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Environmental Education Awareness in Light of Sustainable Development Goals and Its Relationship with Environmental Responsibility Among University Students

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Abstract

This study investigated the relationship between environmental education awareness in light of the Sustainable Development Goals and environmental responsibility among Egyptian university students. A cross-sectional survey design was employed with 582 university students recruited through convenience sampling from four Egyptian educational institutions. Participants completed the Environmental Education Awareness Scale (EEAS-SDG) and the Environmental Responsibility Scale (ERS), both demonstrating excellent psychometric properties. Statistical analyses included Pearson correlation, linear regression, and univariate analysis of variance to examine relationships and group differences. The results revealed an exceptionally strong positive correlation ($r = 0.848$, $p < 0.001$) between environmental education awareness and environmental responsibility, with environmental education awareness explaining 71.9% of the variance in environmental responsibility scores. Female students demonstrated significantly higher levels of both constructs compared to male students ($p < 0.001$), while no significant differences were found based on residential background. The findings challenge traditional assumptions about the knowledge-action gap in environmental education, suggesting that SDG-aligned environmental education can effectively bridge the theory-practice divide when properly implemented. The study recommends integrating comprehensive environmental education programs aligned with SDG frameworks into higher education curricula and developing gender-inclusive approaches to maximize environmental responsibility development among future leaders and decision-makers.

Keywords: environmental education awareness; environmental responsibility; sustainable development goals; university students; higher education

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Received: 19 September 2025
Revised: 17 October 2025
Accepted: 21 October 2025
Published: 22 October 2025

Citation: Aldawsari, N.D.; Nemt-allah, M.A.; Abdellatif, M.S. Environmental Education Awareness in Light of Sustainable Development Goals and Its Relationship with Environmental Responsibility Among University Students. *Sustainability* **2025**, *17*, 9393. https://doi.org/10.3390/su17219393

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1. Introduction

The 21st century confronts humanity with an unprecedented constellation of interconnected environmental crises that demand immediate and coordinated global action. Climate change represents one of the most pressing challenges, manifesting through rising global temperatures, increasingly frequent extreme weather events, accelerating ice cap melting, and progressive ocean acidification. These phenomena are primarily driven

by anthropogenic greenhouse gas emissions from fossil fuel consumption and land use changes [1–3]. Concurrently, the global biodiversity crisis has reached alarming proportions, with species extinction rates accelerating due to habitat destruction, resource overexploitation, pollution, and climate-induced impacts, resulting in rapid species population declines and significant degradation of critical ecosystem services [4–6].

Resource depletion compounds these challenges through unsustainable patterns of water, forest, and energy resource consumption, which simultaneously exacerbate environmental pollution and contribute to widespread land degradation [7]. These environmental challenges are fundamentally interconnected and mutually reinforcing: climate change accelerates biodiversity loss while degraded ecosystems simultaneously reduce climate resilience and diminish carbon sequestration capacity, creating cascading effects that intensify overall environmental vulnerabilities [8].

In response to these complex environmental challenges, the United Nations established the Sustainable Development Goals as a comprehensive global framework designed to address environmental crises through integrated approaches that balance environmental sustainability with socioeconomic development needs. The SDGs place particular emphasis on environmental protection through Goal 13 (Climate Action), Goal 14 (Life Below Water), and Goal 15 (Life on Land), which collectively promote coordinated international action on climate change mitigation, biodiversity conservation, and sustainable resource management [9–11].

The SDG framework explicitly recognizes the complex trade-offs between economic growth imperatives and environmental sustainability limits, advocating for integrated approaches that can simultaneously address multiple sustainability dimensions [12,13]. However, global progress toward achieving these environmental targets remains uneven and continues to be significantly hampered by insufficient financial investment, inadequate policy coherence across sectors, and limited institutional capacity. Successful implementation requires transformative policy interventions, enhanced cross-sectoral collaboration, and systematic capacity building at multiple governance levels [14,15].

Environmental education emerges as a critical mechanism for advancing sustainable development, functioning both as a dedicated objective within the SDG framework and as a cross-cutting enabler that facilitates progress across all seventeen Sustainable Development Goals [16,17]. The profound interconnectedness between SDG 4 (Quality Education) and SDG 13 (Climate Action) demonstrates how environmental education serves as a transformative bridge, with SDG 4 positioning education as a foundational tool essential for achieving all sustainability goals while explicitly recognizing that Education for Sustainable Development (ESD) and environmental education are crucial for equipping learners with necessary sustainability competencies [18].

ESD explicitly addresses Target 4.7, which mandates that all learners must acquire essential knowledge and skills necessary to promote sustainable development across multiple domains [19]. Environmental education facilitates this integration by promoting climate literacy, fostering critical thinking capabilities, and catalyzing behavioral changes essential for creating sustainable societies [20].

Research demonstrates that environmental education functions as a transformative catalyst extending far beyond traditional environmental targets to influence multiple dimensions of sustainable development simultaneously. Environmental education creates interconnected pathways that directly support not only SDG 4 (Quality Education) and SDG 13 (Climate Action), but also contributes to achieving SDG 1 (No Poverty), SDG 3 (Good Health), SDG 5 (Gender Equality), SDG 6 (Clean Water and Sanitation), SDG 8 (Decent Work), SDG 10 (Reduced Inequalities), SDG 11 (Sustainable Cities), SDG 15 (Life on Land), and SDG 16 (Peace, Justice, and Strong Institutions) [21]. This comprehensive,

multi-sectoral approach fosters critical thinking, systems thinking, and problem-solving competencies essential for addressing complex sustainability challenges across diverse economic, social, and environmental contexts.

