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Bridging the Gap: Environmental Health Literacy as Key to Adolescent Well-Being and Sustainable Behaviors

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Abstract: Adolescents who possess environmental health literacy are more equipped to handle the effects of the environment on their health. This study uses data from Portugal's 2022 HBSC survey to investigate the environmental health literacy (EHL) of teenagers. The Environmental Health Literacy Scale (EHLS) was verified by confirmatory component analysis. Within the framework of an ecosystem, this study investigates factors related to health and well-being. There are 7355 adolescents in the sample. EHLS_Social Norms and participation in volunteering activities were found to be significant predictors of EHL_Knowledge, which explained 25.2% of the variance in the final model. EHLS_Social Norms and EHLS_Knowledge accounted for 42.9% of the variance in EHL_Behaviors, while school grade was adversely connected with pro-environmental behavior. While actions and knowledge were major positive predictors, gender and school grades showed negative relationships, and EHL_Social Norms accounted for 46% of the variance. This study establishes a valid measure of environmental health literacy in adolescents, informing science education strategies and public health interventions.

Keywords: environmental health literacy scale; adolescents; HBSC survey; gender differences; school grade differences; knowledge; behaviors; social norms

Academic Editor: Tai-Yi Yu

Received: 8 February 2025
Revised: 9 April 2025
Accepted: 11 April 2025
Published: 16 April 2025

Citation: Matos, M.G.d.; Branquinho, C.; Domingos, L.; Botelho Guedes, F.; Cerqueira, A.; Gaspar, T. Bridging the Gap: Environmental Health Literacy as Key to Adolescent Well-Being and Sustainable Behaviors. *Sustainability* **2025**, *17*, 3594. https://doi.org/10.3390/su17083594

1. Introduction

The literature describes environmental health literacy (EHL) as the ability to understand, evaluate, and act upon information regarding environmental hazards and their health impacts [1]. According to Teksoz et al. (2014) [2], literacy is one of the main factors influencing individuals' understanding and engagement with environmental issues. Thus, EHL extends beyond knowledge acquisition; it involves the capacity to critically assess environmental health risks and apply this knowledge in decision-making processes [3]. As such, EHL is a critical tool for addressing and mitigating environmental challenges, as it enhances individuals' capacity to make informed decisions that contribute to healthier environments. This literacy framework emphasizes not only individual awareness but also collective action in addressing environmental health concerns. Understanding the environ-

mental health knowledge, norms, and behaviors of adolescents is especially important, as they play a pivotal role in shaping future social and environmental policies [4].

Adolescence represents a key phase for the development of environmental health literacy, as it is a period of heightened awareness and behavioral adaptation [5]. However, studies indicate that adolescents often exhibit low levels of EHL, particularly in their ability to link environmental exposure with health outcomes [6]. Research shows a developmental pattern where environmental health literacy increases between the ages of 7 and 10, stabilizes at around age 14, and then declines during the later teenage years [7]. This trend is also mirrored by the complexity of adolescents' relationship with environmental health, as older adolescents tend to show a higher emotional connection with nature yet paradoxically report lower levels of environmental health knowledge and engagement [8].

Factors such as socioeconomic status can significantly influence adolescents' environmental health literacy. Studies have shown that a higher perception of financial stability is associated with greater access to resources, including educational opportunities that specifically address environmental health issues and which foster higher levels of EHL [9]. Furthermore, economic security influences family priorities and behaviors, potentially shaping adolescents' environmental health literacy through health-related household practices and exposure to environmental risks [10].

The role of educational institutions in shaping adolescents' environmental health literacy has been widely recognized in the literature. Studies show that schools with strong environmental health education programs create environments where students are exposed to critical health-focused sustainability topics, positively influencing their attitudes and environmental health literacy [11]. For example, outdoor educational experiences have been identified as particularly effective in fostering a sense of responsibility and connection to environmental determinants of health [12]. However, disparities in school capacity, such as resource limitations or a lack of trained staff, can hinder these efforts, leaving many adolescents with limited opportunities for developing environmental health literacy competencies [13].

Despite this, there remains a significant gap between the concerns adolescents express for the environment and their corresponding behaviors. While adolescents recognize environmental risks and their implications for human health, their actions often do not align with this awareness, revealing a critical gap between knowledge and practice in EHL [4].

Liking school has been highlighted as another determinant of pro-environmental behaviors and environmental health literacy. Adolescents who enjoy their school experience are more likely to engage in environmental initiatives, such as recycling programs or community clean-up activities, often organized within educational settings [13]. Positive experiences at school foster a sense of belonging and responsibility, which are critical for sustained engagement in environmental health issues [14].

