Understanding College Students' Pro-Environmental Behavior: A Reproduction & Extension Study

A critical reproduction of:

"The impact of environmental education at Chinese Universities on college students' environmental attitudes"

By: Jiawen Hu, Yu Zhang, Yu Tian, Jin Liu | PLOS ONE, 2024

Presented by: Esha Teware, Alex Arevalo, Christopher Pawlik, Anders Jacobson

American University | STAT 615 | Spring 2025

Introduction

China centers sustainability on environmental quality

College education is key to shaping sustainable values

Green education builds awareness, ethics, and sustainable behavior

Study uses the Theory of Planned Behavior with key predictors

Research questions & Goals

Research Question	Goals
1 Are students' environmental attitudes (EA) affected by demographic factors?	Evaluate the influence of demographic variables such as gender, location, education level, and family economic status
2 Does school curriculum education (SCE) affect students' environmental attitudes (EA)?	Identify how subjective norms (SN), perceived behavioral control (PBC) and school-curriculum education (SCE) shape students' environmental attitudes (EA)
3 Do subjective norms (SN) in the schooling process affect students' environmental attitudes?	Evaluate the influence of demographic variables such as gender, location, education level, and family economic status.
4 Does perceived behavioral control (PBC) in the schooling process affect students' environmental attitudes?	Inform educators and policymakers on how to strengthen environmental awareness and self-efficacy among students through targeted curriculum and instructional strategies.

About Dataset

Dataset:

Collected via structured questionnaire using 5-point Likert-scale items

Dimensions:

- 398 rows × 34 columns
- Each row represents one student respondent
- Columns include demographic info and multiple items measuring each construct (Environmental attitudes (EA), subjective norms (SN), perceived behavioral control (PBC), school curriculum education (SCE))

Sample Size:

398 students across various Chinese universities

Variables:

- Psychological Constructs: EA (4 items), SN (3), PBC (4), SCE (5)
- Demographics: Gender, Degree Level, Hometown, Monthly Living Expenses

Descriptive Stat

Demographics:

- **Gender**: 46.2% Female, 53.8% Male
- **Degree Program**: 46.7% Undergraduate, 45.7% Graduate
- **Hometown**: 54.8% Rural, 45.2% Urban
- **Monthly Living Expenses**: Most between ¥2,001 - 3,000

Key Variables:

- **EA** (Environmental Attitudes): 6 items
- **SN** (Subjective Norms): 3 items
- **PBC** (Perceived Behavioral Control): 4 items
- **SCE** (Curriculum Education): 3 items
- All constructs are averages of respective Likert-scale items

VARIABLE	VALID CATEGORIES	FREQUENCY	PERCENT (%)
Gender	Male	214	53.8
	Female	184	46.2
Educational Level	Specialties (Vocational)	182	45.7
	Undergraduate	186	46.7
	Master's degree and above	30	7.5
Hometown Location	Rural areas	218	54.8
	Urban areas	180	45.2
Monthly Living Expenses (RMB)	Up to 1,500 (excl.)	91	22.9
	1,500 - 2,000	203	51.0
	2,001 - 3,000 (excl.)	75	18.8
	3,000 or above	29	7.3

Table 1 - Descriptive Statistics of Respondents

Model(s) and the method(s): Reliability Analysis

We used Cronbach's Alpha to measure the reliability and consistency of the responses.

Key Findings:

- All dimensions demonstrate acceptable reliability ($\alpha > 0.70$), except SN ($\alpha = 0.679$)
- Overall scale reliability is excellent ($\alpha = 0.918$)
- SCE dimension shows highest internal consistency ($\alpha = 0.776$)
- Results support the reliability of the measurement instrument

Dimension	No. of Items	Cronbach's Alpha
EA (Attitudes)	4	0.756
SN (Norms)	3	0.679
PBC	4	0.722
SCE	5	0.776
Total	16	0.918

Table 2: Internal Consistency of Measurement Dimensions

Composite Score Construction

- Majority of students responded positively to EA items (Likert 4 or 5).
- The student population surveyed already holds strong environmental values, supporting the notion of increasing environmental awareness in education.

