# Green Chemistry Education and University Students' Environmental Attitudes: A Path Analysis Based on the Theory of Planned Behavior

**Yuxuan Liu**
*Department of Chemistry, Huanggang Normal University, Huanggang, Hubei, China*

**Abstract: Green chemistry has been widely promoted as a component of higher education, yet systematic evidence on how it shapes students' environmental attitudes remains limited. Drawing on the theory of planned behavior, this study examines whether exposure to green chemistry education strengthens university students' environmental attitudes and, through attitudes, subjective norms, and perceived behavioral control, their intention to adopt pro-environmental behaviors. A structured questionnaire was administered to 612 undergraduates at four universities in Hubei Province, China, yielding 580 valid responses. Confirmatory factor analysis confirmed the reliability and convergent validity of the measurement scales. Path analysis showed that green chemistry education significantly predicted environmental attitudes, which in turn was the strongest predictor of behavioral intention. Subjective norms and perceived behavioral control also contributed significantly, and the effect of green chemistry education on intention was largely transmitted indirectly through the three psychological antecedents (RMSEA = 0.049, CFI = 0.943). These findings suggest that embedding green chemistry principles into general education curricula can serve as a lever for cultivating environmental citizenship, and that curriculum interventions should reinforce normative support and efficacy beliefs alongside the transmission of chemical knowledge.**

**Keywords: Green Chemistry Education; Environmental Attitude; Theory of Planned Behavior; Pro-Environmental Behavioral Intention; University Students**

## 1. Introduction

Environmental degradation associated with industrial production has made the cultivation of environmentally responsible citizens a pressing task for higher education. Chemistry occupies an ambivalent position in this task: the discipline underpins many of the industrial processes that generate pollution, yet it also supplies the scientific foundations for cleaner synthesis, safer materials, and waste prevention. Green chemistry, defined as the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances, emerged precisely at this intersection [4]. Over the past two decades, green chemistry has been progressively incorporated into university curricula, laboratory teaching, and textbook systems, and educators have argued that its value extends beyond technical competence to the formation of environmental responsibility [5, 9].

Whether this expectation is empirically grounded, however, remains an open question. A substantial body of research in environmental psychology has demonstrated that pro-environmental behavior is rarely a direct consequence of knowledge alone; instead, it is filtered through attitudes, social norms, and perceptions of control, as summarized in the theory of planned behavior (TPB) proposed by Ajzen [1]. Meta-analyses confirm that these three psychological antecedents jointly explain a substantial share of variance in behavioral intention across domains [2, 3]. Studies in environmental education further show that informational interventions change behavior mainly when they succeed in shifting these antecedents rather than merely increasing what people know [8, 11]. If green chemistry education is to justify its place in general education on civic grounds, its effects should therefore be traced through this psychological pathway rather than assumed.

This study addresses that gap with a survey of undergraduates at four universities in Hubei Province, China. Green chemistry education exposure is modeled as an exogenous antecedent of environmental attitudes, subjective norms, and perceived behavioral control, which in turn predict pro-environmental behavioral intention within the TPB framework. The study makes two contributions. On the theoretical side, it extends the antecedent structure of the TPB by treating a discipline-based educational variable as a distal cause, responding to calls for research on how learning experiences enter the attitude-behavior chain [2, 11]. On the practical side, it offers curriculum designers evidence on whether, and through which pathways, green chemistry courses deliver their civic promise.