Gender differences are also significant, and the literature shows that girls present a greater tendency to adopt pro-environmental behaviors and have greater environmental health literacy compared to boys, which can be explained by differences in subjective and objective knowledge, motivation, and perceived self-efficacy in environmental health contexts [15]. Therefore, actively including young people is essential, promoting not only pro-environmental behaviors but also an understanding of environmental determinants of health and critical thinking about risk factors [16].

Participation in volunteer activities is another critical factor that influences adolescents' pro-environmental behaviors and environmental health literacy. Volunteering provides adolescents with direct, hands-on opportunities to contribute to environmental causes, bridging the gap between knowledge and action [9]. Moreover, it fosters a sense of agency and rein-

forces the importance of community-level environmental efforts. Studies have shown that adolescents involved in volunteer work develop higher levels of environmental self-efficacy and are more likely to engage in long-term pro-environmental behaviors [17,18].

Studies refer to some factors that influence environmental health risk perception and behaviors, such as lifestyle, life satisfaction, personal health practices, and social norms, which influence pro-environmental behavior [19–22]. The nature of these behaviors is, in turn, influenced by the most immediate and most macrosystemic contexts: on the one hand, there is the sociocultural context [23].

Therefore, it is essential not only to characterize and understand the knowledge, behaviors, and norms that influence the environmental health literacy of adolescents but also to develop measures adjusted to the mechanisms responsible for the development of these constructs while ensuring alignment with EHL models, such as Gray's framework, which integrates individual-, community-, and policy-level influences [8,24,25].

Moreover, understanding how social, educational, and personal factors intersect to shape adolescents' environmental health literacy is crucial. Recent studies emphasize the fact that effective environmental health interventions should integrate literacy-based approaches that empower adolescents to assess risks and adopt protective behaviors [10,17]. Programs that integrate these factors holistically are better positioned to cultivate not only environmental responsibility but also a deeper awareness of health implications [18].

This study draws from a large-scale adolescent health questionnaire, first to undertake a confirmatory factor analysis on the items of the new Environmental Health Literacy Scale (EHLS) and then to analyze how other social, educational, and personal variables could influence adolescents' environmental health literacy, differentiating it from general pro-environmental behaviors.

- How do social, educational, and personal variables influence adolescents' environmental health literacy (EHL)?
- What is the relationship between adolescents' environmental health literacy (EHL) and general pro-environmental behaviors?
- How do the different dimensions of the Environmental Health Literacy Scale (EHLS) predict adolescents' knowledge, behaviors, and attitudes toward environmental health?

2. Method

The data used in this study are part of the Health Behavior in School-Aged Children (HBSC) 2022 survey [26]. This survey is carried out every 4 years in collaboration with the Organization World Health Organization (WHO) and follows a strict international protocol [27,28].

The HBSC/WHO aims to study adolescents' health behaviors and habits in their life contexts and their influence on their health/well-being. In Portugal, the HBSC/OMS 2022 study has the approval of the Ethics Committee of the Academic Center of Medicine of Lisbon of the Lisbon North Hospital Center and the General Directorate of Statistics for Education and Science (DGEEC). The school groups participated voluntarily, and informed consent was obtained from all participants' parents or legal guardians. Responses to the questionnaire were obtained online and anonymously. The sample is representative of the years of schooling under study. More details about the data collection procedures for the HBSC/WHO 2022 study in Portugal can be found in Gaspar et al. (2022) [26].

2.1. Participants

The sampling technique used was cluster sampling, where the unit of analysis was the classroom. To obtain a representative sample of the Portuguese school population,

40 school clusters from basic and secondary education across the entire mainland (covering five school regions) were selected, totaling 452 classrooms.

The sample consisted of 7355 participants, with a gender distribution of 46.15% boys (n = 3394) and 53.85% girls (n = 3961). The average age of the participants was 15.05 years (SD = 2.37). The students were from the 6th grade (n = 1668; 22.68%), 8th grade (n = 1844; 25.07%), 10th grade (n = 2057; 27.97%), and 12th grade (n = 1786; 24.28%).

2.2. Data Analysis

SPSS quantitative analysis software v. 29 was used to process the data. Descriptive statistics, ANOVA, and multiple regression models were used to analyze the data. ANOVA was applied to identify significant differences in all dimensions of EHLS based on gender and school year (proxy for age). Spearman's correlations highlighted the associations between social, educational, and personal variables, such as the perception of the financial family level, school capacity, liking school, and participation in volunteer activities. Finally, multiple regression models analyzed the joint effects of the predictor variables on the dependent dimensions (the Stepwise method). The significance level was set at $p < 0.05$.