Score	EA1	EA2	EA3	EA4
Strongly Disagree (1)	0.3	0.0	0.0	0.3
Disagree (2)	1.8	2.0	1.0	1.3
Neutral (3)	6.0	9.8	13.6	10.3
Agree (4)	28.9	38.7	36.2	35.2
Strongly Agree (5)	63.1	49.5	49.2	53.0

Table 3: Distribution of EA Item Responses (%)

ANOVA, T-tests and F-test of EA by Demographics

- **Methods Used:**

Independent t-tests and ANOVA to assess EA differences across demographic groups

- **Results:**

No statistically significant differences across Gender, Degree, Hometown, or Expense levels

- **Implication:**

Environmental Attitudes appear uniformly strong regardless of subgroup affiliation

Category	Subgroup	Mean EA	SD	T/F - test	Sig.
Gender	Male	4.45	0.58	1.95	0.052
	Female	4.35	0.53		
Educational Level	Specialties	4.41	0.50	1.175	0.310
	Undergraduate	4.38	0.62		
	Master's and above	4.54	0.53		
Hometown Location	Rural areas	4.42	0.59	0.53	0.596
	Urban areas	4.39	0.53		
Living Expenses (RMB)	Up to 1,500 (excl.)	4.29	0.69	1.59	0.191
	1,500 - 2,000	4.43	0.52		
	2,001 - 3,000 (excl.)	4.44	0.47		
	3,000 or above	4.47	0.53		
Total Mean		***4.40***	-	-	-

Table 4: ANOVA and t-tests of EA by Demographics

Descriptive Stastitcs and Pearson Correlation

All constructs significantly and positively correlated

- EA - SN (r = 0.73)
- EA - SCE (r = 0.73)
- EA - PBC (r = 0.65)

Interpretation: Strong interrelationships support the TPB framework and validate variable construction

Variable	N	Min	Max	Mean	SD
SN	398	2.0	5.0	4.37	0.57
PBC	398	2.0	5.0	4.26	0.58
SCE	398	1.8	5.0	4.36	0.56

Table 5 : Summary Statistics

	EA	SN	PBC	SCE
EA	1.00	0.73	0.65	0.73
SN	0.73	1.00	0.68	0.73
PBC	0.65	0.68	1.00	0.71
SCE	0.73	0.73	0.71	1.00

Table 6 : Correlation Matrix

Multiple Linear Regression Predicting - EA

- **Model:**

  EA ~ SN + PBC + SCE (Multiple Linear Regression)

- **Purpose:**

  Identify the unique contribution of each TPB construct to predicting EA

- **Findings:**

  SN (β = 0.37), PBC (β = 0.14), and SCE (β = 0.34) are all statistically significant predictors

  VIF values < 2.5 → No multicollinearity concern

- **Interpretation:**

  SN has the strongest direct effect on EA; educational curriculum and control beliefs also play key roles

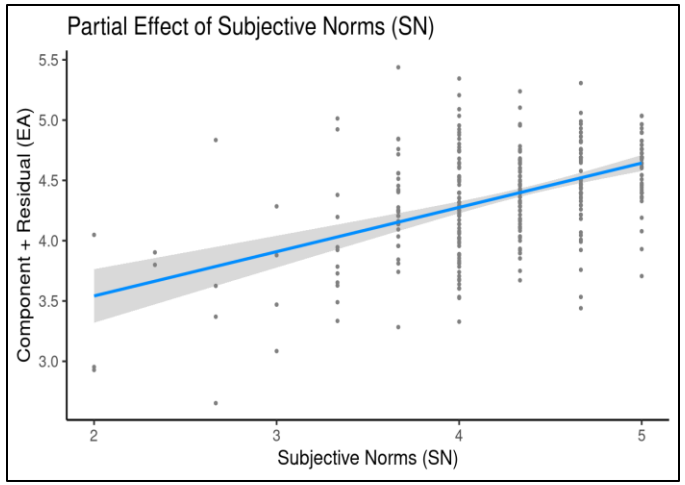
Predictor	B (Unstd.)	Std. Error	t-value	p-value	β (Std.)	VIF
Intercept	0.710	0.147	4.832	<0.001	—	—
SN	0.367	0.047	7.836	<0.001	0.377	2.41
PBC	0.140	0.045	3.116	0.002	0.146	2.27
SCE	0.342	0.050	6.865	<0.001	0.347	2.65

