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Research Article

Post-COVID Environmental Education in Morocco: School Clubs as Drivers of Student Engagement and Sustained Self-Reported Sustainable Practices

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Abstract

Global environmental challenges, amplified by climate change, pollution, and socio-ecological inequities, emphasize the urgent need for educational systems that foster durable self-reported eco-responsible practices among youth. This study investigates whether participation in school-based environmental clubs enhances Moroccan secondary school students' capacity to sustain such practices, specifically the responsible disposal of pandemic-related waste, awareness of vaccination-related medical waste risks, and water conservation within the post-COVID-19 context. A cross-sectional survey was conducted among 433 students (aged 15–19) from Fez, Sefrou, and Tangier, spanning urban and peri-urban contexts. Statistical analyses, including chi-square tests, two-way ANOVA, Principal Component Analysis (PCA), and K-means clustering, assessed the relationships between club membership, environmental knowledge, and self-reported practices. Results indicate that club members consistently reported higher self-reported eco-responsible practices (Cramer's V = 0.20–0.22), with a mean practice score of 3.9 compared to 2.8 for non-members. PCA identified two engagement dimensions, Self-Reported Eco-Responsible Practices and Cognitive & Institutional Engagement, explaining 65.4% of total variance. Cluster analysis revealed three distinct profiles: Sustainably Engaged (25%), Latently Engaged (50%), and Unconcerned (25%). These findings confirm environmental clubs as pivotal drivers of sustained self-reported eco-responsible practices and awareness, despite territorial disparities, and support the integration of hybrid, health-oriented approaches to strengthen environmental education in underserved regions. This study highlights the critical role of school-based environmental clubs in fostering socio-ecological resilience, offering a scalable model for integrating public health and ecological sustainability into education systems, especially in post-crisis contexts.

Keywords: Environmental Clubs; Education for Sustainable Development (ESD); Environmental Knowledge; Pro-environmental Behavior; Sustainable Development; Youth Engagement

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1. INTRODUCTION

The accelerating global environmental crises marked by climate change, biodiversity loss, widespread pollution, and deepening socio-ecological inequalities underscore the urgent need for transformative educational strategies to foster sustainable and resilient societies [1], [2]. Environmental education (EE) and Education for Sustainable Development (ESD) are now widely recognized as key instruments for equipping citizens, particularly youth, with the knowledge, skills, and values needed to adopt responsible environmental behaviors [3]–[5]. The impacts of environmental degradation extend beyond ecosystems and directly affect educational outcomes [6].

However, recent global research suggests that successful EE does not depend solely on disseminating knowledge. The International Climate Psychology Collaboration, drawing on data from over 59,000 participants across 63 countries,

reveals that pro-environmental action is more strongly shaped by social norms, institutional trust, and cultural dynamics than individual knowledge alone [7]. These findings highlight the importance of context-sensitive educational approaches that engage with complex institutional and social realities rather than relying exclusively on awareness-raising [8].

As Gifford & Nilsson [9] and Velis et al. [10] argue, such multidimensional strategies are essential for addressing the scale and complexity of today's environmental degradation. Yet, translating international EE frameworks into effective and inclusive practices remains challenging, particularly in the Global South. Structural governance gaps, infrastructural inequalities, and socio-economic disparities limit access to quality EE across many developing contexts [11]–[15].

The COVID-19 pandemic further exposed and amplified the limitations of educational systems worldwide, acting as both a stress test and a magnifier of systemic weaknesses. While global lockdowns temporarily reduced pollution and renewed interest in sustainable living [16], they also deepened educational inequalities, particularly through prolonged school closures and unequal access to digital resources [17], [18]. Nhamo et al. [19] highlight how pandemic disruptions hindered progress toward SDG 4, focusing on ensuring inclusive and equitable quality education. These disruptions, especially acute in the Global South, severely impacted students' academic and environmental engagement and underscored the fragility of existing environmental education (EE) frameworks [20], [21] in the face of these challenges, it is clear that a more resilient and adaptable approach to EE is essential for addressing the global environmental crises.