2.3. Measures and Variables

Table 1 presents the variable considered to meet the study's objectives.

Table 1. Measures and variables under study [26].

Variables	Measures
Gender	1—Female; 2—Male
School grade	1—6th grade; 2—8th grade; 3—10th grade; 4—12th grade
Perception of financial family level	1—Very bad; 2—Bad; 3—Middle; 4—Good; 5—Very well
School competence	1—Below average; 2—Average; 3—Good; 4—Very good
Liking school	1—I don't like it at all; 2—I don't like it much; 3—I like it somewhat; 4—I like it a lot
Participation in volunteer activities	1—Rarely or never; 2—Only on weekends; 3—Almost or every day; 4—Many hours a day
EHLS_Behaviors	Scale with three items, on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Higher values reveal more environmental health pro-behaviors (e.g., "For sustainable development, it is necessary to preserve all types of living beings (preservation of biological diversity)".
EHLS_Knowledge	Scale with five items, on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Higher values reveal more environmental health knowledge (e.g., "When I can choose a project topic at school, I choose a topic related to the environment.").
EHLS_Social Norms	Scale with three items, on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Higher values reveal more environmental health social norms (e.g., "My family is environmentally friendly.").

3. Results

The means of the dimensions of EHLS studied were as follows: knowledge (M = 4.42; SD = 0.845), behaviors (M = 3.34; SD = 1.13), and social norms (M = 3.7; SD = 0.98).

The EHLS was subjected to exploratory factor analysis and confirmatory factor analysis to verify its structure and psychometric properties. Aiming to have a very short scale with the same number of items in all three factors, the two items with the lowest saturation for the factor EHLS_Knowledge were removed, verifying that the good fit of the model was kept

3.1. Exploratory Factor Analysis (EFA)

The EFA was restricted to three factors, according to the previously validated structure: EHLS_Behaviors, EHLS_Knowledge, and EHLS_Social Norms (EHLS; [29]).

The items showed factor loadings consistent with the original structure of the instrument, indicating good organization in terms of the theoretical dimensions proposed. The model fit indices showed adequacy, with χ^2 = 549.714 (gl = 24, $p < 0.001$), RMSEA = 0.055 (90% Confidence Interval: 0.051–0.059), CFI = 0.985, NFI = 0.985.

To test the fit of the proposed model, the following indices were analyzed: X^2, CFI (Comparative Fit Index), and RMSEA (Root Mean Square Error of Approximation) as discussed in the specialist literature [30]. The following index values were adopted as criteria for the satisfactory fit of the model to the data: a CFI greater than 0.90; RMSEA close to or less than 0.08; and NFI greater than 0.90.

3.2. Confirmatory Factor Analysis (CFA)

The dimensions identified showed good psychometric properties, as evidenced by the following internal consistency coefficients: EHLS_Behaviors/Bhv (α = 0.856), EHLS_Knowledge/KnW (α = 0.879) and EHLS_Social Norms/ScN (α = 0.826). The factor structure explained 73.51% of the model's total variance. Figure 1 presents the confirnatory factor analysis.

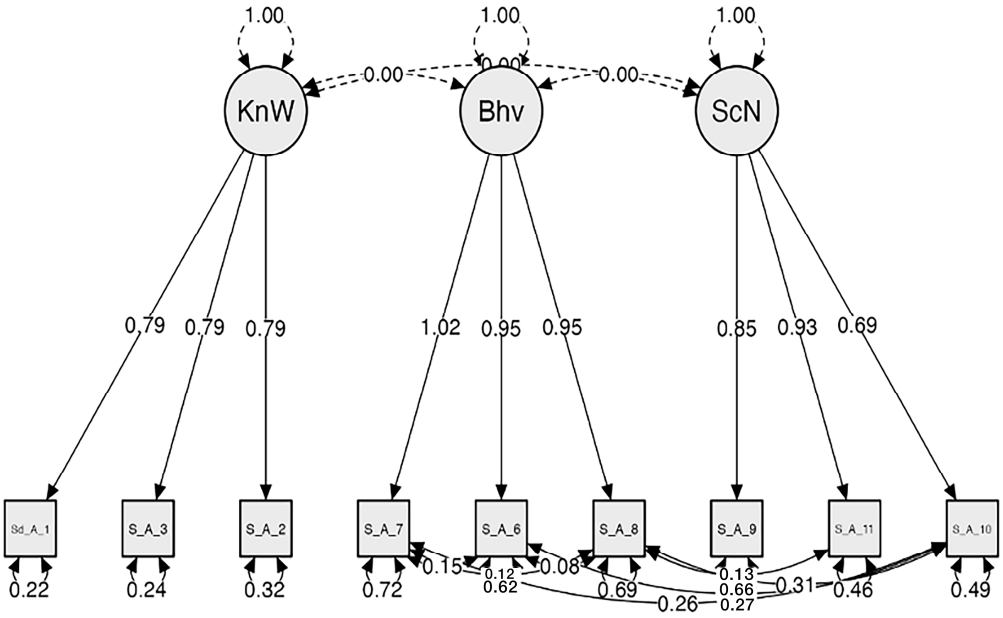

Figure 1. Confirmatory Factor Analysis Model fit indices.

