
	Pre(T1)						Post(T2)					
	Model 1			Model 2			Model 3			Model 4		
Variables	*B*	*SE*	*t*	*B*	*SE*	*t*	*B*	*SE*	*t*	*B*	*SE*	*t*
(Constant)	4.683	0.618	7.583***	3.669	1.055	3.477**	4.384	0.566	7.749***	0.712	1.026	0.694
Age	−0.012	0.015	−0.789	−0.020	0.015	−1.388	0.003	0.014	0.246	−0.009	0.010	−0.839
Under-graduate (ref. = graduate)	0.049	0.116	0.422	0.069	0.107	0.642	0.003	0.106	0.028	0.000	0.083	0.006
Other education (ref. = No)	0.167	0.103	1.622	0.124	0.105	1.188	0.021	0.094	0.221	−0.043	0.071	−0.614
Concern				0.113	0.179	0.631				0.327	0.164	1.991
Efficacy				0.214	0.077	2.773**				0.379	0.091	4.152***
Knowledge				−0.073	0.208	−0.350				0.893	0.621	1.438
R^2	.064			.258			.003			.490		
Adjusted R^2	−.002			.147			−.066			.414		
Durbin-Watson	1.889						2.389					
F	0.974			2.319			0.044			6.407		
p	.414			.051			.987			.000		

**$p < .01$, ***$p < .001$.

Mothers (Pre). We conducted hierarchical multiple regression analyses to examine the impact of demographic variables and environmental perceptions on the pro-environmental attitudes of mothers prior to participating in the program (see Table 4). Results indicated that regression Model 1 was not significant ($F = 0.974$, $p > .05$), but that regression Model 2 was significant ($F = 2.319$, $p < .1$). Model 1 accounted for 6.4% of the variance (R-squared = 0.064), with an adjusted *R*-squared of −.002. Model 2 explained 25.8% of the variance (*R*-squared = .258), with an adjusted *R*-squared of 0.147. The Durbin-Watson statistic was 1.889.

In Model 1, we entered control variables such as age, education level, and other educational experiences. Then, we added environmental perceptions (environmental concern, environmental efficacy, and environmental knowledge) variables to Model 2.

The results showed that environmental efficacy had a significant effect on attitude at T1 ($B = 0.214$, $p < .01$). However, age, education level, previous education experiences, environmental concern, and environmental knowledge had no significant impact on attitude at T1.

Mothers (Post). We examined the hierarchical regression analyses to investigate the impact of demographic variables and environmental perceptions on the mothers' pro-environmental attitudes after the environmental education program (see Table 4). In Model 1, we included only control variables such as age, education level, and other educational experiences. Then, we added environmental perception variables (environmental concern, environmental efficacy, and environmental knowledge) to Model 2. As a result, regression Model 3 was not significant ($F = 0.044$, $p = .987$), but regression Model 4 was significant ($F = 6.407$, $p < .001$).

Model 3 explained 0.3% of the variance (*R*-squared = .003), with an adjusted *R*-squared of −.066. In contrast, Model 4 explained 49% of the variance (*R*-squared = .490), with an adjusted *R*-squared of .414. The Durbin-Watson statistic for the analysis was 2.389. That is, the post-education explanatory power (*R*-squared = .490) was higher than the pre-education explanatory power (*R*-squared = .258). In Model 4, only environmental efficacy was positively significant regarding attitudes ($B = 0.379$, $p < .001$). The same held true for T1: age, education level, other educational experiences, environmental concern, and environmental knowledge had no significant impact on attitude at T2.

Children (Pre). Table 5 shows the results of hierarchical multiple regression analyses for children at T1. In Model 1, we included control variables, including gender, age, and other environmental education experiences. In

Table 5. Results of the Hierarchical Regression Model for Children.

	Attitudes											
	Pre(T1)						Post(T2)					
	Model 1			Model 2			Model3			Model4		
Variables	*B*	*SE*	*t*	*B*	*SE*	*t*	*B*	*SE*	*t*	*B*	*SE*	*t*
(Constant)	0.978	0.172	5.676***	0.943	0.172	5.495***	1.090	0.109	9.984***	0.937	0.125	7.513***
Gender (ref. = Boy)	0.008	0.041	0.195	0.020	0.041	0.485	0.009	0.026	0.355	0.013	0.025	0.514
Age	−0.016	0.022	−0.736	−0.019	0.022	−0.889	−0.025	0.014	−1.795	−0.028	0.013	−2.088*
Other education (ref. = No)	0.052	0.043	1.224	0.033	0.044	0.750	0.042	0.027	1.571	0.032	0.026	1.226
Knowledge				0.113	0.076	1.489				0.196	0.087	2.246*
R^2	.047			.095			.119			.214		
Adjusted R^2	−.020			.008			.058			.139		
Durbin-Watson	2.291						2.200					
F	0.706			1.099			1.943			2.855*		
p	.554			.370			.137			.035		

*$p < .05$. ***$p < .001$.

