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Explaining Pro-Environmental Behavior in Student: An Extended Environmental Consciousness Pathway Model

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Abstract: Environmental knowingness does not necessarily correspond to attitudes or consistent pro-environmental behavior. This study examined associations between environmental knowingness and pro-environmental behavior through consequence of awareness, attitude, personal norm, and self-regulation. A cross-sectional questionnaire survey involved 311 fifth-grade students from six elementary schools across three regencies or cities in Lampung Province, Indonesia. Partial least squares structural equation modeling assessed measurement quality, direct and indirect associations, and cross-validated predictive performance. The final 33-indicator model met the adopted reliability and validity criteria. Knowingness was positively associated with consequence awareness, whereas its association with attitude was not statistically significant. Consequence awareness and attitude were positively associated with personal norm, which was associated with self-regulation. Self-regulation was positively associated with behavior, for which the model explained 56.2% of the variance. The indirect pathway through consequence awareness, personal norm, and self-regulation was supported ($\beta = 0.173$, $p < .001$), whereas the corresponding pathway through attitude was not. Cross-validated predictive gains for behavior were modest. These findings extend the knowingness–attitude–behavior framework by incorporating the dimensions of awareness of consequences, personal norms, and self-regulation into the explanation of pro-environmental behavior among students. Research is needed to examine learning activities that connect awareness of consequences, personal responsibility, and action planning. Longitudinal and intervention studies are also required to investigate the temporal sequence and effectiveness of such activities.

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INTRODUCTION

Environmental education seeks to develop understanding and responsible action, but gains across environmental outcomes are uneven. A meta-analysis of 169 studies involving children and adolescents found larger effects on knowledge ($g = 0.953$) than on attitudes ($g = 0.384$), intentions ($g = 0.256$), or behavior ($g = 0.410$), alongside substantial unexplained heterogeneity and predominantly self-reported behavioral outcomes (Van De Wetering et al., 2022). These differences warrant examining how environmental knowingness, assessed as students' self-reported understanding, is associated with consequence awareness, attitudes, personal norms, self-regulation, and reported environmental behavior.

This issue is particularly relevant to elementary education. A systematic review of 76 studies involving children aged 6–12 identified multiple internal and external correlates of pro-environmental behavior, indicating that children's actions cannot be explained by environmental understanding alone (Liu & Green, 2024). These limitations underscore the need to distinguish theoretically specified associations from observed action and behavioral change. Indonesian evidence also highlights differences between environmental understanding, attitudes, intentions, and reported behavior. Primary school students in Sorong reported higher knowledge and attitude scores than behavioral scores, particularly for effortful actions (Ramadany et al., 2025). Among elementary school students in Padang, knowledge and attitudes

were associated with sustainable waste-management intentions, although actual behavior was not measured (Gusti, 2015). Studies involving vocational students in Bogor and young Indonesian consumers also examined relationships among knowledge, attitudes, and environmental behavior, with non-significant behavioral associations reported for subjective norms and perceived behavioral control in the former study and environmental responsibility in the latter (Simanjuntak & Fitri, 2024; Siswono et al., 2020). Collectively, these findings motivate examining additional psychological constructs alongside environmental understanding and attitudes. However, these Indonesian studies did not jointly examine consequence awareness, personal norms, and environmental self-regulation within an elementary school model. The present study addresses this gap by proposing two indirect pathways linking environmental knowingness with reported behavior through consequence awareness or attitude, followed by personal norm and self-regulation.

The present study uses environmental consciousness as an organizing framework while examining its associated constructs separately. Environmental knowingness (KNO) represents students' self-assessed understanding of environmental concepts and relationships, rather than objectively demonstrated knowledge. The Sustainability Consciousness Questionnaire distinguishes knowingness, attitudes, and behavior, although its knowingness component concerns recognition of necessary features of sustainable development rather than the self-assessment format adopted here (Gericke et al., 2019). Awareness of consequences (AC) concerns recognition of environmental harm and the benefits of protective actions, whereas environmental attitude (ATT) concerns evaluations, feelings, and concern about the environment. Personal norm (PN) represents an internalized obligation to protect the environment. Environmental self-regulation (SR) is operationalized more narrowly as maintaining environmental commitment and responding to barriers, while pro-environmental behavior (PEB) concerns the reported frequency of everyday environmental actions.

Knowingness is proposed to relate to both consequence awareness and environmental attitude, but for different reasons. Students who consider themselves more knowledgeable about environmental relationships may more readily recognize how everyday practices, such as burning waste or using disposable plastics, relate to environmental harm. This provides the rationale for the positive KNO–AC association proposed in H1. Environmental understanding may also provide reasons for evaluating environmental protection favorably, supporting the proposed KNO–ATT association in H2. Research among adult consumers found positive relationships between environmental knowledge and attitudes toward green purchasing (Laheri et al., 2024). This evidence supports investigating a cognitive–evaluative relationship, but differences in age, measurement, and behavioral context mean that its applicability to elementary students' self-assessed understanding remains an empirical question.

The connection between consequence awareness and personal norm is informed by the norm activation model. A contemporary account of this model explains that recognizing environmental consequences and accepting personal responsibility are relevant to activating moral obligations (Ai & Rosenthal, 2024). Recognizing that personal practices can harm others or the environment provides a reason to regard environmental protection as a personal duty. Accordingly, H3 proposes a positive association between AC and PN. The present model draws selectively on this normative logic rather than testing the complete norm activation model, because attribution of responsibility is not specified as a separate construct.