Environmental education has undergone significant conceptual and methodological transformation since its inception, evolving from basic awareness-raising campaigns to comprehensive, interdisciplinary approaches that integrate sustainability across multiple dimensions. Initially, environmental education focused primarily on raising public awareness about environmental issues and promoting fundamental environmental knowledge through informational programs and public campaigns [22,23]. This foundational phase emphasized simple pro-environmental behaviors and passive knowledge acquisition rather than active engagement with complex environmental challenges [24,25].

However, the field has substantially evolved to embrace ESD, which incorporates environmental, social, and economic sustainability dimensions while fostering systems thinking capabilities, ethical responsibility awareness, and active citizenship engagement [26]. Contemporary environmental education approaches utilize advanced digital technologies and experiential learning methodologies to enhance student engagement and develop comprehensive sustainability awareness among diverse learner populations [27].

Higher education institutions have emerged as pivotal leaders in embedding Sustainable Development Goals into curricula design, research priorities, and community engagement initiatives, thereby shaping future leaders and influencing broader societal mindsets toward sustainability [17,28,29]. Universities particularly contribute to SDG achievement through systematic integration of sustainability curricula that simultaneously enhance educational quality and build climate action capacity among students and faculty [30].

The global community has increasingly prioritized education as a central mechanism for achieving sustainable development through comprehensive policy frameworks and institutional initiatives, supported by the UN's 2030 Agenda and UNESCO's Decade of ESD and the Global Action Programme [31]. This systematic integration of environmental education within higher education drives behavioral change and empowers individuals to make informed decisions that support multiple sustainability goals simultaneously [32]. However, successful integration requires substantial institutional commitment, comprehensive curriculum reform, and systematic approaches to overcome significant implementation challenges including curriculum overload, inadequate teacher training, and insufficient institutional support systems [33–35].

Research consistently demonstrates a positive correlation between environmental awareness and actual environmental responsibility behaviors, with studies indicating that individuals possessing higher levels of environmental awareness are significantly more likely to engage in pro-environmental actions including recycling, energy conservation, and sustainable consumption practices [36–38]. However, this relationship is mediated by several critical psychological and social factors including personal norms, perceived responsibility, and social context, suggesting that awareness alone may be insufficient for sustained behavioral change without supportive environmental conditions and social reinforcement mechanisms [39–42].

The knowledge-action gap in environmental behavior among students represents a complex, multifaceted phenomenon where possession of comprehensive environmental knowledge does not automatically translate into consistent responsible environmental actions. Research demonstrates that action-related knowledge, which provides specific behavioral guidance and practical implementation strategies, is significantly more predictive of actual pro-environmental behavior than general or systemic environmental knowledge [43]. This distinction proves crucial as students may possess comprehensive the-

oretical understanding of environmental problems yet lack concrete, actionable knowledge about effective interventions they can personally implement.

Furthermore, the relationship between environmental knowledge and behavioral implementation is consistently mediated by attitudes, behavioral intentions, and motivational factors [44]. Environmental concern levels and perceived personal responsibility serve as critical intermediary variables, with students demonstrating higher behavioral engagement when they possess an internal locus of control and maintain strong pro-environmental attitudes [45,46]. Additionally, social and contextual barriers significantly impede knowledge-to-action translation, as insufficient institutional support, limited available resources, and inadequate opportunities can prevent students from acting on their environmental knowledge despite possessing strong behavioral intentions [47].

The theory-practice gap in environmental education manifests through educational systems' predominant emphasis on cognitive learning outcomes rather than behavioral and affective transformations that lead to actual environmental action [48]. Despite students acquiring substantial environmental knowledge through formal education, this knowledge rarely translates into consistent pro-environmental behaviors, creating a persistent "value-action gap" where expressed environmental values fail to materialize into meaningful environmental action [49,50]. Educational programs continue prioritizing measurable academic achievements over participatory engagement and real-world application, while institutional barriers including rigid curricula structures and insufficient teacher support further impede the effective translation of environmental knowledge into practical environmental responsibility [51,52].

Research demonstrates that bridging the theory-practice gap in environmental education requires a multifaceted approach combining active pedagogical strategies with comprehensive institutional support. Problem-based and project-based learning methodologies have proven particularly effective in developing critical thinking and real-world application skills that translate environmental awareness into sustained behaviors [53–55]. Interdisciplinary curricula foster systems thinking and strategic competencies essential for addressing complex environmental challenges [55,56]. Community-engaged learning approaches enhance students' sense of agency and collective responsibility, facilitating the translation of theoretical knowledge into practical environmental action [57]. Furthermore, justice-oriented and citizenship-focused pedagogies integrate environmental justice principles that promote empathy, responsibility, and sustained behavioral change among university students [58,59].