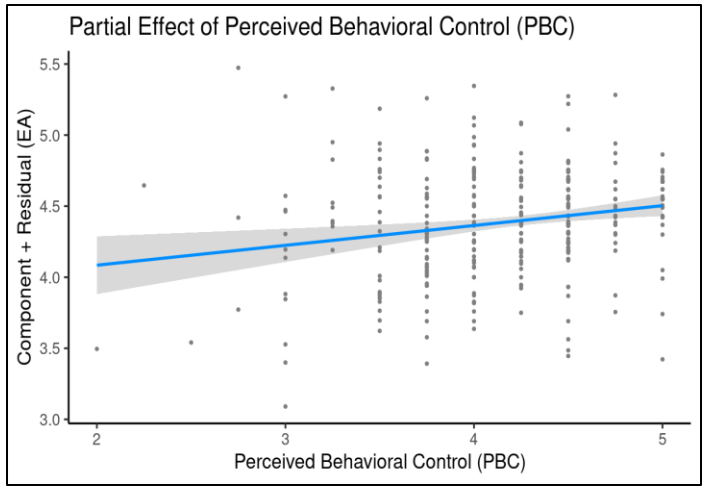
Table 7: Linear Regression Predicting EA

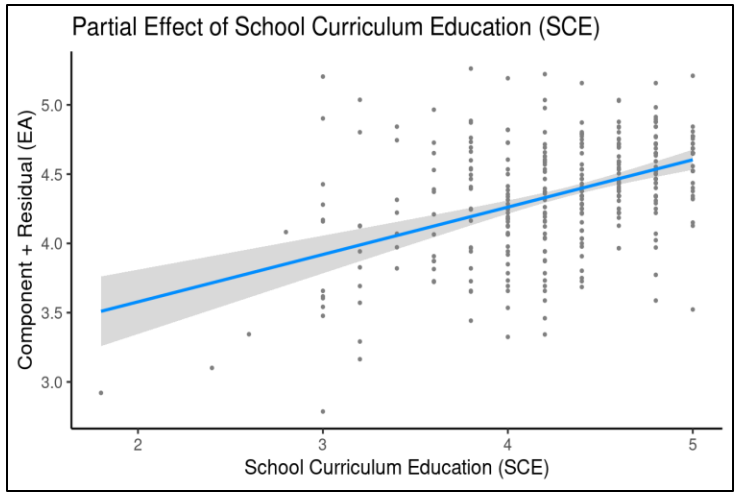
Assumption Checks

Assumption Checks	Method Performed	Result
No Collinearity	Variation Inflation Factors (VIF)	Scores for SN, PBC & SCE all < 5
Linearity	Added Variable Plot	Positive linear association for each predictor
Normality	Histogram & QQ Plot	Histogram appears symmetric, QQ plot largely linear
Constant Variance	Residuals vs Fitted Plot	Mild violation
Internal Consistency Reliability	Cronbach's Alpha	All values above .75