Environmental attitude provides a complementary rationale for personal obligation. Evaluating a clean environment positively and feeling concern about environmental damage may make environmental protection personally important, providing a basis for accepting responsibility. However, favorable evaluation and moral obligation remain conceptually distinct: liking or valuing environmental protection does not necessarily mean feeling personally obliged to act. Research among Chinese children identified environmental sensitivity and personal norms as relevant to environmental behavior, while studies among schoolchildren and adolescents examined normative relationships involving environmental values and identity (Balundė et al., 2020; Zeiske et al., 2021). These constructs are not interchangeable with ATT, but the findings support examining afective and normative considerations together. H4 therefore tests whether positive environmental attitudes are associated with stronger personal norms in the present population.

Personal obligation may provide a standard for action, but maintaining behavior in everyday situations also requires regulatory effort. A self-regulation account of environmental behavior distinguishes setting environmental goals from pursuing them despite competing demands and disruptions (Nielsen, 2017). Applied to the present model, students who feel personally obliged to protect the environment are expected to report greater commitment to maintaining environmental practices and addressing barriers, providing the rationale for H5. Such regulatory efforts are, in turn, expected to be positively associated with reported environmental behavior, as proposed in H6. Research among secondary school students in Austria and Germany found that action planning, action control, and commitment were associated with everyday climate-friendly action (Frick et al., 2025). Exploratory preschool research also links attentional regulation with environmental outcomes, although this differs from the commitment and barrier-related planning examined here (Akar & Tuğluk, 2026). These findings support examining regulation alongside moral obligation, while leaving the PN–SR association and its relevance to younger students open to testing.

These arguments motivate two specific indirect pathways. The first connects KNO with PEB through AC, PN, and SR (H7a): understanding environmental relationships is expected to correspond with recognizing consequences, which is associated with personal obligation, followed by regulatory commitment and reported action. The second connects KNO with PEB through ATT, PN, and SR (H7b): understanding is expected to correspond with favorable environmental evaluations, which are associated with personal obligation and subsequently with regulation and reported action. The pathways distinguish recognition of environmental consequences from evaluation of environmental protection, while sharing the proposed normative and regulatory links. Their joint examination allows the study to assess whether each indirect association receives support within the same model, without assuming that either pathway necessarily occurs.

The research gap concerns the integration of these relationships in elementary education. Existing studies provide evidence concerning environmental understanding and attitudes, children's normative motivations, and adolescents' regulatory processes, but do not establish the two complete pathways proposed here. This study addresses that gap by examining six constructs and two specific indirect associations among fifth-grade students in Lampung, Indonesia. Its contribution is to extend a knowingness–attitude–behavior account by specifying how consequence awareness, personal obligation, and environmental self-regulation may relate to reported action within one model. Because the design is cross-sectional, the proposed ordering provides a theoretical basis for testing associations rather than evidence of temporal or causal processes. The following hypotheses are proposed:

H1. Environmental knowingness (KNO) is positively associated with awareness of consequences (AC).
H2. Environmental knowingness (KNO) is positively associated with environmental attitude (ATT).
H3. Awareness of consequences (AC) is positively associated with personal norm (PN).
H4. Environmental attitude (ATT) is positively associated with personal norm (PN).
H5. Personal norm (PN) is positively associated with environmental self-regulation (SR).
H6. Environmental self-regulation (SR) is positively associated with self-reported pro-environmental behavior (PEB).
H7. a. Environmental knowingness (KNO) has a positive indirect association with self-reported pro-environmental behavior (PEB) through awareness of consequences (AC), personal norm (PN), and environmental self-regulation (SR).
H7. b. Environmental knowingness (KNO) has a positive indirect association with self-reported pro-environmental behavior (PEB) through environmental attitude ATT), personal norm (PN), and environmental self-regulation (SR).

METHOD

Research Design

This quantitative cross-sectional survey examined an extended environmental consciousness model comprising KNO, AC, ATT, PN, SR, and self-reported PEB among elementary school students. KNO was specified as exogenous and PEB as the principal outcome. PLS-SEM assessed the proposed

relationships and cross-validated predictive performance, consistent with the study's explanatory and predictive aims (Hair et al., 2019). The cross-sectional design supported interpretation of associations without establishing temporal or causal ordering.

Participants

The analytical sample comprised 311 elementary school students from Lampung Province, Indonesia. The study included six elementary schools located in Bandar Lampung City, Indonesia during the 2025/2026 academic year. The three schools were selected purposively, using accreditation status ("Excellent" or "Good") as an eligibility criterion, while also considering geographical proximity and accessibility to facilitate data collection. Participants were fifth-grade students aged 10–11 years. This grade level was chosen to assess environmental orientations among students at a similar stage of education—students capable of relating the content of the questionnaire to environmental topics and their own daily experiences. The sample comprised 162 girls (52.1%) and 149 boys (47.9%).

Permission to conduct the research was obtained from the school principal and the relevant classroom teachers. Before completing the questionnaire, students received a verbal explanation regarding the purpose of the study, the activities involved, and the voluntary nature of their participation. Student consent was obtained verbally following this explanation. Students were informed that they could decline or discontinue their participation without any consequences for their academic grades. During the completion process, the privacy of the students' responses was maintained, and they were not prompted or directed to select any specific answers. The data are treated as confidential and are accessible only to the research team.