3.3. Gender Differences

An analysis of variance (ANOVA) was carried out to assess the differences between genders in the EHLS_Knowledge, EHLS_Behaviors, and EHLS_Social Norms factors. The results indicated statistically significant differences between genders in the EHLS_Knowledge factor (F(1,7353) = 93.723, $p < 0.001$) and EHLS_Behaviors factor (F(1,7353) = 10.436, $p < 0.001$).

However, in the EHLS_Social Norms factor, no statistically significant differences were identified between the genders (F(1,7353) = 1.738, $p = 0.187$). The female gender stood out in the EHLS_Knowledge and EHLS_Behavior dimensions (Table 2).

Table 2. Mean values for the 3 Subscales | Scores by gender.

		N	*M*	*SD*	df	F
EHLS_Knowledge	Boy	3394	4.316	0.93	1	93.723 ***
	Girl	3961	4.507	0.754		
EHLS_Behaviors	Boy	3394	3.298	1.199	1	10.436 ***
	Girl	3961	3.384	1.071		
EHLS_Social Norms	Boy	3394	3.713	1.017	1	1.738
	Girl	3961	3.683	0.949		

Note: *** $p < 0.001$.

3.4. Age Differences

For the EHLS_Knowledge factor, the analysis revealed a significant difference between the groups (F(3,7351) = 33.985, $p < 0.001$). With regard to the EHLS_Behaviors dimension, a significant difference was also observed between the groups (F(3,7351) = 76.570, $p < 0.001$). Finally, for the EHLS_Social Norms factor, the analysis showed a significant difference between the groups (F(3,7351) = 145.653, $p < 0.001$). The 12th grade stood out in the EHLS_Knowledge dimension, while the 6th grade stood out in the EHLS_Behaviors and EHLS_Social Norms dimensions (Table 3).

Table 3. Mean values for the 3 Subscales | Scores by age proxy.

		N	M	SD	df	F
EHLS_Knowledge	6th grade	1668	4.317	0.94	3	33.985 ***
	8th grade	1844	4.321	0.904		
	10th grade	2057	4.468	0.799		
	12th grade	1786	4.557	0.705		
EHLS_Behaviors	6th grade	1668	3.657	1.092	3	76.570 ***
	8th grade	1844	3.367	1.109		
	10th grade	2057	3.293	1.130		
	12th grade	1786	3.088	1.128		
EHLS_Social Norms	6th grade	1668	4.077	0.939	3	145.653 ***
	8th grade	1844	3.726	0.9638		
	10th grade	2057	3.599	0.967		
	12th grade	1786	3.422	0.941		

Note: *** $p < 0.001$.

3.5. Correlation Between EHL and Social, Educational, and Personal Variables

The Spearman correlation analysis revealed several significant relationships between the variables under study. The EHLS_Knowledge variable showed a positive correlation between EHLS_Behaviors, EHLS_Social Norms, school grade, liking school, perception of family financial level, school capacity, and a negative correlation with participation in volunteer activities.

EHLS_Behaviors presented positive correlations with EHLS_Social Norms, the perception of family financial level and school capacity, participation in volunteer activities, liking school, and negative correlations with school grades. EHLS_Social Norms showed the same pattern as EHLS_Behaviors (Table 4).

Table 4. Correlation between EHL and variables under study.

	1	2	3	4	5	6	7	8
1. EHLS_Knowledge	--							
2. EHLS_Behaviors	0.471 ***	--						
3. EHLS_Social Norms	0.417 ***	0.647 ***	--					
4. School grade	0.113 ***	−0.172 ***	−0.245 ***	--				
5. Perception of family financial level	0.029 ***	0.097 ***	0.163 ***	−0.140 ***	--			
6. School competence (perception)	0.136 ***	0.070 ***	0.110 ***	−0.138 ***	0.145 ***	--		
7. Liking school	0.096 ***	0.126 ***	0.201 ***	−0.183 ***	0.106 ***	0.278 ***	--	
8. Participation in volunteer activities	−0.035 **	0.175 ***	0.106 ***	−0.094 ***	0.020 ***	−0.023	0.005	--

Note: *** $p < 0.001$; ** $p < 0.01$.