Model 2, we added an environmental knowledge variable to the regression equation. As a result, Model 1 ($F = 0.706$, $p > .05$) and Model 2 ($F = 1.099$, $p > .05$) were not significant. For Model 1, the *R*-squared value was .047, with an adjusted *R*-squared of −.020. For Model 2, the *R*-squared value was .095, and the adjusted *R*-squared was .008. The Durbin-Watson statistic was 2.291 for both models.

Children (Post). Table 5 shows the results of hierarchical regression analyses for children at T2. First, we entered gender, age, and other environmental education experiences as control variables in Model 3. Then, we added the environmental knowledge variable to Model 4. The results indicated that Model 3 was not significant ($F = 1.943$, $p > .05$), but that Model 4 was significant ($F = 2.855$, $p < .05$). For Model 3, the *R*-squared was .119 and the adjusted *R*-squared was −.058. For Model 4, the *R*-squared was .214, and the adjusted *R*-squared was .139. The Durbin-Watson statistic for the analysis was 2.200.

In Model 4, age was negatively relevant to attitude ($B = -0.028$, $p < .05$), and environmental knowledge was positively relevant to attitude ($B = 0.196$, $p < .05$). This outcome means that the younger the age of the children, the more positive the impact on their attitudes, and environmental knowledge positively impacted their attitudes. Overall, the findings revealed that the hypotheses H1, H2, and H3 are accepted, as shown in Table 6.

Validity Check: Longitudinal Analysis

To address the absence of a control group, we assessed the external validity of our regression analysis using longitudinal analyses. Specifically, we implemented cross-lagged path linear models followingthe procedures of Hornik et al. (2021). For the analysis, we employed AMOS 21.0. Our aim was to determine whether environmental perception variables could predict pro-environmental attitudes. For this purpose, we conducted separate cross-lagged path analyses for children and mothers.

Mothers. We examined whether mothers' environmental perceptions at T1 explained pro-environmental attitudes at T2. We controlled for age, education experience, and education at T1 in all analyses. These results appear in Figures 1 to 4.

Figure 1 represents the causal relationship between environmental concern and pro-environmental attitudes with a cross-lagged model for mothers. Results indicated that T1 environmental concern had a significant effect on T2 concern ($B = 0.344$, $SE = 0.117$). Furthermore,

Table 6. The Hypotheses Testing Results.

No.	Hypotheses	Results
H1	H1-1: Parents' environmental knowledge will show the increase after the environmental education program.	Accept
	H1-2: Parents' environmental concern will show the increase after the environmental education program.	Accept
	H1-3: Parents' environmental efficacy will show the increase after the environmental education program.	Accept
	H1-4: Parents' environmental attitudes will show the increase after the environmental education program.	Accept
H2	H2-1: Children's environmental knowledge will show the increase after the environmental education program.	Accept
	H2-2: Children's pro-environmental attitudes will show the increase after the environmental education program.	Accept
H3	H3: the regression model of environmental perception factors (knowledge, concern, efficacy) on pro-environmental attitudes will greater explanation power over before the participation on the program.	Accept