Research Instrument

The Indonesian-language questionnaire was modified from the Student's Environmental Attitude and Knowledge Scale (Leeming et al., 1995), the Sustainability Consciousness Questionnaire (Gericke et al., 2019), and the awareness-of-consequences and personal-norm measures used by D'Arco and Marino (2022). The adaptation process involved simplifying the wording, adjusting the context, and employing four response categories. For instance, an SCQ statement regarding the need to reduce water consumption for sustainable development was adapted to: "Excessive water use can reduce the supply of clean water needed for life" (KNO1). This abstract concept was presented by establishing a link between water usage and the availability of clean water. A relationship that are more tangible for elementary school students. Regarding D'Arco and Marino's (2022) personal norm measure, a statement concerning the moral obligation to protect the environment was reformulated as: "I feel an obligation to help preserve the environment" (PN4).

Table 1. Constructs and response formats of the administered questionnaire

Scale	Items	Scope	Response format
KNO	10	Resources, biodiversity, environmental impacts, human activity, and natural changes	1 = Not understood to 4 = Very well understood
AC	4	Negative consequences and benefits of environmental actions	1 = Strongly disagree to 4 = Strongly agree
ATT	6	Environmental evaluation, affect, and concern	1 = Strongly disagree to 4 = Strongly agree
PN	4	Personal responsibility and moral obligation	1 = Strongly disagree to 4 = Strongly agree
SR	3	Commitment and responses to barriers	1 = Strongly disagree to 4 = Strongly agree
PEB	9	Waste reduction, resource conservation, waste management, participation, and initiative	1 = Never to 4 = Always
Total	36	Six separately specified constructs	Four-point response formats

Contexts involving daily actions were also incorporated, such as the air pollution caused by burning trash (AC2) and the cleaning of drainage ditches to prevent water stagnation (AC3). Four response categories are used to simplify the options for students, a decision supported by evidence regarding the psychometric characteristics of primary school students (Alan & Kabasakal, 2020). Table 1 shows Constructs and response formats of the administered questionnaire.

The initial 40-item questionnaire underwent readability assessment and preliminary item screening with 15 elementary school students using corrected item. Total correlations and Cronbach's alpha (α = .978). Four items were removed, leaving 36 for main data collection. Given the small preliminary sample, measurement quality was subsequently assessed in the main sample.

Data Collection

Questionnaires were administered during school hours in classroom settings with assistance from the research team or classroom teachers. Students received instructions explaining the response formats and were encouraged to answer according to their own understanding, feelings, and behavior. They were informed that the questionnaire was not a test of correct and incorrect answers and were asked to avoid responses intended merely to satisfy teachers or researchers. Completion took approximately 25–35 minutes. Returned questionnaires were checked for completeness before data entry. All 311 questionnaires were included in the analysis, and no cases were excluded.

Data Analysis

Analyses used SmartPLS 4 (version 4.1.1.8). Descriptive scores were respondent-level means across retained indicators. Measurement assessment applied loadings ≥ 0.70, AVE ≥ 0.50, and reliability ≥ 0.70, with composite reliability ≥ 0.95 examined for possible redundancy (Hair et al., 2019). Discriminant validity was assessed using HTMT point estimates below 0.85 (Henseler et al., 2015).

Figure 1 presents the hypothesized structural model, identifying the six direct relationships (H1–H6) and two specific indirect pathways (H7a–H7b). Arrows represent the direct relationships specified in H1–H6. H7a and H7b represent the complete indirect pathways listed beneath the diagram. Positive signs indicate hypothesized associations, not observed results.

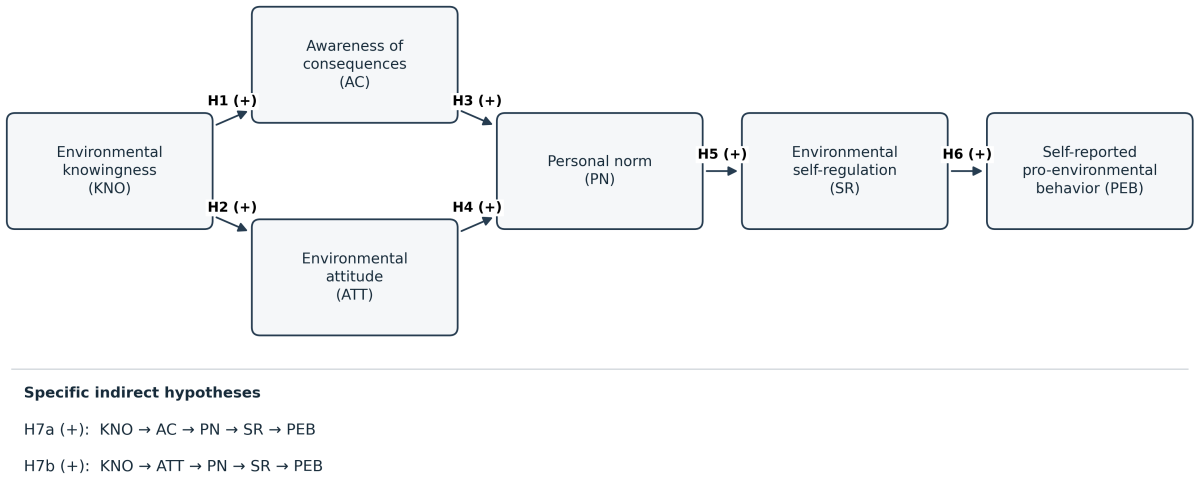

Figure 1. Hypothesized structural model showing direct and specific indirect hypotheses