Stepwise multiple regression analyses were conducted to predict EHLS_Knowledge, EHLS_Behaviors, and EHLS_Social Norms based on independent variables: EHLS, school grade, gender, perception of family financial level, perception of school competence, liking school, and participation in volunteering activities.

3.6. Predictor Variables on the EHLS_Knowledge

In total, 15.5% of the variation was explained by the first model, which included EHLS_Social Norms as the only predictor (R^2 = 0.155; F(1,5634) = 1036.87, $p < 0.001$). R^2 = 0.252; F(7,5628) = 271.20, $p < 0.001$; the final model, which included all predictors (except perception of family financial level, excluded from all models), explained 25.2% of the variance (Table 5). Table 6 summarizes the results of the ANOVA for all models, verifying the adequacy of the model. The standardized (β) and unstandardized (B) coefficients for every predictor in the finished model are shown in Table 7. According to the findings, the best predictors were participation in volunteering activities (β = −0.174, $p < 0.001$) and EHLS_Social Norms (β = 0.313, $p < 0.001$). The model was also strongly influenced by other predictors, including school competence (perception) (β = 0.094, $p < 0.001$), liking school (β = 0.035, $p < 0.01$), school grade (β = 0.152, $p < 0.001$), EHLS_Behaviors (β = 0.174, $p < 0.001$), and gender (β = 0.115, $p < 0.001$).

Table 5. Summary of regression models for EHLS_Knowledge.

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate
1	0.394	0.155	0.155	0.74717
2	0.431	0.186	0.186	0.73351
3	0.457	0.209	0.208	0.72326
4	0.479	0.229	0.229	0.71402
5	0.491	0.241	0.240	0.70867
6	0.501	0.251	0.250	0.70389
7	0.502	0.252	0.251	0.70343

Table 6. Analysis of variance (ANOVA) for EHLS_Knowledge.

Model	Sum of Squares	df	Mean Square	F	*p*
1	578.851	1	578.851	1036.865	<0.001
2	693.389	2	346.694	644.370	<0.001
3	778.029	3	259.343	495.777	<0.001
4	853.285	4	213.321	418.415	<0.001
5	896.684	5	179.337	357.093	<0.001
6	935.169	6	155.861	314.576	<0.001
7	939.342	7	134.192	271.197	<0.001

Table 7. Linear regression coefficients for the final model of EHLS_Knowledge.

Predictor	B	Standard Error	β	t	*p*
(Constant)	2.267	0.073	-	31.111	<0.001
EHLS_Social Norms	0.263	0.013	0.313	20.755	<0.001
Participation in volunteering activities	−0.198	0.013	−0.174	−14.732	<0.001
School grade	0.155	0.012	0.152	13.004	<0.001
EHLS_Behaviors	0.126	0.011	0.174	11.548	<0.001
Gender	0.187	0.019	0.115	9.838	<0.001
School competence (perception)	0.094	0.012	0.094	7.794	<0.001
Liking school	0.035	0.012	0.035	2.904	<0.01

3.7. Predictor Variables on the EHLS_Behaviors

To investigate the predictors of behaviors, a multiple linear regression analysis was used. Only EHLS_Social Norms were included in the first model (Model 1), which explained 39.7% of the behavioral variance ($R^2 = 0.397$, $F(1,5634) = 3714.89$, $p < 0.001$). In total, 42.9% of the behavioral variance was explained by the inclusion of independent factors in Model 6 (adjusted $R^2 = 0.428$, $F(6,5629) = 704.65$, $p < 0.001$).

The perception of school competence and the financial level of the family were not included in this model. EHLS_Social Norms had the greatest positive influence on behaviors, according to the analysis ($\beta = 0.564$, $p < 0.001$). Furthermore, there were positive correlations found between EHLS_Knowledge ($\beta = 0.132$, $p < 0.001$) and participation in volunteering activities ($\beta = 0.140$, $p < 0.001$). On the other hand, although these impacts were less strong, school grade ($\beta = -0.032$, $p = 0.002$) and liking school ($\beta = -0.020$, $p = 0.048$) demonstrated negative associations (Table 8). The ANOVA results for each regression model are shown in Table 9, verifying the adequacy of the model. The regression coefficients for the finished model are shown in Table 10.

Table 8. Summary of regression models for EHLS_Behaviors.

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate
1	0.630	0.397	0.397	0.87468
2	0.641	0.411	0.411	0.86469
3	0.652	0.425	0.425	0.85425
4	0.654	0.428	0.427	0.85269
5	0.655	0.429	0.428	0.85206
6	0.655	0.429	0.428	0.85184

Table 9. Analysis of variance (ANOVA) for EHLS_Behaviors.