Effective institutional structures play a crucial role in supporting these pedagogical approaches through whole-institution frameworks that embed sustainability across curricula, campus operations, and community partnerships [49]. Professional development programs and interdisciplinary faculty collaboration networks enhance the quality and consistency of sustainability education delivery [54,60]. Assessment and feedback mechanisms provide continuous monitoring of progress and reinforcement of responsible environmental behaviors [61,62]. The integration of transformative educational practices with supportive institutional frameworks creates an environment where environmental awareness can effectively translate into sustained environmental responsibility behaviors among university students [63].

Educational initiatives aligned with SDGs become crucial for fostering environmental awareness and responsibility among university students, as they represent future leaders responsible for addressing these interconnected environmental challenges. Understanding the mechanisms through which environmental education awareness translates into environmental responsibility behaviors provides essential insights for developing more

effective educational interventions and institutional policies that can bridge the persistent gap between environmental knowledge and environmental action.

The Egyptian higher education context provides a relevant setting for examining the awareness-responsibility relationship within the SDG framework. Aligned with the UN SDGs, Egypt's National Strategy for Sustainable Development (Egypt Vision 2030) positions environmental sustainability as a national priority [64]. Egyptian universities have increasingly incorporated environmental education across diverse curricula, particularly in education colleges preparing future teachers. Education colleges have adopted UNESCO's Education for Sustainable Development framework, emphasizing experiential learning, community engagement, and connections between individual behaviors and sustainability outcomes [65]. This institutional context may create conditions conducive to translating environmental awareness into responsibility, as students encounter consistent messaging across multiple dimensions of their university experience.

This study investigates the relationship between environmental education awareness in light of the Sustainable Development Goals and environmental responsibility among Egyptian university students. Specifically, the research seeks to examine the extent to which environmental education awareness, conceptualized within the SDG framework, correlates with and predicts environmental responsibility behaviors among university students. The study further aims to assess the levels of both constructs within the target population and explore potential demographic differences based on gender and residential background. Through comprehensive statistical analysis including correlation and regression modeling, this research endeavors to provide empirical evidence regarding the strength and nature of the awareness-responsibility relationship, thereby contributing to theoretical understanding while offering practical insights for developing more effective environmental education interventions within higher education contexts that can bridge the persistent gap between environmental knowledge and sustainable behavioral practices.

2. Materials and Methods

2.1. Participants

The study employed a cross-sectional survey design with a total sample of 582 university students from Egyptian colleges. The participants were recruited through convenience sampling from four different educational institutions: Education for Boys—Tafahna Al-Ashraf (n = 111, 19.1%), Education for Girls—Cairo (n = 85, 14.6%), Education for Boys—Cairo (n = 107, 18.4%), and Human Studies—Tafahna Al-Ashraf (n = 279, 47.9%). The sample was divided into three groups for analytical purposes: an Exploratory Factor Analysis (EFA) sample (n = 398), a Confirmatory Factor Analysis (CFA) sample (n = 323), and the main analytical sample (n = 582).

The demographic characteristics of the participants are presented in Table 1. The mean age of participants was 19.65 years (SD = 1.40), with ages ranging from 18 to 23 years. The majority of participants were female (n = 370, 63.6%) compared to male participants (n = 212, 36.4%). Regarding academic year distribution, first-year students comprised the largest group (n = 207, 35.6%), followed by third-year students (n = 251, 43.1%), fourth-year students (n = 63, 10.8%), and second-year students (n = 61, 10.5%). In terms of residential background, 60.7% of participants (n = 353) came from rural areas, while 39.3% (n = 229) were from urban areas. During their studies, the majority of students lived with their families (n = 385, 66.2%), while 28.0% (n = 163) lived in independent housing, and 5.8% (n = 34) resided in university dormitories.

Table 1. Sample Characteristics Comparison.

Characteristic	EFA Sample (*n* = 398)	CFA Sample (*n* = 323)	Main Sample (*n* = 582)
Age			
Mean (SD)	19.82 (1.41)	19.72 (1.42)	19.65 (1.40)
18 years	87 (21.9%)	75 (23.2%)	169 (29.0%)
19 years	84 (21.1%)	84 (26.0%)	102 (17.5%)
20 years	111 (27.9%)	78 (24.1%)	148 (25.4%)
21 years	62 (15.6%)	47 (14.6%)	108 (18.6%)
22 years	36 (9.0%)	21 (6.5%)	36 (6.2%)
23 years	18 (4.5%)	18 (5.6%)	19 (3.3%)
Academic Year			
First year	121 (30.4%)	113 (35.0%)	207 (35.6%)
Second year	60 (15.1%)	51 (15.8%)	61 (10.5%)
Third year	168 (42.2%)	122 (37.8%)	251 (43.1%)
Fourth year	49 (12.3%)	37 (11.5%)	63 (10.8%)
Gender			
Female	316 (79.4%)	239 (74.0%)	370 (63.6%)
Male	82 (20.6%)	84 (26.0%)	212 (36.4%)
Place of Residence			
Urban	170 (42.7%)	161 (49.8%)	229 (39.3%)
Rural	228 (57.3%)	162 (50.2%)	353 (60.7%)
Residence During Studies			
With family	269 (67.6%)	205 (63.5%)	385 (66.2%)
Independent housing	105 (26.4%)	93 (28.8%)	163 (28.0%)
University dormitory	24 (6.0%)	25 (7.7%)	34 (5.8%)
College			
Education for Boys—Tafahna Al-Ashraf	236 (59.3%)	142 (44.0%)	111 (19.1%)
Education for Girls—Cairo	77 (19.3%)	84 (26.0%)	85 (14.6%)
Education for Boys—Cairo	80 (20.1%)	97 (30.0%)	107 (18.4%)
Human Studies—Tafahna Al-Ashraf	5 (1.3%)	0 (0.0%)	279 (47.9%)