Structural assessment examined predictor VIF, standardized path coefficients, R^2, adjusted R^2, and f^2. VIF < 5 was the general reference, with < 3 considered conservative; SRMR and NFI provided supplementary fit information. Inference used 10,000 bootstrap subsamples, two-tailed tests (α = 0.05), and 95% percentile confidence intervals. The specific indirect pathways KNO → AC → PN → SR → PEB (H7a) and KNO → ATT → PN → SR → PEB (H7b) were tested separately using bootstrapping, with confidence intervals excluding zero indicating statistical support. Full or partial mediation was not classified because no direct KNO → PEB path was specified.

Predictive performance was assessed using PLSpredict with 10 folds and 10 repetitions, examining Q^2predict, RMSE, and MAE against indicator-average and linear-model benchmarks (Shmueli et

al., 2019). CVPAT assessed prediction-loss differences, with negative values favoring PLS-SEM. These cross-validation results were distinguished from in-sample explained variance and independent-sample validation.

RESULT AND DISCUSSION

Descriptive Statistics

The analysis included 311 responses across six constructs. Scores were respondent-level means across retained indicators, ranging from 3.280 for PEB to 3.382 for KNO (Table 2). These scores describe reported orientations and behavior, rather than relationships between constructs.

Table 2. Descriptive statistics of the retained construct scores

Scale	Items	Mean	SD	Minimum	Maximum
KNO	9	3.382	0.52	1,667	4,000
AC	4	3.299	0.54	1,750	4,000
ATT	5	3.332	0.6	1,200	4,000
PN	4	3.311	0.66	1,250	4,000
SR	3	3.29	0.59	1,000	4,000
PEB	8	3.28	0.53	1,125	4,000

Measurement Model Assessment

The administered questionnaire contained 36 reflective indicators, following preliminary screening of 40 items. KNO10 (loading = −.009), ATT6 (−.111), and PEB9 (.024) were removed, leaving 33 indicators across all six constructs: nine KNO, four AC, five ATT, four PN, three SR, and eight PEB indicators.

The final model met the adopted reliability and convergent validity criteria: loadings ranged from .711 to .898, AVE from .594 to .789, Cronbach's α from .812 to .929, ρA from .815 to .930, and composite reliability from .877 to .942 (Hair et al., 2019; Table 3). Alpha and AVE increased for KNO, ATT, and PEB after elimination, but these improvements alone do not establish content coverage.

Table 3. Reliability and convergent validity of the final measurement model

Scale	Loading range	α	ρA	ρc	AVE
KNO	0.711–0.810	0.915	0.918	0.929	0.594
AC	0.748–0.851	0.812	0.815	0.877	0.64
ATT	0.756–0.842	0.87	0.876	0.906	0.657
PN	0.824–0.867	0.868	0.868	0.91	0.716
SR	0.881–0.898	0.867	0.869	0.918	0.789
PEB	0.791–0.865	0.929	0.93	0.942	0.669

HTMT estimates ranged from .063 to .844, below the adopted .85 threshold (Henseler et al., 2015; Table 4). PN–SR (.844) and SR–PEB (.834) were close to this threshold. Assessment used point estimates without bootstrap confidence intervals.

Table 4. HTMT estimates for the final measurement model

Scale	KNO	AC	ATT	PN	SR	PEB
KNO	—	—	—	—	—	—
AC	0.672	—	—	—	—	—
ATT	0.063	0.092	—	—	—	—
PN	0.419	0.637	0.523	—	—	—
SR	0.344	0.507	0.466	0.844	—	—
PEB	0.274	0.42	0.431	0.745	0.834	—

Structural Model Assessment

Six direct relationships and two specific indirect pathways were assessed, without a direct KNO → PEB path. Inner VIF values rounded to 1.000; this value was expected for single-predictor equations. The model explained 33.8% of AC variance, approximately none of ATT, 50.2% of PN, 53.8% of SR, and 56.2% of PEB (Table 5). These estimates describe in-sample explanatory performance; cross-sectional paths were interpreted as associations.

Table 5. Explained variance of endogenous constructs

Construct	Predictors	R^2	Adjusted R^2
AC	KNO	0.338	0.336
ATT	KNO	0	−0.003
PN	AC, ATT	0.502	0.499
SR	PN	0.538	0.537
PEB	SR	0.562	0.56

Bootstrapping with 10,000 subsamples, two-tailed tests (α = .05), and 95% percentile confidence intervals supported H1, H3–H6, and H7a, but not H2 or H7b (Table 6). Five direct paths had large f^2 values, the highest for SR → PEB (1.281) and PN → SR (1.165), whereas KNO → ATT contributed negligibly (.000). These values pertain to the specified equations and do not rank the paths against omitted predictors.