Model	Sum of Squares	df	Mean Sqaure	F	*p*
1	2842.15	1	2842.15	3714.89	<0.001
2	2940.82	2	1470.41	1966.61	<0.001
3	3042.66	3	1014.22	1389.84	<0.001
4	3058.38	4	764.60	1051.61	<0.001
5	3065.09	5	613.02	844.36	<0.001
6	3067.93	6	511.32	704.65	<0.001

Table 10. Linear regression coefficients for the final model EHLS_Behaviors.

Predictor	B	Standar Error	β	t	*p*
(Constant)	−0.170	0.092	—	−1.860	0.063
EHLS_Social Norms	0.658	0.013	0.564	49.428	<0.001
Participation in volunteering activities	0.222	0.016	0.140	13.574	<0.001
EHLS_Knowledge	0.183	0.016	0.132	11.537	<0.001
Gender	0.110	0.023	0.049	4.776	<0.001
School grade	−0.045	0.015	−0.032	−3.066	<0.01
Liking school	−0.028	0.014	−0.020	−1.977	<0.05

3.8. Predictor Variables on the EHLS_Social Norms

According to the findings, the final model explained almost 46% of the total variation (adjusted $R^2 = 0.460$) and was statistically significant ($F(7,5628) = 687.443$, $p < 0.001$) (Table 11). The ANOVA results for each regression model are shown in Table 12, verifying the adequacy of the model. The regression coefficients showed the two most positive predictors of EHLS_Social. Norms were EHLS_Knowledge (β = 0.225, $p < 0.001$) and EHLS_Behaviors (β = 0.531, $p < 0.001$). There was a substantial negative correlation between school grade and EHLS_Social Norms (β = −0.080, $p < 0.001$), suggesting that EHLS_Social Norms were stronger among those with lower education levels. Additionally, the perception of family financial level (β = 0.073, $p < 0.001$) and liking school (β = 0.075, $p < 0.001$) were found to be favorable predictors. While participating in volunteering activities had a minor but significant effect (β = 0.021, $p = 0.037$), gender had a negative impact (β = −0.070, $p < 0.001$) (Table 13).

Table 11. Summary of regression models for EHLS_Social Norms.

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate
1	0.630	0.397	0.397	0.74939
2	0.660	0.435	0.435	0.72569
3	0.666	0.444	0.444	0.71986
4	0.671	0.451	0.450	0.71577
5	0.675	0.456	0.455	0.71248
6	0.679	0.461	0.460	0.70936
7	0.679	0.461	0.460	0.70915

Table 12. Analysis of variance (ANOVA) for EHLS_Social Norms.

Predictor	B	Standard Error	β	t	*p*
(Constant)	0.796	0.088	-	9.006	<0.001
EHLS_Behaviors	0.455	0.009	0.531	48.906	<0.001
EHLS_Knowledge	0.267	0.013	0.225	20.726	<0.001
School grade	−0.097	0.012	−0.080	−7.948	<0.001
Family financial level (perception)	0.077	0.011	0.073	7.236	<0.001
Liking school	0.090	0.012	0.075	7.556	<0.001
Gender	−0.135	0.019	−0.070	−7.053	<0.001
Participation in volunteering activities	0.029	0.014	0.021	2.087	<0.05

Table 13. Linear regression coefficients for the final model EHLS_Social Norms.

Model	Sum of Squares	df	Mean Square	F	*p*
1	2086.225	1	2086.225	3714.894	<0.001
2	2283.747	2	1141.873	2168.311	<0.001
3	2331.713	3	777.238	1499.892	<0.001
4	2365.313	4	591.328	1154.215	<0.001
5	2392.222	5	478.444	942.502	<0.001
6	2417.752	6	402.959	800.814	<0.001
7	2419.942	7	345.706	687.443	<0.001

4. Discussion

The results obtained from this study offer significant insights into environmental health literacy among Portuguese adolescents.

In accordance with previous research, the study revealed that girls exhibited higher EHL levels than boys, both in terms of knowledge and behavior [15]. This aligns with Gray's model of EHL, which emphasizes the interaction of individual, societal, and educational factors in shaping environmental health literacy [9]. The findings also suggest that adolescents' knowledge of environmental health tends to increase with higher school years, while their environmental health-related behaviors and perceived social norms appear to decrease as they age, which is a trend also identified in earlier studies [7,8].