2.2. Instruments

2.2.1. Environmental Education Awareness Scale (EEAS-SDG)

The EEAS-SDG was developed to measure students' awareness of environmental education concepts within the framework of the United Nations Sustainable Development Goals. Scale construction followed psychometric principles, starting with a review of the environmental education literature, UNESCO objectives, and the UN SDG framework. An item pool was generated based on five core principles: awareness, knowledge, attitude, skills, and participation, emphasizing integration with SDGs, including Quality Education (SDG 4), Climate Action (SDG 13), and Responsible Consumption and Production (SDG 12). The final 13-item unidimensional scale uses a 5-point Likert format (1 = Strongly Disagree to 5 = Strongly Agree). Items assess both cognitive awareness (understanding concepts and connections) and attitudinal components (beliefs about the importance and relevance of environmental education) for students across academic disciplines. The scale yields scores

from 12 to 60, with higher scores indicating greater awareness, and takes approximately 5–8 min to complete. Representative items include "Environmental education should be integrated into all university curricula, not just environmental science programs" and "I understand how my daily choices as a student contribute to achieving the Sustainable Development Goals" (Appendix B).

2.2.2. Environmental Responsibility Scale (ERS)

The ERS is a tool designed to evaluate university students' personal accountability and commitment towards environmental protection and sustainable practices. It is based on the environmental psychology literature and social cognitive theory, focusing on concepts of environmental responsibility, moral obligation, and pro-environmental behavior among young adults. The scale operationalizes environmental responsibility across multiple dimensions, including personal accountability, pro-environmental behaviors, moral duty towards sustainability, social influence, active environmental engagement, and intergenerational responsibility. The 12-item unidimensional scale uses a 5-point Likert response format and incorporates behaviors and attitudes relevant to university students' daily lives, such as energy conservation, sustainable consumption, waste management, transportation choices, and environmental advocacy. The scale produces total scores ranging from 12 to 60, with higher scores indicating greater environmental responsibility. It takes approximately 5–8 min to complete, making it suitable for paired administration with environmental education awareness measures. Sample items include "I feel personally responsible for the environmental problems that exist in my community" and "I actively reduce my energy consumption (electricity, water, fuel) in my daily life" (Appendix A).

2.3. Procedure

Data collection was conducted through an online survey administered via Google Forms, ensuring accessibility and convenience for participants across multiple institutions. Prior to data collection, both instruments underwent rigorous validation procedures. Content validity was established through expert review using the Content Validity Index (CVI), with both scales achieving acceptable validity coefficients (ERS: CVI = 0.766; EEAS-SDG: CVI = 0.842).

The psychometric properties of both instruments were evaluated through comprehensive statistical analyses. For the ERS, EFA revealed a unidimensional structure explaining 37.492% of the total variance, with factor loadings ranging from 0.520 to 0.669. The Kaiser–Meyer–Olkin measure of sampling adequacy was excellent (KMO = 0.924), and Bartlett's test of sphericity was significant (χ^2 = 1549.723, df = 66, $p < 0.001$). CFA supported the unidimensional model with acceptable fit indices (CMIN/DF = 3.581, GFI = 0.902, AGFI = 0.858, CFI = 0.936, RMSEA = 0.075). The scale demonstrated excellent internal consistency reliability (Cronbach's α = 0.930, ω = 0.930) and adequate composite reliability (CR = 0.930) and average variance extracted (AVE = 0.528).

Similarly, the EEAS-SDG showed strong psychometric properties. EFA supported a single-factor solution accounting for 40.345% of the total variance, with factor loadings ranging from 0.505 to 0.747. The sampling adequacy was excellent (KMO = 0.934), and sphericity was confirmed (χ^2 = 2179.886, df = 91, $p < 0.001$). CFA indicated acceptable model fit (CMIN/DF = 3.669, GFI = 0.886, AGFI = 0.841, CFI = 0.923, RMSEA = 0.080). The scale exhibited excellent reliability coefficients (Cronbach's α = 0.924, ω = 0.925) with adequate CR = 0.929 and AVE = 0.503. Test–retest reliability was assessed through a subsample of 101 participants who completed the survey twice with a two-week interval. The correlation coefficient between the two administrations was strong and significant (r = 0.863, $p < 0.01$), indicating excellent temporal stability of the instruments.

2.4. Data Analysis

The data analysis strategy followed a multi-step approach to address the research objectives. Descriptive statistics were calculated for all study variables to examine distributions and identify potential outliers. The psychometric evaluation included exploratory and confirmatory factor analyses to establish the factorial validity of the instruments. Reliability analyses encompassed internal consistency measures (Cronbach's alpha and McDonald's omega) and test–retest reliability assessment.