Table 6. Direct and specific indirect hypothesis tests

Hypothesis and path	β	t	p	95% CI	Support
H1 KNO → AC	0.581	16.59	<0.001	0.514–0.650	Yes
H2 KNO → ATT	−0.011	0.172	0.864	−0.129–0.113	No
H3 AC → PN	0.541	14.79	<0.001	0.469–0.613	Yes
H4 ATT → PN	0.462	12.2	<0.001	0.388–0.537	Yes
H5 PN → SR	0.734	24.65	<0.001	0.673–0.789	Yes
H6 SR → PEB	0.749	28.94	<0.001	0.697–0.800	Yes
H7a KNO → AC → PN → SR → PEB	0.173	8.111	<0.001	0.136–0.218	Yes
H7b KNO → ATT → PN → SR → PEB	−0.003	0.17	0.865	−0.032–0.030	No

The total indirect KNO–PEB association was positive (β = .170, t = 6.210, p < .001). Support for H7a but not H7b does not establish a significant difference between their coefficients. Full or partial mediation was not classified because no direct KNO → PEB path was specified; the cross-sectional data do not establish temporal ordering.

Supplementary fit indices were mixed: estimated-model SRMR was .062, whereas NFI (.875) fell below .90 (Table 7). The d_ULS and d_G statistics were descriptive because bootstrap reference values were unavailable. Overall fit was therefore not judged to meet all criteria.

Table 7. Supplementary model fit indices

Index	Saturated model	Estimated model
SRMR	0.045	0.062
d_ULS	1.158	2.146
d_G	0.447	0.467
NFI	0.879	0.875

Table 8 presents PLS predict used 10-fold cross-validation with 10 repetitions. Q^2predict was positive for AC (.328), PN (.131), SR (.085), and PEB (.055), but negative for ATT (−.008), indicating that ATT did not outperform the mean-based benchmark. Predictive improvement for PEB was modest despite its in-sample R^2 of .562.

Table 8. Construct level PLS predict results

Endogenous construct	Q²predict	RMSE	MAE
AC	0.328	0.825	0.675
ATT	-0.008	1.016	0.798
PN	0.131	0.941	0.733
SR	0.085	0.965	0.77
PEB	0.055	0.979	0.798

Because PEB was the outcome, its prediction was also examined at the indicator level. All eight indicators had positive Q²predict values, ranging from 0.023 to 0.048. PLS-SEM produced lower RMSE and MAE than the linear model (LM) benchmark for every PEB indicator (Table 9). The absolute RMSE advantage ranged from 0.008 to 0.019, indicating consistent but modest improvements over LM on the reported scale.

Table 9. PLS prediction results for PEB indicators

Indicator	Q²predict	PLS RMSE	LM RMSE	PLS MAE	LM MAE
PEB1	0.046	0.626	0.639	0.525	0.529
PEB2	0.031	0.628	0.645	0.48	0.491
PEB3	0.036	0.573	0.585	0.49	0.495
PEB4	0.023	0.658	0.677	0.555	0.568
PEB5	0.048	0.6	0.61	0.511	0.515
PEB6	0.039	0.621	0.629	0.518	0.52
PEB7	0.034	0.687	0.705	0.568	0.578
PEB8	0.034	0.651	0.663	0.503	0.513

CVPAT complemented these descriptive comparisons by testing prediction loss against the benchmarks. The reported overall loss differences were negative relative to both the indicator-average (IA) benchmark (Δ loss = −0.034, $p < 0.001$) and LM (Δ loss = −0.018, $p < 0.001$), indicating lower prediction loss for PLS-SEM. For PEB, the differences were −0.015 against IA ($p = 0.007$) and −0.018 against LM ($p < 0.001$). ATT, however, had a positive difference against IA (0.003), which did not support predictive superiority for that construct. Predictive performance was therefore not uniform across constructs (Table 10).

Table 10. Reported CVPAT loss differences against prediction benchmarks

Construct	Δ loss vs IA	p vs IA	Δ loss vs LM	p vs LM
Overall	-0.034	<0.001	-0.018	<0.001
AC	-0.097	<0.001	-0.012	0.008
ATT	0.003	0.005	-0.018	<0.001
PN	-0.059	<0.001	-0.024	0.004
SR	-0.03	0.001	-0.016	0.005
PEB	-0.015	0.007	-0.018	<0.001

The final model is presented in Final Structural Model Figure 1 to bring together the measurement and structural estimates. Values on the structural paths are standardized coefficients, values within endogenous constructs are R^2, and values on indicator paths are outer loadings. The diagram retains all six specified direct paths, including the non-significant KNO → ATT path.

Final Structural Model

The final model comprised six constructs measured by 33 reflective indicators: nine for environmental knowingness (KNO), four for awareness of consequences (AC), five for environmental attitude (ATT), four for personal norm (PN), three for self-regulation (SR), and eight for pro-environmental behavior (PEB). In Figure 2, the coefficients on the arrows represent standardized path estimates, while

the values within the endogenous constructs indicate the proportion of variance explained by their specified predictors (R^2).