Linearity

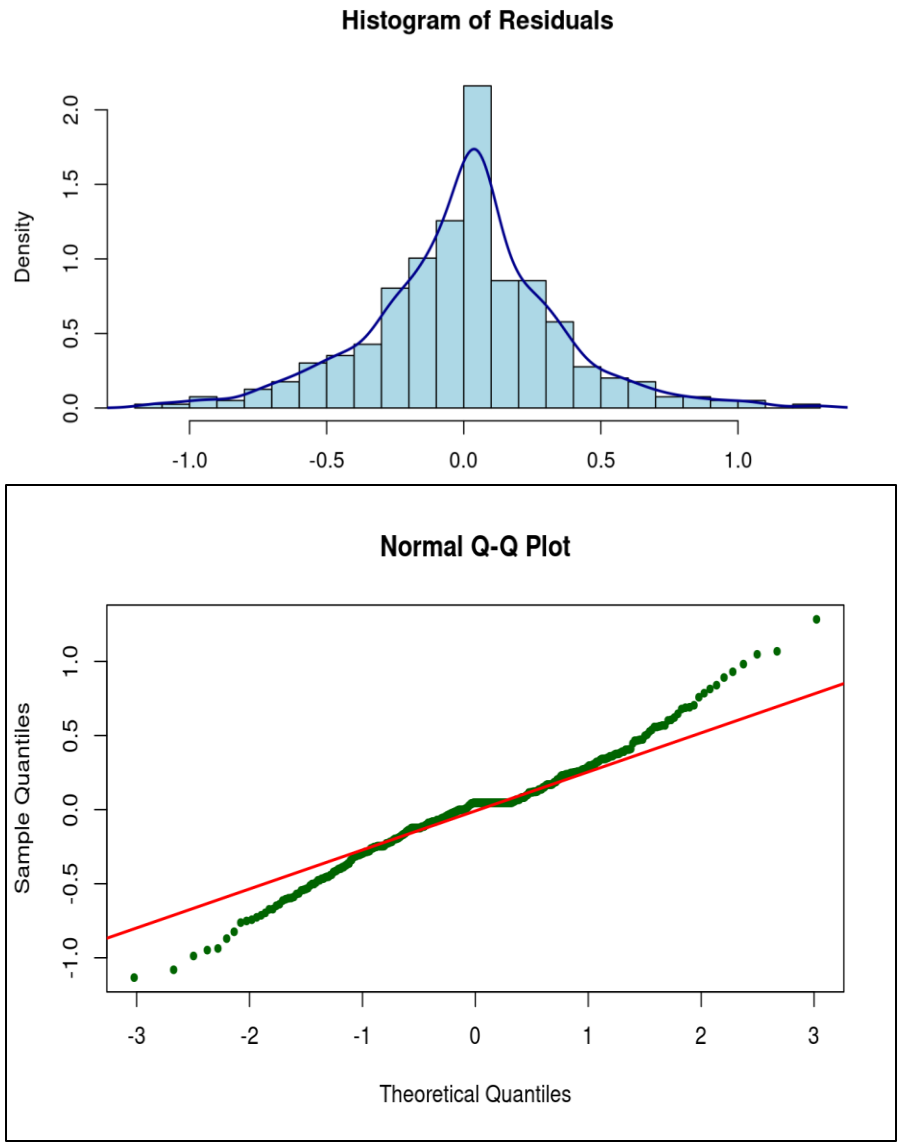






- The added-variable plots show a positive linear association between each predictor against EA.
- SN and SCE have a stronger positive linear associations with EA, while PBC appears flatter, indicating a weaker effect.