## 2. Theoretical Framework and Hypotheses

### 2.1 The Theory of Planned Behavior in Environmental Research

The theory of planned behavior holds that the immediate determinant of volitional behavior is behavioral intention, which is itself determined by three factors: attitude toward the behavior, subjective norms, and perceived behavioral control [1]. Attitude reflects a favorable or unfavorable evaluation of the behavior; subjective norms capture perceived social pressure from important others; perceived behavioral control refers to the perceived ease or difficulty of performing the behavior. The framework has proven especially productive in environmental research. Bamberg and Möser synthesized two decades of empirical studies and concluded that intention, moral norms, and perceived control form the core of the psychological architecture of pro-environmental behavior [10]. Steg and Vlek similarly recommended intention-oriented models as the starting point for intervention design [12]. Within this tradition, environmental attitude is typically treated not as a unitary disposition but as an evaluation pattern measurable with instruments such as the New Ecological Paradigm scale [6], and its link to behavior is contingent rather than automatic [7, 8].

### 2.2 Green Chemistry Education as an Antecedent of Environmental Attitudes

Green chemistry education differs from generic environmental education in one specific respect: it embeds environmental values inside a disciplinary context. Twelve principles covering waste prevention, atom economy, safer solvents, and energy efficiency give students concrete criteria for judging the environmental merit of a chemical route [4, 5]. Reviews of green chemistry teaching in higher education indicate that courses combining case analysis, greened laboratory experiments, and discussion of industrial consequences can improve students' awareness of the environmental dimensions of chemistry [9]. From a psychological standpoint, such courses do more than convey knowledge. Repeated evaluation of chemical processes in environmental terms can be expected to leave its mark on attitudes; the visible approval of teachers and professional communities speaks to subjective norms; and practice in applying explicit judgment criteria should strengthen perceived behavioral control. UNESCO's framework for education for sustainable development likewise expects discipline-embedded sustainability teaching to produce both cognitive and socio-emotional learning outcomes [11]. On these grounds, green chemistry education is modeled here as an exogenous variable influencing all three TPB antecedents.

### 2.3 Conceptual Model and Hypotheses

The conceptual model specifies six structural paths. Green chemistry education (GCE) is expected to predict environmental attitudes (EA), subjective norms (SN), and perceived behavioral control (PBC); the three antecedents are expected to predict pro-environmental behavioral intention (BI); and GCE may also exert a residual direct effect on BI. Five hypotheses follow: H1, GCE positively predicts EA; H2, GCE positively predicts SN; H3, GCE positively predicts PBC; H4, EA, SN, and PBC positively predict BI; H5, the effect of GCE on BI is transmitted indirectly through the three antecedents rather than directly. H5 amounts to a mediation claim: education influences behavior indirectly, by way of the psychological antecedents, consistent with evidence that information alone rarely changes behavior [8, 10].

## 3. Research Design

### 3.1 Participants and Procedure

A cross-sectional survey was conducted in the autumn semester among undergraduates at four universities in Hubei Province, including one normal university, one comprehensive university, and two institutions of engineering and technology. Cluster sampling by class was used to recruit participants; questionnaires were distributed and collected on site with the assistance of course instructors unrelated to the grading of participants. Of 612 distributed questionnaires, 580 were valid after removing responses with excessive missing values or straight-line answering, an effective rate of 94.8%. Table 1 reports the sample composition. Participation was voluntary and anonymous, and no incentives were provided.

**Table 1. Sample Characteristics (N = 580)**

| Variable | Category | Frequency | Percentage (%) |
|---|---|---|---|
| Gender | Male | 268 | 46.2 |
| Gender | Female | 312 | 53.8 |
| Grade | Freshman | 142 | 24.5 |
| Grade | Sophomore | 158 | 27.2 |
| Grade | Junior | 151 | 26.0 |
| Grade | Senior | 129 | 22.3 |
| Major | Chemistry-related | 196 | 33.8 |
| Major | Other science and engineering | 194 | 33.4 |
| Major | Humanities and social sciences | 190 | 32.8 |
| Green chemistry course exposure | Completed or enrolled | 264 | 45.5 |
| Green chemistry course exposure | No exposure | 316 | 54.5 |