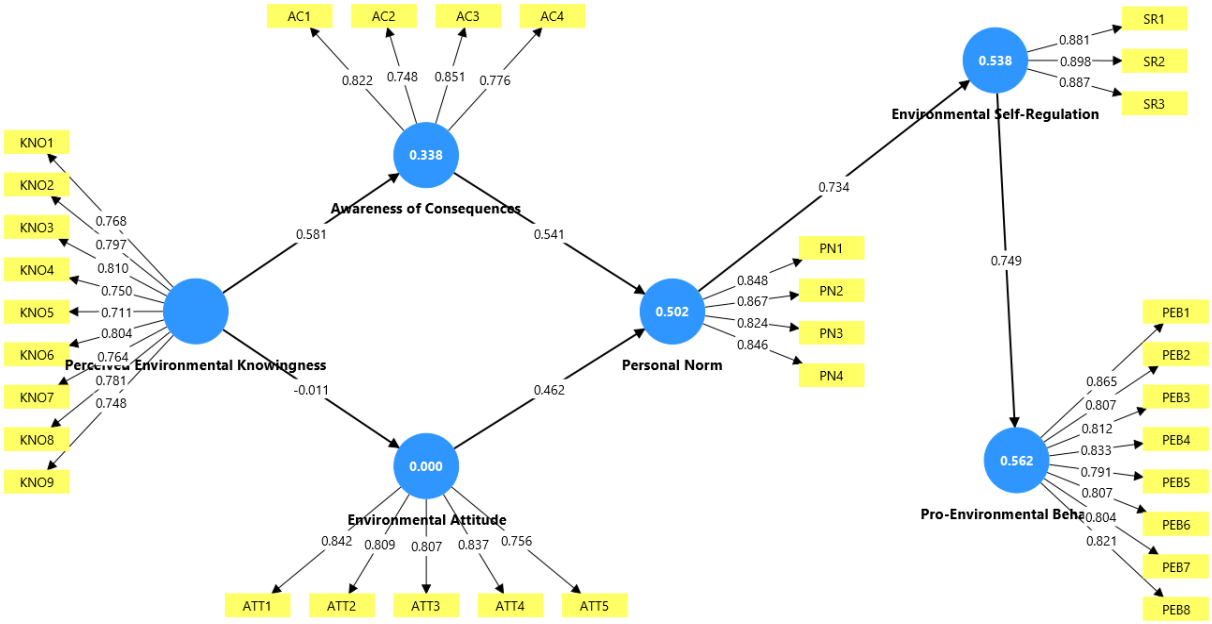

Figure 2. Structural model after indicator elimination

Based on the results of the analysis, KNO was positively associated with AC (H1: β = .581, p < .001), supporting H1, whereas its association with ATT was not significant (H2: β = −.011, p = .864), leaving H2 unsupported. AC (H3: β = .541, p < .001) and ATT (H4: β = .462, p < .001) were positively associated with PN, supporting H3 and H4 and jointly explaining 50.2% of its variance (R^2 = .502). PN was positively associated with SR (H5: β = .734, p < .001), and SR was positively associated with PEB (H6: β = .749, p < .001), supporting H5 and H6. The specific indirect association from KNO to PEB through AC, PN, and SR was significant (H7a: β = .173, p < .001), supporting H7a, whereas the corresponding pathway through ATT, PN, and SR was not significant (H7b: β = −.003, p = .865), leaving H7b unsupported.

DISCUSSION

The findings distinguish the relationships of environmental knowingness, consequence awareness, attitude, personal norm, and self-regulation with reported pro-environmental behavior. H1 and H3–H6 were supported, whereas H2 was not supported. The specific indirect association through AC, PN, and SR supported H7a, while the corresponding association through ATT, PN, and SR did not support H7b. This pattern suggests that consequence awareness and attitude occupy distinguishable positions within the proposed model. The following discussion considers each hypothesis and its educational implications while interpreting the paths as cross-sectional associations.

H1 Environmental Knowingness, And Awareness of Consequences

H1 is supported: environmental knowingness (KNO) is positively associated with awareness of environmental consequences (AC) (β = 0.581; p < 0.001; 95% CI [0.514; 0.650]) and explains 33.8% of the variance in AC. Students with a high level of "knowingness" tend to report a stronger awareness of the adverse impacts of certain behaviors, as well as the benefits of environmental protection actions. This finding is consistent with the positive relationship between environmental knowledge and awareness of consequences observed among respondents in Yogyakarta (Sugandini et al., 2019). These findings provide a basis for designing instructional approaches that connect students' self-reported understanding with the consequences of their own actions. For instance, when students demonstrate a strong understanding that waste can pollute rivers, teachers can guide them to examine how their own waste-disposal habits might contribute to such pollution. The effectiveness of this pedagogical approach in strengthening awareness of consequences warrants further investigation.

H2 Environmental knowingness and environmental attitude

H2 was not supported: KNO was not significantly associated with ATT (β = −.011, p = .864, 95% CI [−.129, .113]). The model explained approximately none of the variance in ATT. A high average KNO score reflects students' assessments of their understanding rather than demonstrated factual accuracy and does not, by itself, explain the non-significant KNO → ATT path. Because the confidence interval for this path included zero, the result indicates insufficient evidence for an association within the sample and model tested. It does not establish that knowingness and attitude are unrelated in other settings.

The non-significant KNO → ATT relationship differs from positive knowledge–attitude relationships reported among elementary school students in Padang and vocational school students in Bogor (Gusti et al., 2015; Siswono et al., 2020), as well as among consumers in Indonesia and India (Laheri et al., 2024; Simanjuntak & Fitri, 2024). Measurement differences warrant consideration: the present study assessed students' own understanding, whereas the Padang and Bogor studies used correct-or-incorrect knowledge measures. However, consumer research has also reported significant relationships using awareness-based or self-report measures. Measurement format alone is therefore insufficient to account for the differences across studies.