To examine the relationship between environmental education awareness and environmental responsibility, Pearson correlation analyses were conducted. Predictive relationships were investigated through regression analysis to determine the extent to which environmental education awareness could predict environmental responsibility among university students. Additional analyses included univariate analysis of variance to explore differences in environmental responsibility based on demographic variables such as gender and type of residence, including interaction effects. All statistical analyses were conducted using appropriate software packages, with significance levels set at $p < 0.05$.

2.5. Educational Context

The study was conducted within Egyptian education colleges preparing pre-service teachers. These institutions have implemented environmental education components aligned with Egypt Vision 2030 and UN SDG frameworks. Common elements include: (1) mandatory courses or modules addressing environmental issues and sustainable development; (2) integration of sustainability themes across disciplinary courses; (3) experiential learning opportunities including campus sustainability projects and community initiatives; (4) emphasis on preparing future teachers to integrate sustainability education into professional practice. Pedagogical approaches emphasize active learning methodologies (problem-based learning, project-based learning, collaborative inquiry) designed to develop students' capacity to apply environmental knowledge to real-world contexts. This multi-dimensional exposure creates an educational environment where multiple channels reinforce environmental concepts.

3. Results

3.1. Descriptive Statistics

The study examined environmental education awareness and environmental responsibility among 582 university students from Egyptian institutions. The EEAS-SDG demonstrated a mean score of 53.29 (SD = 6.71), indicating relatively high levels of environmental education awareness among participants. The ERS yielded a mean score of 48.87 (SD = 6.49), suggesting moderate to high levels of environmental responsibility among the university students sampled. Descriptive statistics for both EEAS-SDG and ERS are presented in Table 2.

Table 2. Descriptive Statistics for EEAS-SDG and ERS.

Variable	N	M	SD	Range
EEAS-SDG	582	53.29	6.71	12–65
ERS		48.87	6.49	12–60

3.2. Correlation Analysis

The correlation analysis revealed a strong positive relationship between environmental education awareness and environmental responsibility among university students. The Pearson correlation coefficient indicated a significant positive correlation (r = 0.848,

$p < 0.001$) between the two constructs, with 95% confidence intervals ranging from 0.823 to 0.869. This substantial correlation suggests that students with higher levels of environmental education awareness tend to demonstrate correspondingly higher levels of environmental responsibility.

The magnitude of this correlation is particularly noteworthy, as it represents a large effect size according to conventional statistical standards. The shared variance between environmental education awareness and environmental responsibility accounts for approximately 72% of the total variance ($r^2 = 0.719$), indicating a strong association between these constructs among the university student population studied. The complete correlation matrix with confidence intervals is displayed in Table 3.

Table 3. Correlation Matrix and Confidence Intervals.

Variable	1	2	95% CI Lower	95% CI Upper
1. EEAS-SDG	0		0.823	0.869
2. ERS	0.848 **	0		

*Note: ** $p < 0.01$; CI = Confidence Interval.*

3.3. Regression Analysis

Linear regression analysis was conducted to examine the associative relationship between environmental education awareness and environmental responsibility. The analysis revealed that environmental education awareness was significantly associated with environmental responsibility, accounting for 71.9% of the variance in environmental responsibility scores ($R = 0.848$, $R^2 = 0.719$). While this statistical model positions environmental education awareness as the predictor variable and environmental responsibility as the outcome variable, the cross-sectional design does not permit causal inferences about directional relationships. The regression model was statistically significant ($F = 1484.896$, $p < 0.001$), indicating that environmental responsibility serves as a strong predictor of environmental education awareness among university students. The regression equation demonstrates that environmental education awareness scores are associated with environmental responsibility scores, with each one-unit increase in awareness associated with a 0.876-unit increase in responsibility ($B = 0.821$, $SE = 0.021$, $\beta = 0.848$, $t = 38.534$, $p < 0.001$). The standardized beta coefficient of 0.848 indicates a strong positive association between these variables. Full regression analysis results are presented in Table 4.

Table 4. Linear Regression Analysis—Association Between Environmental Education Awareness and Environmental Responsibility.

Coefficients	B	SE	β	T	*p*-Value	95% CI
Constant	10.501	1.120	--	9.374	<0.001	[8.301, 12.701]
ERS	0.876	0.023	0.848	38.534	<0.001	[0.831, 0.920]

3.4. Group Differences Analysis

Univariate analysis of variance was conducted to examine differences in both environmental education awareness and environmental responsibility based on gender and residential background (Table 5). For EEAS-SDG, female students ($M = 54.07$, $SD = 6.46$) scored significantly higher than male students ($M = 51.93$, $SD = 6.91$), with this difference being statistically significant ($F(1, 578) = 12.188$, $p = 0.001$). Students from rural areas showed slightly higher awareness scores ($M = 53.72$, $SD = 6.33$) compared to urban students ($M = 52.64$, $SD = 7.21$), though this difference was not statistically significant

(F(1, 578) = 1.946, p = 0.164). The gender by residence interaction was not significant for environmental education awareness (F(1, 578) = 0.005, p = 0.942).

Table 5. Group Differences in EEAS-SDG and ERS.