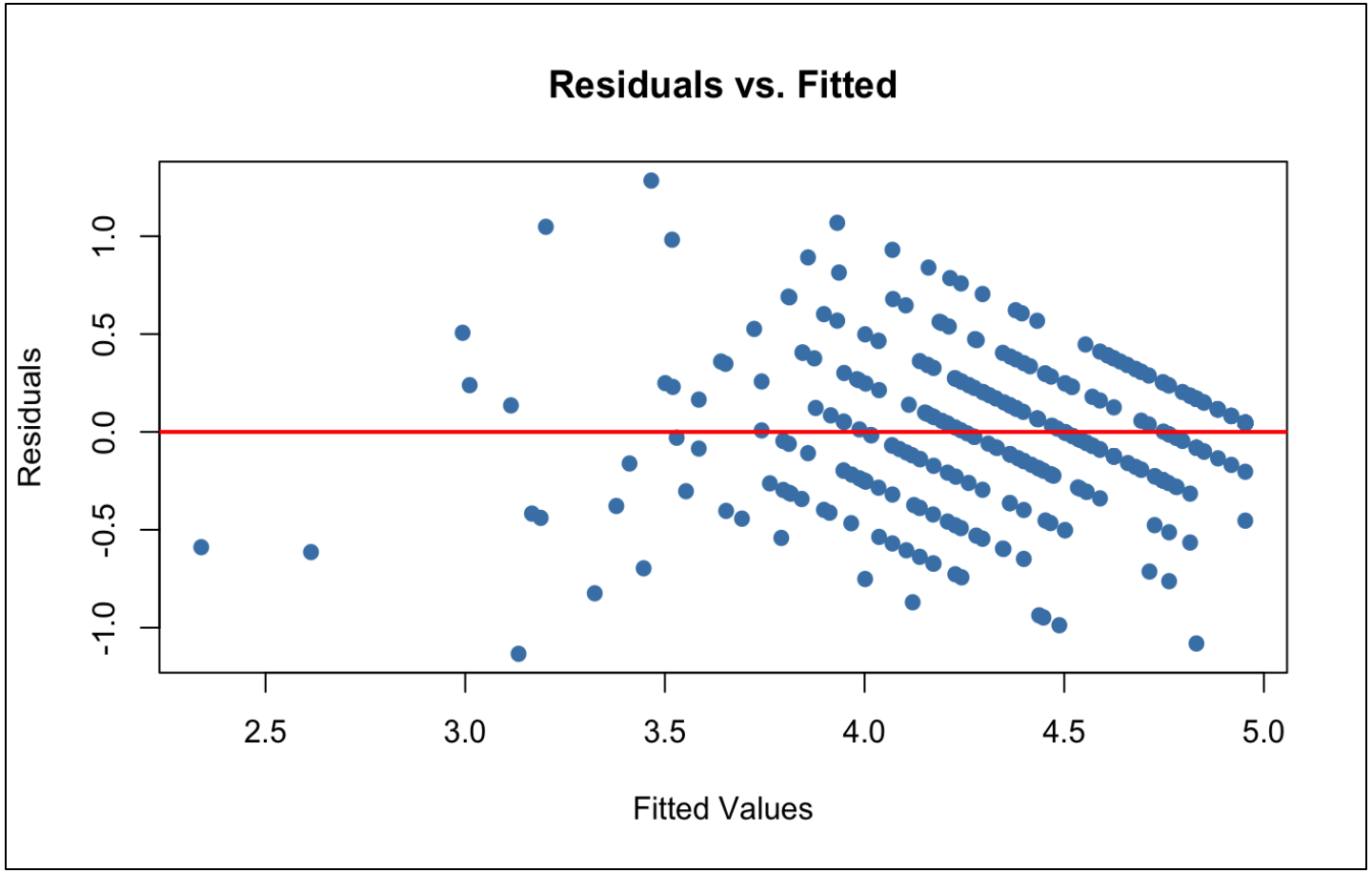
Normality of Residuals



- Histogram is near symmetric, no strong skewedness, and unimodal

- QQ plot shows most points fall on reference line with slight deviation at the tails

Constant Variance (Homoscedasticity)



- The plot shows mild funneling, which indicates mild heteroscedasticity (non-constant variance
- Not a major concern with large sample size (n = 398)

Hypothesis Testing & Interpretation of results

KEY TAKEAWAY

All three hypotheses were validated through statistically significant and theoretically coherent results

Hyp. #	Variable	Relationship with Environmental Att. (EA)	Interpretation
1.	School Curriculum Education (SCE)	Positive *(β = 0.347, p < 0.001)*	A one standard deviation increase in SCE is associated with a 0.347 SD increase in Environmental Attitudes, holding SN and PBC constant. This supports the idea that environmental education effectively shapes students' attitudes.
2.	Subjective Norms (SN)	Positive *(β = 0.377, p < 0.001)*	A one standard deviation increase in SN leads to a 0.377 SD increase in EA, controlling for SCE and PBC. This highlights the strong role of peer and societal influence.
3.	Perceived Behavioral Control (PBC)	Positive *(β = 0.146, p < 0.01)*	A one standard deviation increase in PBC results in a 0.146 SD increase in EA, controlling for SN and SCE. Students who feel more empowered to act pro-environmentally tend to hold more favorable attitudes.