Broader evidence also suggests that gains in knowledge need not be accompanied by equally large gains in attitude. A meta-analysis of 169 studies reported larger effects of environmental education on knowledge than on attitudes (Van De Wetering et al., 2022). This intervention evidence provides context for the distinction between the two constructs, although it does not directly explain the non-significant cross-sectional path observed here. Research on consumers further found that environmental values were more strongly associated with attitudes toward purchasing green products than environmental knowledge was (Laheri et al., 2024). These findings identify possible additional correlates of attitude, without establishing why H2 was not supported in this sample.

The fact that H2 was not supported suggests that students' self-reported understanding should not be taken as evidence of a stronger environmental concern. Therefore, teachers may want to assess understanding and attitudes separately. Attitudes remain relevant in environmental education, as their connection to personal norms is evidenced by the support found for Hypothesis 4 (H4).

H3 Awareness of Consequence and Personal Norm

H3 is supported: awareness of consequences (AC) is positively associated with personal norms (PN) (β = 0.541; p < 0.001; 95% CI [0.469; 0.613]). Students who are more aware of the adverse impacts of certain behaviors and the benefits of environmental protection actions tend to feel a greater sense of obligation to protect the environment. This relationship aligns with norm-activation theory, which posits that awareness of consequences and the acceptance of responsibility can underpin the emergence of a moral obligation to act (Ai & Rosenthal, 2024). Research involving adults has also examined the links between awareness of consequences, responsibility, and personal norms (D'Arco & Marino, 2022). However, the present study only examines the AC–PN relationship; it does not test the full norm-activation process, which would include the acceptance of responsibility as a distinct variable.

These findings provide a basis for linking discussions on environmental impact to students' personal obligations. For instance, after exploring the effects of waste on rivers and the community, students are encouraged to reflect on why they feel a personal responsibility to help keep the rivers clean. The effectiveness of this activity in strengthening personal norms warrants further investigation.

H4 Environmental Attitude and Personal Norm

H4 was supported: ATT was positively associated with PN (β = .462, p < .001, 95% CI [.388, .537]). Together, AC and ATT accounted for 50.2% of the variance in PN. Students who evaluated environmental protection favorably and expressed concern about environmental damage tended to report stronger personal obligations, even when consequence awareness was included in the same equation. The coefficient for AC (awareness of consequences) is larger than that for ATT (attitude), but the difference has not been statistically tested. Therefore, these results do not definitively indicate that awareness of consequences is more significant than attitude in explaining personal norms.

The link between environmental orientation and personal norms has also been observed in research involving children and adolescents, albeit with different predictors (Wu, 2018; Zeiske et al.,

2021). Among adolescents, biospheric values and an environmentally-oriented self-identity account for 63–66% of the variance in personal norms regarding general environmental behavior, 3–20% for specific behaviors, and 30% in other studies (Balundė et al., 2020). While these findings reinforce the relevance of personal norms, they do not directly substantiate an ATT–PN (attitude–personal norm) relationship, as values, identities, and attitudes are distinct constructs. Furthermore, variations in predictors, populations, and behavioral measures limit the comparability of the magnitude of the explained variance.

Research on young Indonesian consumers identifies environmental responsibility as a predictor of attitude (β = 0.34; Simanjuntak & Fitri, 2024), whereas the present study positions attitude as a predictor of personal norms. These findings are not contradictory, as environmental responsibility and personal norms are separate constructs. An educational implication of this is the need to connect students' concerns with reflection on their personal obligations. For instance, a sense of discomfort regarding a dirty schoolyard could serve as a starting point for a discussion on why students might feel a personal duty to help maintain its cleanliness.

H5 Personal Norm and Environmental Self-Regulation

H5 is supported: personal norms (PN) are positively associated with environmental self-regulation (SR) (β = 0.734; p < 0.001; 95% CI [0.673; 0.789]) and account for 53.8% of the variance in SR. Students who feel a greater sense of obligation to protect the environment tend to report a stronger commitment to maintaining eco-friendly habits and overcoming obstacles. This relationship aligns with the concept of self-regulation, which posits that personal standards serve as the foundation for setting and striving toward environmental goals (Nielsen, 2017). These findings extend this body of evidence by linking moral obligation to environment-focused self-regulation.

In an educational context, students who feel an obligation to reduce their use of single-use plastics could be encouraged to identify alternatives when "reusable containers" are unavailable. This activity links a sense of obligation to the effort to sustain specific behaviors, though its effectiveness warrants further investigation.

H6 Environmental Self-Regulation and Pro-Environmental Behavior

H6 is supported: environmental self-regulation (SR) is positively associated with pro-environmental behavior (PEB) (β = 0.749; p < 0.001; 95% CI [0.697; 0.800]) and explains 56.2% of the variance in PEB. Students who report stronger commitment and greater effort in overcoming obstacles tend to report more frequent pro-environmental behaviors. These findings are consistent with research on adolescents, which links action planning and commitment to climate-friendly actions—though the extent of the contribution varies depending on the type of action (Frick et al., 2025). While the present study extends this discussion to elementary school students, differences in age, the specific actions studied, and measurement methods limit direct comparisons.