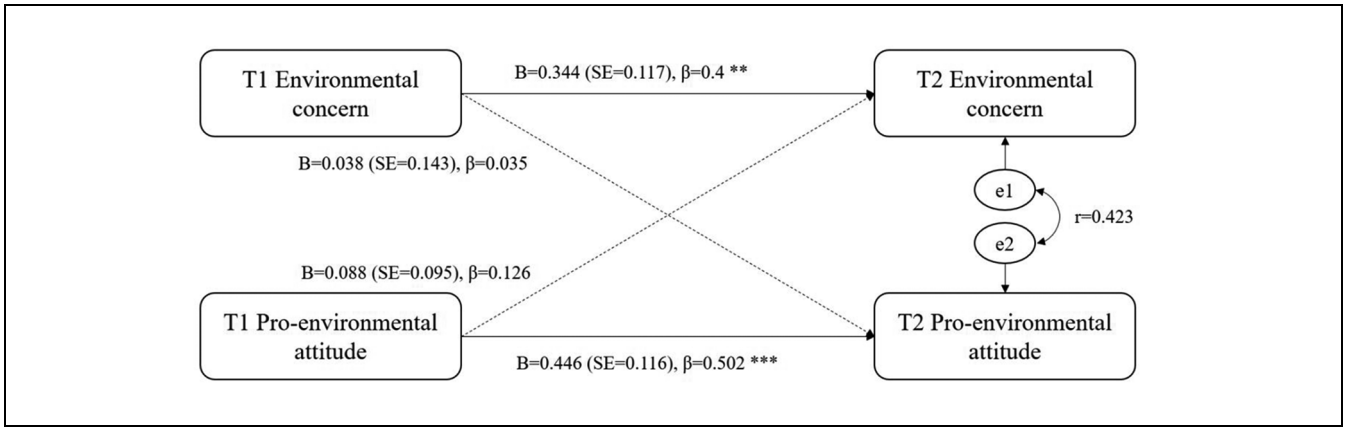


Figure 1. Cross-lagged analysis results about environmental concern and pro-environmental attitude (controlling for age, education experience, education, environmental efficacy, and environmental knowledge).

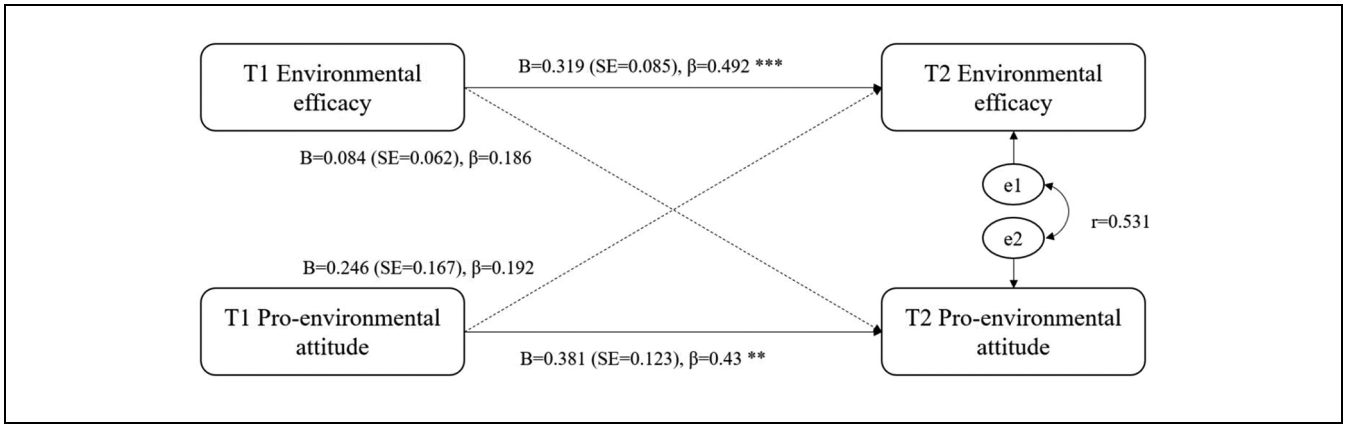


Figure 2. Cross-lagged analysis results about environmental efficacy and pro-environmental attitude (controlling for age, education experience, education, environmental concern, and environmental knowledge).

T1 pro-environmental attitude had a significant effect on T2 pro-environmental attitude ($B = 0.446$, $SE = 0.116$). However, T1 environmental concern did not influence T2 pro-environmental attitude, and T1 pro-environmental attitude did not predict T2 environmental concern.