The analysis further showed that participation in volunteer activities, liking school, and family financial perception were all significant positive predictors of EHL rather than just pro-environmental behaviors. These factors align with Gray's conceptualization of EHL as a multidimensional construct, where personal, environmental, and educational influences converge to shape risk awareness, decision-making, and protective behaviors. Research suggests that a higher perception of financial stability is linked to better access to resources, such as environmental education and extracurricular activities, which play a crucial role in fostering environmentally friendly attitudes [9].

Another significant aspect influencing EHL is enjoying school. Teenagers who have good school experience are more likely to take part in health-related environmental activities that are often encouraged in educational settings, such as recycling programs or community clean-ups [13]. According to Barr et al. [14], a supportive school environment fosters a sense of responsibility and engagement, which are crucial for sustaining health-conscious environmental behaviors. Another important element influencing adolescents' EHL is their involvement in volunteer work. Volunteering provides adolescents with

real-world exposure to environmental health issues, reinforcing the connection between environmental conditions and health outcomes [9]. This hands-on engagement allows them to bridge the gap between environmental health knowledge and action, which is a core component of EHL models.

This study also highlights an important gap between environmental health knowledge and behavior. While adolescents demonstrate awareness of environmental risks and their impact on health, this awareness does not always translate into proactive behaviors. This supports findings in the EHL literature that emphasize the need for interventions that go beyond knowledge dissemination, focusing on fostering decision-making skills and action-oriented literacy [4].

Involvement in extracurricular activities has been highlighted in previous studies as an important variable in promoting EHL, and a perception of financial scarcity is associated with a lower likelihood of engaging in health-promoting environmental practices [31,32]. The EHLS_Knowledge and EHLS_Social Norms dimensions also showed significant positive correlations and could be seen as possible predictors of more pro-environmental behavior. This reveals a gap between their knowledge/social norms and behavior regarding the environment [4].

In EHLS_Knowledge, the final model explained 25.2% of the variation. In addition to school grades, EHLS_Behaviors, gender, school competence, liking school, EHLS_Social Norms, and participation in volunteering activities were significant predictors. According to the findings, adolescents who are more engaged in volunteer work and who adhere more strongly to social norms related to environmental health tend to have higher levels of EHL knowledge.

The final model of EHLS_Behaviors explained 42.9% of the variance. The best predictor was EHLS_Social Norms, which was followed by EHLS_Knowledge and participation in volunteering activities. Unlike traditional pro-environmental behavior models, this suggests that social norms related to environmental health play a key role in shaping not only behaviors but also risk perception and engagement with health-focused environmental actions. Pro-environmental behaviors were negatively associated with school grades and liking school, reinforcing previous research that indicates a decline in environmental engagement as adolescents grow older.

The final model of EHLS_Social Norms accounted for 46% of the variance. The biggest predictors were EHLS_Behaviors and EHLS_Knowledge, although gender and school grade showed negative correlations, indicating that EHLS_Social Norms were more prominent among girls and younger children. Positive predictors included family income and school preference, while volunteerism had a small but noteworthy impact.

These results support the notion that environmental health literacy is influenced by a complex interplay between social, educational, and personal factors. They suggest that effective interventions should focus on fostering critical thinking about environmental health risks, strengthening social norms that support protective behaviors, and ensuring equitable access to environmental health education. This aligns with Gray's model, which stresses the importance of multi-level interventions that integrate individual knowledge, social influences, and structural factors to enhance EHL across different contexts.

The conclusions of this study present important directions for the development of health promotion strategies and interventions aimed at adolescents. In this work, we highlight the following:

(i) Focusing on enhancing environmental health education, increasing adolescents' knowledge of environmental issues, and their impact on health promotes pro-environmental behaviors.

(ii) Considering gender differences in the design of interventions, ensure that these programs address the specific needs of both girls and boys in relation to environmental health.
(iii) Adopting holistic approaches is important to promote overall adolescent well-being, integrating educational, social, and personal factors.
(iv) Encouraging school-wide participation and recognizing that the school can be a key player in promoting environmental literacy and health is significant.
(v) Collaboration can be facilitated between schools, families, non-governmental organizations, and governmental bodies to develop comprehensive, community-oriented strategies for improving environmental health literacy.

4.1. Strengths and Limitations

The present study provides a comprehensive overview of environmental health literacy (EHL) among adolescents, addressing key concepts, influencing factors, and measurement approaches. Additionally, this study employs a robust methodology, a representative sample of the national panorama, and rigorous statistical analysis. The results offer significant insights into the relationships between EHL, health and well-being variables, and environmental behaviors among adolescents.