### 3.2 Measures

All constructs were measured with multi-item scales on a five-point Likert format from 1 (strongly disagree) to 5 (strongly agree). Green chemistry education exposure was adapted from curriculum participation inventories and comprised four items covering course enrollment, greened laboratory experience, exposure to the twelve principles, and participation in green-chemistry-related lectures or competitions. Environmental attitude drew on the abbreviated New Ecological Paradigm orientation [6] with six items concerning limits to growth, human exemptionalism, and ecological crisis. Subjective norms and perceived behavioral control were measured with three items each following standard TPB formulations [1], referring to expectations of family, friends, and classmates, and to self-assessed capability and opportunity to act in an environmentally friendly way. Behavioral intention contained three items on willingness to sort waste, reduce disposable products, and choose low-impact transport. Item wording was refined after a pilot test with 42 students.

### 3.3 Data Analysis

Data screening, descriptive statistics, and reliability analysis were performed in SPSS 26.0; confirmatory factor analysis and structural path analysis were performed in AMOS 24.0 with maximum likelihood estimation. Model fit was evaluated with the ratio of chi-square to degrees of freedom, the comparative fit index (CFI), the Tucker-Lewis index (TLI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR). Conventional thresholds of CFI and TLI above 0.90 and RMSEA and SRMR below 0.08 were applied. Indirect effects were tested with a bootstrap procedure using 2,000 resamples and bias-corrected 95% confidence intervals.

## 4. Results

### 4.1 Measurement Model

Cronbach's alpha coefficients ranged from 0.78 to 0.87 across the five scales, indicating acceptable internal consistency. Confirmatory factor analysis of the five-factor measurement model yielded a satisfactory fit, and all standardized loadings exceeded 0.60 and were significant at the 0.001 level. Composite reliability values ranged from 0.79 to 0.88, and average variance extracted values from 0.52 to 0.61, supporting convergent validity. Discriminant validity was supported in that the square root of each construct's average variance extracted exceeded its correlations with the other constructs. Common method bias was examined with Harman's single-factor test; the first factor explained 27.6% of variance, below the conventional 40% threshold.

### 4.2 Structural Paths

Table 2 reports the estimates of the structural model; path coefficients are standardized, and critical ratios are computed from the unstandardized solution. Green chemistry education significantly predicted environmental attitudes ($\beta = 0.46$, $p < 0.001$), supporting H1; it also predicted subjective norms ($\beta = 0.33$, $p < 0.001$) and perceived behavioral control ($\beta =$

0.24, $p < 0.001$), supporting H2 and H3. Among the antecedents of behavioral intention, environmental attitudes exerted the strongest effect ($\beta = 0.38$, $p < 0.001$), followed by subjective norms ($\beta = 0.29$, $p < 0.001$) and perceived behavioral control ($\beta = 0.21$, $p < 0.001$), supporting H4. The direct path from green chemistry education to behavioral intention was small and statistically insignificant ($\beta = 0.07$, $p = 0.119$), indicating that the total effect of education is transmitted almost entirely through the psychological antecedents. The structural model explained 34% of the variance in behavioral intention.

**Table 2. Standardized Path Coefficients of the Structural Model**

| Path | β | S.E. | C.R. | p |
|---|---|---|---|---|
| GCE → EA | 0.46 | 0.048 | 9.62 | <0.001 |
| GCE → SN | 0.33 | 0.052 | 6.35 | <0.001 |
| GCE → PBC | 0.24 | 0.050 | 4.80 | <0.001 |
| EA → BI | 0.38 | 0.044 | 8.64 | <0.001 |
| SN → BI | 0.29 | 0.043 | 6.74 | <0.001 |
| PBC → BI | 0.21 | 0.040 | 5.25 | <0.001 |
| GCE → BI | 0.07 | 0.045 | 1.56 | 0.119 |

### 4.3 Mediation and Model Fit

The bootstrap analysis confirmed H5. The indirect effect of green chemistry education on behavioral intention through environmental attitudes was 0.175 (95% CI [0.132, 0.221]); the path through subjective norms was 0.096 (95% CI [0.061, 0.134]); and the path through perceived behavioral control was 0.050 (95% CI [0.028, 0.075]). The total indirect effect of 0.321 (95% CI [0.264, 0.383]) substantially exceeded the insignificant direct effect, indicating full mediation. The structural model achieved acceptable fit: $\chi^2/df = 2.41$, CFI = 0.943, TLI = 0.936, RMSEA = 0.049, and SRMR = 0.043, all within conventional thresholds.