Figure 2 shows a causal relationship between environmental efficacy and pro-environmental attitudes with a cross-lagged model for mothers. T1 environmental efficacy was a lagged predictor of T2 environmental efficacy ($B = 0.319$, $SE = 0.085$), and T1 pro-environmental attitude was a lagged predictor of T2 pro-environmental

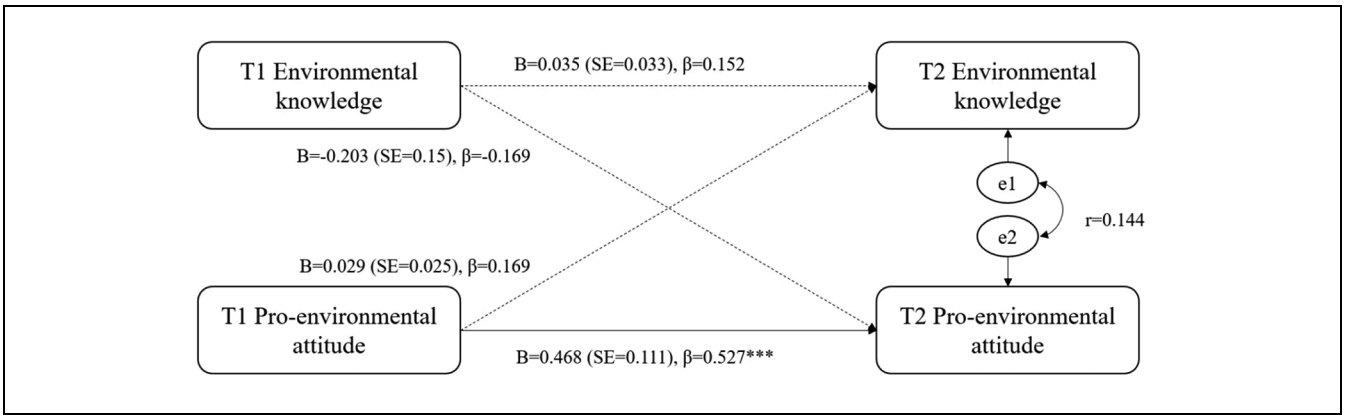


Figure 3. Cross-lagged analysis results about environmental knowledge and pro-environmental attitude (controlling for age, education experience, education, environmental concern, and environmental efficacy).

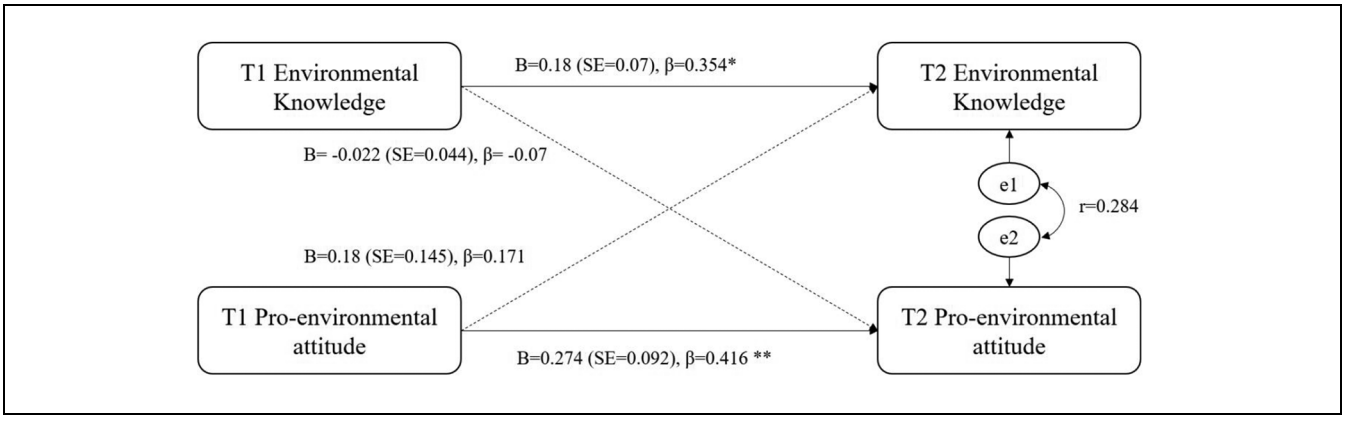


Figure 4. Cross-lagged analysis results about environmental knowledge and pro-environmental attitude (controlling for age, gender, and education experience).

attitude ($B = 0.381$, $SE = 0.123$). However, T1 environmental efficacy did not predict T2 pro-environmental attitude, nor did T1 pro-environmental attitude explain T2 environmental concern.

Figure 3 indicates a causal relationship between environmental knowledge and pro-environmental attitude with a cross-lagged model for mothers. However, environmental knowledge and pro-environmental attitude did not show a causal relationship. Only the T1 pro-environmental attitude significantly explains the T2 pro-environmental attitude ($B = 0.468$, $SE = 0.111$). This outcome suggests that environmental knowledge did not cause pro-environmental attitudes.