Variable		Group	N	M	SD	F	*p*-Value
EEAS-SDG	Gender	Male	212	51.93	6.91	12.188	0.001
		Female	370	54.07	6.46		
	Residence	Urban	229	52.64	7.21	1.946	0.164
		Rural	353	53.72	6.33		
	Gender × Residence					0.005	0.942
ERS	Gender	Male	212	47.56	6.64	12.261	<0.001
		Female	370	49.62	6.30		
	Residence	Urban	229	48.43	6.99	0.569	0.451
		Rural	353	49.15	6.14		
	Gender × Residence						0.052

Similarly, for ERS, the analysis revealed significant main effects and group differences. Female students (M = 49.62, SD = 6.30) demonstrated significantly higher environmental responsibility scores compared to male students (M = 47.56, SD = 6.64), with this gender difference being statistically significant (F(1, 578) = 12.261, p < 0.001). However, no significant difference was found between students from urban (M = 48.43, SD = 6.99) and rural (M = 49.15, SD = 6.14) backgrounds (F(1, 578) = 0.569, p = 0.451). The interaction between gender and residence was not significant (F(1, 578) = 0.052, p = 0.820).

The results demonstrate a robust and significant relationship between environmental education awareness and environmental responsibility among Egyptian university students. The strong positive correlation (r = 0.848, p < 0.001) and substantial predictive capacity (R^2 = 0.719) indicate that environmental education awareness serves as a powerful determinant of environmental responsibility behaviors, accounting for nearly three-quarters of the variance in students' environmental responsibility scores. The findings also reveal important demographic patterns, with female students consistently demonstrating significantly higher levels of both environmental education awareness and environmental responsibility compared to their male counterparts, while residential background showed no significant influence on either construct. These results provide compelling evidence for the critical role of environmental education in fostering environmental responsibility among university students and highlight the importance of considering gender differences in designing effective environmental education interventions within higher education contexts.

4. Discussion

The most striking finding of this study is the exceptionally strong correlation (r = 0.848) between environmental education awareness and environmental responsibility among Egyptian university students. This correlation magnitude substantially exceeds what is typically reported in the international literature, where meta-analyses generally document moderate correlations or effect sizes between environmental knowledge/awareness and pro-environmental behavior, often in the range of r = 0.25–0.41 or equivalent effect sizes (g = 0.41 for behavior, g = 0.38 for attitudes) [66]. Many studies highlight a persistent "attitude-behavior gap," where increased awareness does not always translate into responsible action, due to psychological, social, and contextual barriers [48]. While positive and significant relationships are common in environmental education research, such a strong

correlation as found in the Egyptian context is exceptional and rarely documented in the literature [66].

The substantial association between environmental education awareness and environmental responsibility, with awareness accounting for 71.9% of the variance in responsibility scores, suggests that well-designed environmental education programs may effectively bridge the persistent knowledge-action gap that has long challenged environmental educators. While our cross-sectional design prevents definitive causal conclusions, the strength of this association provides preliminary evidence supporting the potential effectiveness of SDG-aligned environmental education in fostering behavioral change. This finding contrasts with extensive research documenting the challenges of translating environmental knowledge into behavioral change, where the theory-practice gap in environmental education manifests through educational systems' predominant emphasis on cognitive learning outcomes rather than behavioral and affective transformations that lead to actual environmental action [48]. The success observed in this study may reflect the effectiveness of contextualized environmental education within the SDG framework, which appears to provide students with actionable pathways connecting theoretical knowledge to practical environmental responsibility behaviors.

The robust awareness-responsibility association observed in this study may reflect several contextual factors specific to the Egyptian higher education environment and the SDG-aligned educational framework, though establishing causal attributions requires experimental or longitudinal investigation. Environmental education that enhances knowledge, attitudes, and values serves as the foundation for responsible behavior, and the strength of the awareness-responsibility link appears to depend on curriculum integration, experiential learning, and cultural context [22,67]. The SDG framework's emphasis on integrated approaches may help students develop systems thinking capabilities that enable them to perceive direct connections between their learning and broader sustainability outcomes, thereby reducing the motivational barriers that typically prevent knowledge-to-action translation.

The consistent pattern of female students demonstrating significantly higher levels of both environmental education awareness and environmental responsibility aligns with extensive international research documenting gender differences in environmental concern and behavior. Females are often socialized to be more caring, empathetic, and responsible for family and community well-being, which translates into greater environmental concern and responsibility, as supported by studies across diverse contexts, including China, Pakistan, India, and Brazil, where women's roles as caretakers foster stronger pro-environmental attitudes and behaviors [68–70]. Meta-analyses and psychological studies indicate that higher levels of conscientiousness, agreeableness, and empathy among females mediate their greater environmentalism compared to males [71,72].

The gender differences observed are consistent with systematic reviews and meta-analyses that confirm women generally exhibit higher environmental awareness, concern, and willingness to change behavior, though the effect size is typically modest [72,73]. Some research finds no significant gender differences, or context-dependent results, especially at higher education levels or in certain countries, indicating that the gender gap is not universal and varies by culture and education [74,75]. The educational level factor is particularly relevant, as the gender gap is most pronounced at primary education levels and tends to decrease with higher education, suggesting that early socialization and gender expectations play a significant role, but formal education can help narrow the gap [74].