Critiques and expansion of analysis

Strengths of the Study:

- Strong theoretical foundation using TPB
- Good internal consistency
- Inclusion of education as a contextual factor (SCE)

Critiques:

- No residual or assumption diagnostics discussed in the original paper
- Hypotheses were not explicitly labeled or directly tested statistically
- No use of binary EA outcome in original study
- No trial of interaction terms

Interaction terms

We extended the base model by introducing **interaction terms** between the TPB predictors.

Main Effects:

- SN, SCE, PBC all remain statistically significant of Environmental Attitudes (EA).

Interaction Effects:

- None of the interaction terms (SN × PBC, SN × SCE, PBC × SCE) were statistically significant (all p > 0.55).
- This suggests that the effect of one predictor on EA does **not depend** on the level of the others, in this sample.

Model Performance:

- The model explains **62.4% of the variance** (R^2) in EA.
- Strong model fit, but interaction terms did not add explanatory power.

Conclusion:

- TPB constructs operate **additively**, rather than interactively, in predicting EA.
- Supports original study's focus on main effects.

Predictor	Estimate	Std. Error	t value	p value
Intercept	4.421	0.020	223.441	< 2e-16
SN (centered)	0.344	0.053	6.493	2.56e-10
PBC (centered)	0.146	0.048	3.032	0.0026
SCE (centered)	0.326	0.055	5.871	9.25e-09
SN × PBC	-0.013	0.092	-0.137	0.891
SN × SCE	-0.043	0.074	-0.585	0.559
PBC × SCE	-0.015	0.081	-0.189	0.850

Table 8 : Interaction Effects Model

Extension: Logistic Regression on Environmental Attitudes

Why Logistic Regression?

- Original study used linear regression to predict EA (Environmental Attitudes).
- We extended it by modeling **likelihood of high EA** (score ≥ 4) as a **binary outcome**.

Goal:

- Identify which factors significantly **increase odds** of strong pro-environmental attitudes.

Logistic Regression Results

Model Summary

- Dependent: EA_binary (1 = EA ≥ 4; 0 = otherwise)
- Score of 4 or 5 reflects **positive endorsement** of environmental values.
- Predictors: SN, PBC, SCE

Predictor	Estimate	Std. Error	z value	p-value
Intercept	-14.007	1.863	-7.520	<0.001
SN	1.408	0.436	3.227	<0.001
PBC	0.689	0.388	1.776	0.076
SCE	1.668	0.404	4.124	<0.001

Table 9 : Logistic Regression Results

Interpretation of Logistic Model

Key Takeaways

- **SN (Subjective Norms)** and **SCE (School Curriculum Education)** significantly increase the odds of students having high environmental attitudes.
- **PBC** shows a positive but marginally significant effect ($p \approx 0.076$).

Odds ratio interpretation :

- SN: Students with higher SN scores are more than 4 times likely to have high EA.
- SCE: Strong school curriculum support nearly 5x odds of high EA.

Conclusion

- Logistic regression confirms the importance of SN and SCE seen in the linear model.
- This **binary approach complements the original study** by showing clear group-based distinctions.

Conclusion

- **Reproduction of results:**
  - SN, PBC, and SCE are all statistically significant predictors
- **Expansion of analysis:**
  - Assumptions were checked and confirmed
  - New model with interaction terms tested, but hardly any change in R^2
  - Logistic regression shows clearer differentiation between SN and SCE
  - Higher SCE scores translate to 5x higher EA scores, vs. high SN translating to 4x higher EA

- **Implications in context of problem:**
  - This was an observational study with convenience sampling
  - Social Norms and School Curricular Education have the greatest impact on Environmental Attitudes
  - Larger sample size, random sampling and more predictors might allow for more generalizable conclusions, e.g.:
    - Psychological factors
    - Cultural values
  - Variables could be measured with predictors beyond self-reported survey results

Thank you!

Questions?