None of the environmental perception variables for mothers (i.e., environmental efficacy, environmental concern, and environmental knowledge) significantly influenced pro-environmental attitudes over time. This result suggests that environmental perceptions are not the causal variables of pro-environmental attitudes.

Children. For children, we investigated the causal relationship between environmental knowledge and pro-environmental attitude (see Figure 4). The results showed that T1 environmental knowledge explained T2 environmental knowledge ($B = 0.18$, $SE = 0.07$), and T1 pro-environmental attitude predicted T2 pro-environmental attitude ($B = 0.274$, $SE = 0.092$). However, T1 environmental knowledge did not influence T2 pro-environmental attitude, and T1 pro-environmental attitude did not predict T2 environmental knowledge. The environmental knowledge variable for children was not the causal variable of pro-environmental attitude.

Discussion and Conclusions

In this study, we aimed to evaluate the effectiveness of a VOC-focused environmental education for children and their parents. The VOC-focused environmental program differs from existing education programs in that it

requires increased parental involvement and incorporates concrete actionable knowledge of VOCs. In detail, the findings of this study revealed that pro-environmental attitudes, environmental knowledge, environmental concern, and environmental efficacy significantly improved after the newly developed environmental education program (H1 and H2), a result supported by Damerell et al. (2013) and Wetering et al. (2022). Furthermore, by examining the relationships among these variables and their influence on attitudes through regression analysis, the study demonstrated that the environmental education program enhanced the explanatory power of the regression model. These findings are also in line with Mosler and Martens (2008) and Mensah et al. (2023).

This study provides strong evidence to support the assumption that VOC-focused environmental education positively affects education outcomes for children as well as parents. For children as primary learners, there were significant increases in knowledge and pro-environmental attitudes. In addition, for parents who facilitated their children's learning while watching VOC-focused educational videos, we found significant increases in environmental knowledge, environmental efficacy, and pro-environmental attitudes.

The findings support previous studies by demonstrating the positive relationship between environmental education and educational outcomes. For example, Wetering et al. (2022) performed a meta-analysis of various outcomes of environmental education and indicated that participation in environmental education increased environmental knowledge and attitudes.

In addition, this study strengthens the discussion regarding the flow of learinng effectivess between primary learners and secondary participants. Damerell et al. (2013) indicated that children passed their newly obtained knowledge to their parents. That is, although environmental education primarily targets children, it can influence their parents as secondary partipants if they are actively involved in their children's learning.

Next, this study also showed that pro-environmental attitudes were a strong predictor of pro-environmental behavior, whereas only mothers' environmental efficacy had a significant positive effect on pro-environmental attitudes, both before and after their participation in the program. These findings support Ahmad et al.'s (2022) findings that environmental efficacy significantly influenced positive attitudes.

Meanwhile, the interesting point is that the percentage of variance explained by the model for data collected after the program was significantly greater than the model before the program. In the children group, significant predictors were not found before the program, but afterward, children's age and educational knowledge showed significantly positive effects on attitudes.

Overall, the results imply that although not all factors of environmental perception factors do not necessarily predict environmental attitudes, the impact of environmental perception predictors on pro-environmental attitudes can be enhanced if environmental education is based on parental involvement and delivered in a sufficiently tangible and actionable form. That is, providing specific and practical educational content can strengthen the link between environmental perception and positive attitudes toward the environment.

Furthermore, we showed through longitudinal analysis that environmental education strengthened positive environmental perceptions and pro-environmental attitudes over time, even though T1 environmental perceptions did not explain T2 pro-environmental attitudes. That is, we found that the attitude held prior to the education program was further reinforced through the education program. In addition, parents' environmental perceptions, parents' environmental concerns, parents' environmental efficacy, and children's environmental knowledge were also strengthened through the environmental education.

These findings have theoretical and practical implications. First, at the theoretical level, this study demonstrates that, contrary to the traditional view that children are the sole learners within the education program framework (Schmitz & Da Rocha, 2018; Wetering et al., 2022), parents, who have been viewed as facilitators and enablers of learning, can be included in the program and may benefit from the education.

Second, we suggest that environmental education programs filled with "action knowledge" can have positive educational outcomes. We achieved this result by creating specialized learning content focused on VOCs in a sufficiently concrete and actionable form. The importance of action knowledge in environmental education has been advocated by previous studies (Blumstein & Saylan, 2007; Wetering et al., 2022).