The absence of significant differences based on residential background (urban versus rural) contrasts with some expectations that rural students might have different environmental perspectives due to more direct contact with natural environments. This finding

may reflect the pervasive nature of environmental challenges across both urban and rural contexts in Egypt, creating similar levels of environmental exposure and concern regardless of residential background. Alternatively, the higher education environment may serve as an equalizing factor, exposing all students to similar environmental education content and frameworks that transcend their pre-university environmental experiences.

The findings provide several important implications for environmental education practice in higher education contexts. The strong awareness-responsibility relationship suggests that environmental education programs aligned with comprehensive frameworks like the SDGs can be highly effective in fostering behavioral change when properly implemented through curriculum integration, experiential learning opportunities, and culturally relevant approaches. The gender differences observed suggest the need for differentiated approaches to environmental education that can effectively engage both male and female students, as embedding environmental education as a core, experiential component in university curricula can significantly boost responsible behaviors, but programs should address psychological and social barriers, not just knowledge deficits, to maximize behavioral change.

This study contributes to theoretical understanding of environmental education effectiveness by demonstrating that under appropriate conditions, the knowledge-action gap can be substantially narrowed through integrated, contextually relevant educational approaches. The exceptionally strong correlation observed challenges traditional assumptions about the inevitability of the attitude-behavior gap in environmental education, suggesting that the SDG-aligned framework combined with culturally appropriate pedagogical approaches can create conditions where environmental awareness effectively translates into environmental responsibility. Future research should investigate the specific pedagogical approaches and institutional factors that contribute to this strong relationship, with particular attention to the transferability of these findings across different cultural and educational contexts while maintaining attention to gender-inclusive approaches that can effectively engage all students in developing environmental responsibility.

The exceptionally strong correlation observed in this study invites examination within a broader international framework. While prior research generally reports moderate associations between environmental awareness and behavior across diverse cultural and educational contexts, the magnitude found here appears notably higher. This may reflect unique factors within Egyptian higher education, such as cultural norms emphasizing collective responsibility, institutional alignment with sustainability goals, and pedagogical practices that effectively connect theory to action. However, without cross-cultural validation, it remains unclear whether these findings represent a generalizable trend or are specific to the Egyptian context. Comparative studies across regions (e.g., Boca et al., 2019; Estrada-Araoz et al., 2023; Floriano Rodríguez et al., 2024; Liang et al., 2018 [76–79]) suggest that cultural, institutional, and methodological differences significantly shape the strength of education-behavior relationships, underscoring the need for further research to determine the extent to which these dynamics are universal or context-dependent.

The findings of this study offer essential policy and pedagogical implications for advancing SDG-aligned environmental education in higher education. Universities should embed sustainability across curricula by integrating mandatory environmental education linked to SDG frameworks, contextualizing content within disciplines, and adopting interdisciplinary approaches that promote systems thinking. Pedagogically, institutions must shift from passive instruction to active learning through problem-based projects, place-based education, participatory research, and reflective practices that foster behavioral change. These methods should address psychological and social factors influencing the awareness–behavior link. Inclusive strategies are also needed to engage male students,

such as diversifying content, showcasing varied role models, and framing sustainability around leadership and innovation. Institutional support is vital, including campus initiatives, faculty development, affective-behavioral assessments, and co-curricular programming. Bridging the knowledge-action gap requires teaching action competencies, designing behavioral experiments, and cultivating environmental identities through social support. Finally, university leadership should align sustainability policies with national SDG agendas, allocate resources, build partnerships, and participate in inter-institutional networks to ensure systemic and sustained impact.

This study has several limitations that should be considered when interpreting the findings. The cross-sectional design restricts causal inference, making it difficult to determine whether environmental education awareness leads to increased responsibility, or if the relationship is bidirectional. Future longitudinal and experimental research is needed to clarify the directionality and establish causality. Additionally, the use of convenience sampling from four Egyptian institutions limits external validity, as these institutions may not represent the broader student population or other cultural contexts. Cultural and institutional factors—such as collective values, Islamic teachings on stewardship, and national sustainability initiatives—may have contributed to the unusually strong correlation observed, which may not generalize across settings. The reliance on self-reported measures introduces the risk of social desirability bias, potentially inflating the association between awareness and responsibility. Participants may have overstated their attitudes or behaviors to align with perceived norms. To strengthen future research, complementary behavioral data and probability sampling across diverse institutions are recommended, along with cross-cultural comparisons to assess the generalizability of these findings.

Future research should explore the stability of the awareness-responsibility relationship over time and whether high levels of environmental education during university years translate into sustained pro-environmental behaviors post-graduation. Cross-cultural comparative studies are needed to determine if the strong correlation observed in Egypt can be replicated in other contexts. Experimental and quasi-experimental designs should be used to establish causal relationships between environmental education interventions and environmental responsibility outcomes. Mixed-methods research incorporating qualitative interviews and behavioral observations can provide deeper insights into the mechanisms through which environmental awareness translates into responsible behaviors. Additionally, studies should investigate gender-inclusive environmental education approaches, examining how different pedagogical strategies, motivational frameworks, and content emphases can reduce gender disparities in environmental engagement. Furthermore, studies on institutional support, community engagement, and structural factors can provide valuable insights for developing more effective environmental education programs in higher education contexts.