Additionally, the study's CFA shows that the model fits the data well, with internal consistency coefficients indicating high psychometric qualities and factor loadings that are in line with the instrument's original structure. It is crucial to remember, however, that certain items show factor loadings that are larger than anticipated. Even though a factor loading near one is generally expected, this result could indicate redundancy or possible problems with the model's specification, like multicollinearity between items or the need for model change. In order to improve the model's adequacy, different factorial configurations and item adjustments were tested. However, the modifications introduced did not lead to significant improvements in the fit indices, suggesting that the observed difficulties were inherent to the age differences among participants and the way they interpreted the assessed constructs. This limitation reinforces the need for either a specific instrument for this age group or deeper adaptations in item formulation.

Another critical issue concerns the differences in the development of the dimensions measured by the instrument. Knowledge, social norms, and behaviors related to the assessed topic may have different meanings for this age group, compromising construct validity and suggesting the need for scale adaptations.

Finally, the findings have significant translational implications, particularly for the design of health promotion strategies and targeted interventions aimed at improving environmental health literacy and environmentally responsible behaviors in adolescents.

However, this study has certain limitations. Its national scope restricts the generalizability of findings to other countries and cultural contexts. Additionally, the cross-sectional design prevents causal inferences between variables. Another limitation is the reliance solely on self-reported data, which may introduce biases such as social desirability effects, potentially influencing adolescents' responses to environmental behaviors and literacy levels.

4.2. Key-Findings

- The tested model revealed weaknesses in its ability to fit the data, raising questions about the validity of replicating the Environmental Health Literacy Scale (EHLS). Although the chi-square test (χ^2) is significant, it is common for it to yield statistically significant results in very large samples [33]. These results suggest the need for revisions in the scale's structure to ensure greater accuracy in measuring adolescents'

environmental health literacy. All the findings should be analyzed with caution due to these model's weaknesses.

- Gender Differences: Consistent with previous research, girls exhibited significantly higher scores in both environmental health knowledge and behaviors compared to boys, reinforcing findings that females are generally more engaged in pro-environmental actions.
- School Year/Grade Effects: Environmental health behaviors and social norms were stronger in younger adolescents, while environmental health knowledge increased with grade level. This trend indicates that older adolescents tend to engage less in pro-environmental behaviors despite gaining more knowledge.
- Relationships between Behaviors: Volunteering, liking school, and a family's financial perception were positively associated with pro-environmental behaviors, emphasizing the importance of social and educational factors in fostering environmental health literacy.
- Volunteering: Teens who participated in volunteer work had improved environmental habits and knowledge, which helped close the gap between awareness and action.
- Knowledge and Social Norms as Predictors: Both knowledge and social norms significantly predicted environmental health behaviors, suggesting a disconnect between what adolescents know about environmental health and how they act upon it.
- Final Forecasts for the Model:
    - EHL_Knowledge accounted for 25.2% of the variance, with social norms and participation in volunteering activities serving as important predictors.
    - Social norms and knowledge were the main predictors of EHL_Behaviors, which explained 42.9% of the variation. Pro-environmental behavior was negatively associated with school grades.
    - EHL_Social Norms explained 46% of the variance; gender and school grade showed negative relationships, whereas actions and knowledge were substantial positive predictors.
- Strategies and Interventions:
    - Exploring ways to enhance environmental health education that may contribute to improving both knowledge and behaviors.
    - Considering approaches to address gender disparities in environmental health initiatives that may promote more balanced engagement among adolescents.
    - Examining the potential of holistic interventions that support both environmental- and health-related literacy.
    - Encouraging school-wide initiatives, recognizing that educational institutions play a central role in promoting EHL.
    - Exploring opportunities for collaboration between governmental agencies, educational institutions, non-governmental organizations, and families to strengthen environmental health literacy at a broader societal level.

Author Contributions: Conceptualization, M.G.d.M., C.B. and T.G.; methodology, M.G.d.M., C.B., F.B.G., A.C. and T.G.; software, M.G.d.M. and C.B.; validation, M.G.d.M. and T.G.; formal analysis, M.G.d.M. and C.B.; investigation, M.G.d.M., F.B.G., A.C. and T.G.; resources, M.G.d.M. and T.G.; data curation, M.G.d.M. and T.G.; writing—original draft preparation, C.B., F.B.G., A.C., L.D. and T.G.; writing—review and editing, M.G.d.M., C.B. and T.G.; visualization, M.G.d.M.; supervision, M.G.d.M.; project administration, M.G.d.M. and T.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study has the approval of the Ethics Committee of the Academic Center of Medicine of Lisbon of the Lisbon North Hospital Center and the General Directorate of Statistics for Education and Science (DGEEC).

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

Data Availability Statement: Data could be available, under request.

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

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