Lastly, this study shows a way of overcoming a limitarion of an absence of a control group when the study aimed to obtain the external validity of the analysis results. To address the issue, we collected data twice, five weeks apart, to evaluate the effectiveness of the education program. The data were analyzed using both cross-sectional and longitudinal analyses, following the approach found in Hornik et al. (2021) to obtain the external validity of the findings.

The practical implications are as follows. When establishing an environmental education program for children, it is crucial to actively involve parents in the program. When the issue are unfamiliar to children, Parental involvement can help children apply and practice actions in their real-life contexts. Parental involvement can also facilitate educational outcomes and empower more effective pro-environmental decisions within a family unit. In

this sense, Duvall and Zint (2007) research is meaningful in that they also highlighted family interaction in environmental education.

Next, this study suggests that educational content should be practical and specific rather than theoretical and general. Especially, for children, action knowledge must be easily translated into actions, given their developmental characteristics.

This study has se limitations. We designed the survey to account for the children's age and developmental stage; thus, we were careful not to include too many questions. We therefore measured only their environmental knowledge and attitudes, whereas we measured parents' knowledge, concern, and environmental efficacy. Second, the program lasted only 5 weeks, so it was not possible to study long-term effects. Lastly, the study is based on self-reported data and lacks a control group, which may raise concerns about unmeasured confounders and potential bias. Future studies are expected to overcome these limitations and make more advanced contributions to the academic discourse.

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Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Ewha Womans University (ewha-202310-0002-01) on Sep 27, 2023, with the need for written informed consent waived.

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Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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Appendix 1

Questionnaire Items for Parents and Children

For Parents.

Variables	Items	References
Pro-environmental attitude	1. I feel good when I can control my whims for buying unnecessary things 2. I don't like to waste food or beverage. 3. I prefer to buy organic food, since it is environmentally friendly. 4. I prefer to pay more to purchase environmentally friendly products. 5. I prefer to use paper bags, since they are biodegradable. 6. I like to purchase only what I need. 7. I feel happy to give priority to environmental welfare. 8. I believe wasting food and other consumables is unethical. 9. I am aware that excess consumption can cause a shortage of natural resources 10. I believe that it is important to use eco-friendly products and services. 11. I am trying to avoid using plastic. 12. I believe that individuals should care for the future generation. 13. I believe that it is our responsibility to care for the natural environment. 14. I know that the natural resources are decreasing at an alarming rate. (The 5-point Likert scale)	Quoquab and Mohammad (2020)
Environmental Perceptions 1: Environmental concern	1. Environmental pollution seems to be worse for my health than I realize. 2. Environmental pollution in one country can harm the environment in other countries. 3. The balance of nature can be easily broken because of environmental pollution. 4. Several species of plants and animals are likely to disappear in a few decades. 5. The current problem of environmental pollution is likely to cause serious changes in the environment. 6. I am worried that environmental problems are harming everyone. 7. I am worried that environmental problems are harming children. 8. I am worried that environmental problems are harming plants. (The 5-point Likert scale)	Hansla et al. (2008), Schultz (2001)
Environmental Perceptions 2: Environmental efficacy	1. I believe I can contribute to environmental conservation through concrete actions in my daily life. 2. I believe I can reduce the negative impact of microplastics and VOCs. 3. I can dispose of waste (e.g., household waste) well. 4. I know how to recycle appropriately. (The 5-point Likert scale)	Wu and Mweemba (2010), Abraham et al. (2015)
Environmental Perceptions 3: Environmental knowledge	1. I know what volatile organic compounds (VOCs) are. 2. I recognize the human health effects of microplastics, one of the sources of environmental hormones. 3. I am aware of ways to protect the environment and my health from VOCs. 4. I recognize the problems associated with the use of plastics. 5. I am familiar with microplastics in cosmetics. (Yes = 1, No = 0)	Developed

For Children

Variables	Items	References
Pro-environmental attitude	As shown in the picture, you have two friends. Which of your two friends is more like you? (22 questions) (Nature-friendly attitude picture = 1, Non-nature-friendly attitude picture = 0)	Musser and Diamond (1999), Lee (2016)
Environmental perception (knowledge)	1. I know what volatile organic compounds (VOCs) are. 2. I recognize what microplastics are. 3. I am aware of how plastics should be used. 4. I know why using plastics is bad for the environment. (Yes = 1, No = 0)	Developed