5. Conclusions

The study reveals an exceptionally strong positive association between environmental education awareness and environmental responsibility among Egyptian university students ($r = 0.848$, $p < 0.001$). While the cross-sectional design precludes causal inferences, this robust correlation suggests that the knowledge-action gap in environmental education may be substantially narrowed under appropriate conditions. Environmental education awareness accounts for 71.9% of the variance in environmental responsibility scores, providing preliminary evidence for the potential effectiveness of comprehensive, SDG-aligned environmental education approaches in fostering behavioral change. However, longitudinal and experimental studies are needed to establish causal relationships and determine whether enhanced awareness leads to sustained responsible behaviors. Female students

show significantly higher levels of environmental education awareness and responsibility, aligning with international patterns. The study also suggests that the higher education environment may serve as an equalizing factor in environmental education effectiveness, transcending students' pre-university environmental experiences. These findings have significant implications for environmental education policy and practice in higher education contexts, suggesting that SDG-aligned programs can develop environmental responsibility among future leaders and decision-makers. However, further research across diverse contexts is needed to advance environmental education and maximize its contribution to global sustainability efforts.

Author Contributions: Conceptualization: N.D.A., M.A.N.-a. and M.S.A.; Methodology: M.A.N.-a. and M.S.A.; Software: M.A.N.-a.; Validation: N.D.A., M.A.N.-a. and M.S.A.; Formal Analysis: M.A.N.-a.; Investigation: N.D.A. and M.S.A.; Resources: N.D.A. and M.S.A.; Data Curation: M.A.N.-a.; Writing—Original Draft Preparation: N.D.A., M.A.N.-a. and M.S.A.; Writing—Review and Editing: N.D.A., M.A.N.-a. and M.S.A.; Supervision: M.S.A.; Project Administration: N.D.A. and M.S.A. All authors have read and agreed to the published version of the manuscript.

Funding: The authors extend their appreciation to Prince Sattam bin Abdulaziz University for funding this research work through the project number (PSAU/2025/01/33478).

Institutional Review Board Statement: The study protocol was approved by the Research Ethics Committee of the Faculty of Education at Al-Azhar University, Dakahlia, Egypt (Ref. No. EDU-REC-2025-0085, 12 March 2025). All procedures performed in this study involving human participants were under the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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

Data Availability Statement: The data presented in this study are available upon reasonable request from the corresponding author.

Acknowledgments: The authors would like to express their sincere gratitude to the university students from the participating Egyptian educational institutions who voluntarily participated in this study. The authors extend their appreciation to Prince Sattam bin Abdulaziz University for funding this research.

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

Abbreviations

The following abbreviations are used in this manuscript:

EEAS-SDG	Environmental Education Awareness Scale in light of Sustainable
ERS	Environmental Responsibility Scale
ESD	Education for Sustainable Development
SDG	Sustainable Development Goals
UN	United Nations

Appendix A

Environmental Responsibility Scale (ERS)

5 = Strongly Agree 4 = Agree 3 = Neutral 2 = Disagree 1 = Strongly Disagree
Scale Items:

1. I feel personally responsible for the environmental problems that exist in my community.
2. I actively reduce my energy consumption (electricity, water, fuel) in my daily life.
3. I make purchasing decisions based on the environmental impact of products.
4. I feel obligated to participate in activities that help protect the environment.
5. I consistently practice waste reduction, reuse, and recycling in my daily activities.

6. I believe I have a moral duty to live in an environmentally sustainable way.
7. I actively encourage friends and family to adopt more environmentally responsible behaviors.
8. I choose sustainable transportation options (walking, cycling, public transport, carpooling) whenever possible.
9. I feel it is my responsibility to stay informed about environmental issues and solutions.
10. I am willing to make personal sacrifices (time, money, convenience) to protect the environment.
11. I actively seek opportunities to volunteer for or support environmental organizations and causes.
12. I consider myself accountable for leaving a healthy environment for future generations.

Appendix B

Environmental Education Awareness Scale (EEAS-SDG)

5 = Strongly Agree 4 = Agree 3 = Neutral 2 = Disagree 1 = Strongly Disagree
Scale Items:

13. Environmental education should be integrated into all university curricula, not just environmental science programs.
14. I understand how my daily choices as a student contribute to achieving the Sustainable Development Goals.
15. Learning about environmental issues helps me make more informed decisions as a global citizen.
16. I can identify specific connections between environmental degradation and social inequality.
17. I believe that addressing climate change requires coordinated action across all academic disciplines.
18. Understanding sustainable development goals is essential for preparing students for future careers.
19. I recognize the interconnections between environmental health, human health, and economic well-being.
20. Environmental education should develop students' critical thinking skills about sustainability claims and solutions.
21. I understand how consumption patterns in developed countries affect environmental conditions in developing nations.
22. Environmental education helps students understand their role in creating a more sustainable future.
23. I understand how sustainable development goals address the needs of both current and future generations.
24. Environmental education should prepare students to address complex, interdisciplinary sustainability challenges.
25. I can evaluate the effectiveness of different environmental policies and initiatives in achieving sustainable development outcomes.

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