## 5. Discussion

### 5.1 Interpreting the Pathways

The most informative result is the strong path from green chemistry education to environmental attitudes ($\beta = 0.46$). Discipline-embedded sustainability teaching, in other words, is not merely additive knowledge; it reshapes how students evaluate the relationship between chemistry and the environment. This converges with the argument that green chemistry provides concrete, operational criteria for environmental judgment, which generic environmental publicity lacks [4, 9]. The negligible direct path from education to behavioral intention is also worth noting: education appears to work as theory predicts, through the antecedents rather than around them, which is consistent with accumulated evidence that information influences behavior chiefly by way of attitudes, norms, and control beliefs [8, 10]. Finally, the relative magnitudes among the antecedents, with attitudes foremost, echo meta-analytic findings on the intention architecture of pro-environmental behavior [10, 12]. The meaningful contribution of perceived behavioral control is a reminder that intention alone predicts little when people doubt their ability to act, as Stern's value-belief-norm reasoning would also suggest [7].

### 5.2 Implications for Curriculum Design

For curriculum designers, the results suggest that the civic return on green chemistry teaching depends on how courses are taught, not only on whether they exist. Because attitudes respond most strongly to education, courses should foreground evaluative experiences, such as comparative assessment of conventional and green synthetic routes, discussion of industrial accidents and remediation, and reflection on the twelve principles as value statements rather than as a checklist [5, 9]. Because subjective norms matter, instructors should make the professional consensus visible, for example by introducing national green chemistry standards and the practice of leading enterprises, so that students perceive green practice as the norm of their reference community rather than as an ideal of enthusiasts. Because perceived behavioral control matters, courses should equip students with actionable criteria they can apply in daily decisions, from reading product labels to judging waste-sorting schemes, thereby converting disciplinary knowledge into a sense of competence [12]. These design principles align with the learning objectives proposed for education for sustainable development, which explicitly couples cognitive content with socio-emotional and behavioral outcomes [11].

### 5.3 Limitations

The conclusions must be read against the design of the study. The cross-sectional design cannot establish causal direction; although the mediation pattern is theoretically coherent, longitudinal or experimental designs are needed before strong causal claims are warranted. Green chemistry exposure is also naturally confounded with major: chemistry students take more green chemistry courses and may differ in environmental attitudes for other reasons, so part of the estimated educational effect may reflect disciplinary self-selection rather than instruction itself. The sample was confined to four universities in one province, and self-reported measures may inflate associations. Future research could employ behavioral observation, control for disciplinary background, compare green chemistry courses with different pedagogical designs, and test the model in vocational and secondary education contexts.

## 6. Conclusion

Drawing on the theory of planned behavior, this study modeled green chemistry education as an antecedent of the psychological determinants of pro-environmental behavior among 580 undergraduates in Hubei Province. Green chemistry education significantly strengthened environmental attitudes, subjective norms, and perceived behavioral control, and its effect on behavioral intention was transmitted almost entirely through these three antecedents, with attitudes playing the leading role. The findings give empirical content to the claim that green chemistry carries a civic mission: when principles of waste prevention, atom economy, and safer design are taught as evaluative criteria embedded in the discipline, they leave a measurable imprint on how students value and intend to act toward the environment. Cultivating environmental citizenship through chemistry thus appears to be a realistic curricular goal, provided that teaching engages values, norms, and efficacy beliefs rather than technical content alone.

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