Research on preschoolers in Turkey has also linked attentional regulation to environment-related outcomes, with an explained variance of approximately 2–10% in certain analyses (Akar & Tuğluk, 2026). However, those findings are exploratory and focus on executive functions rather than the commitment and response to obstacles examined in this study. The strength of the SR–PEB relationship should also be interpreted in the context of the measurement results; the HTMT values for PN–SR (0.844) and SR–PEB (0.834) meet the established criteria but approach the 0.85 threshold, suggesting that the distinctness of these constructs warrants further investigation. Furthermore, the use of self-reports introduces the possibility of a "common method bias," the extent of which has not been quantified here.

Indirect Association Through Consequence Awareness

H7a is supported: environmental knowingness (KNO) has an indirect positive relationship with pro-environmental behavior (PEB) through awareness of consequences (AC), personal norms (PN), and self-regulation (SR) (β = 0.173; p < 0.001; 95% CI [0.136; 0.218]). These findings indicate that students' reported understanding relates to their behavior via a pathway that connects awareness of the impacts of one's actions, a sense of obligation to protect the environment, and efforts to maintain commitment. This pathway integrates norm-activation theory with the concept of self-regulation in the pursuit of environmental goals (Ai & Rosenthal, 2024; Nielsen, 2017). While the theoretical foundation is supported by these references, the present study provides evidence for this complete pathway among elementary

school students.

H7b is not supported: the indirect relationship between environmental knowingness (KNO) and pro-environmental behavior (PEB)—mediated by awareness of consequences (ATT), personal norms (PN), and self-regulation (SR)—is not significant (β = −0.003; p = 0.865; 95% CI [−0.032; 0.030]). This aligns with the non-significant relationship found between KNO and ATT, even though the paths from ATT to PN, PN to SR, and SR to PEB are supported. In other words, while the evidence does not support the entire proposed sequence, it does indicate that personal norms remain linked to attitudes. Research on adult consumers has identified different pathways—involving attitudes and purchase intentions—that connect environmental factors to pro-environmental purchasing (Laheri et al., 2024). However, differences in the populations studied, the mediators involved, and the specific behaviors examined limit direct comparisons with the present study.

The support found for H7a provides a basis for exploring educational approaches that link students' self-reported understanding to the consequences of their actions, their sense of personal obligation, and their commitment to overcoming obstacles. For instance, students who claim a strong understanding of river pollution could be guided to discuss the impacts of dumping waste into rivers, their own responsibilities, and ways to avoid such behaviors. The lack of support for H2 and H7b suggests that self-reported understanding cannot be used as a basis for assuming the presence of more positive attitudes. Understanding and attitudes should be assessed separately; meanwhile, the significant relationship found between ATT (Attitudes) and PN (Personal Norms) supports the testing of activities that connect environmental concern with a sense of personal obligation. The effectiveness of such activities remains to be tested.

Practical application should also consider the model's predictive capacity. Although the model explains 56.2% of the variance in PEB within the study sample, the Q^2predict value of 0.055 and the RMSE advantage over a linear model (ranging from 0.008 to 0.019) indicate that the improvement in predictive power is limited. These results do not yet constitute validation on an independent sample of schools, nor do they provide evidence of the effectiveness of the instruction. Furthermore, whether the mediation is full or partial remains undetermined, as the direct path from KNO to PEB was not tested. Future evaluations should supplement self-reports with behavioral observations and test the model using other samples.

Limitations and Recommendations

The cross-sectional design only reveals associations between variables; therefore, it cannot establish causality or the sequence of relationships posited in H7a and H7b. The selection of schools based on geographical proximity and ease of access (convenience sampling), combined with the inclusion of only six schools, involving fifth-grade students aged 10–11, limits the generalizability of the findings to other schools, regions, or age groups.

KNO (Knowledge) measures students' self-assessed understanding, while PEB (Pro-environmental Behavior) measures self-reported behavior; neither has been verified through objective testing or direct observation. Whether the mediation is full or partial cannot be determined, as the direct path from KNO to PEB was not included in the model.

Future research should employ longitudinal or intervention-based designs to examine the sequence of relationships and changes in variables over time. Probability sampling with a broader scope, along with testing in additional schools, is necessary to assess the generalizability of the findings. Objective knowledge tests could complement KNO by allowing for a comparison between students' self-reported understanding and their actual demonstrated knowledge. Observations or teacher reports could supplement the measurement of PEB, while a larger initial sample and further examination of the distinctions between PN (Personal Norms), SR (Social Responsibility), and PEB could strengthen the quality of the instruments.

CONCLUSION

Environmental knowingness was indirectly associated with Students pro-environmental behavior through consequence of awareness, personal norms, and self-regulation. The pathway through attitude was unsupported, although attitude remained positively associated with personal norms. These findings extend knowledge–attitude–behavior accounts by integrating normative and regulatory dimensions into

an explanatory framework for elementary school students.

The findings suggest that environmental learning should connect understanding with reflection on consequences, personal responsibility, and action planning. However, these educational implications require intervention testing. The cross-sectional design, self-report measures, purposive recruitment, and uneven predictive performance limit causal inference and generalization. Future studies should use longitudinal and experimental designs, behavioral observations, and independent samples to examine the proposed relationships and their educational relevance.

DECLARATION OF AI USE

The authors used ChatGPT to create the graphical representations in Figure 1 and to improve the structure and clarity of the manuscript, Claude to summarize the source materials, and Grammarly to improve grammar. All AI-assisted outputs were reviewed and verified by the authors, who take full responsibility for the accuracy, integrity, and final content of the manuscript.

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