Integrating digital resources and artificial intelligence into environmental education presents new opportunities to personalize learning and enhance student engagement [22], [23]. Incorporating technology in EE can bridge gaps in educational access, particularly for students in underserved regions. However, digital inclusion remains a critical prerequisite for equitable access to environmental education, as seen in Morocco, where disparities in access to digital resources have hindered the effectiveness of EE programs [24]. Similar challenges are evident in other parts of the Global South, where infrastructural and socio-economic inequalities exacerbate barriers to quality education [25], [26]. Thus, addressing these barriers through targeted policy interventions and infrastructure development is crucial for ensuring that all students can fully participate in and benefit from environmental education programs.

Environmental education (EE) has been officially integrated into national policies in Morocco, notably through the National Charter for Environment and Sustainable Development [27]. Despite these formal commitments, a persistent gap remains between policy aspirations and field-level implementation. The Charter outlines strategic objectives such as promoting ecological transition, citizen engagement, and intersectoral cooperation. However, as highlighted by the Global Environmental Education Partnership [28], its implementation heavily relies on decentralized partnerships involving NGOs, regional observatories, and local authorities. These decentralized actors play a crucial role in operationalizing national goals at the territorial level by adapting policies to local contexts and addressing specific environmental challenges.

Socio-territorial disparities between urban centers and underserved areas pose a significant barrier to equitable and effective EE. According to the German Council on Foreign Relations [29], Morocco faces significant urban-rural and peri-urban divides in infrastructure, educational outcomes, and access to extracurricular programming, which limit environmental learning opportunities. Rural areas, for instance, record secondary school completion rates up to 20% lower than urban centers and have markedly reduced access to structured environmental education initiatives. Well-resourced urban schools benefit from better-trained facilitators, extracurricular structures, and digital resources [30], [31]. In contrast, students in peri-urban and rural settings often face limited engagement opportunities and lack the necessary infrastructure for effective learning.

Practical case studies provide valuable insights into the impact of EE in underserved areas. For example, Nourredine et al. [32] highlight the value of engaging students in sustainable water management through school-based initiatives. These programs emphasize experiential learning and local problem-solving. Maaroufi et al. [33] focus on regional disparities in environmental awareness, especially in Morocco's Oriental region, where access to environmental education is minimal. Hungerford & Volk [34] and El Batri et al. [31] show that ecological clubs promote peer-driven and contextually relevant learning in Moroccan secondary schools. Research by Riouch et al. [35] further underscores the importance of student involvement in sustainability practices, such as proper disposal of pandemic-related waste and water conservation.

Recent studies suggest that well-structured institutional practices like environmental clubs and school sustainability policies enhance students' self-reported eco-responsible behaviors by fostering pro-environmental intentions and social norms [36], [37]. However, the effectiveness of these initiatives remains uneven. Perkumienė et al. [38] point out that cities like Fez benefit from stronger institutional support and better infrastructure. At the same time, peri-urban areas like Sefrou or parts of Tangier remain disadvantaged, limiting both access and impact. These disparities risk reinforcing social and territorial inequalities under the banner of sustainability. To address these challenges, further research suggests that tailored interventions considering local conditions and resources are essential for bridging the gap and ensuring inclusive EE across all regions [32], [39].

A promising response to the implementation gap in environmental education (EE) is developing and promoting school-based ecological clubs. Rooted in participatory pedagogy, these clubs are increasingly recognized as crucial mechanisms for bridging the gap between environmental knowledge and action, fostering long-term sustainability practices among youth. Despite the growing attention to EE and Education for Sustainable Development (ESD) globally [40], [41], empirical data on the long-term impact of such initiatives, particularly in post-crisis contexts and across diverse Moroccan settings, remains scarce. This lack of evidence presents a significant research gap, especially

concerning how school-based environmental clubs contribute to sustained behavioral change and community-level impacts.

Recent research highlights the critical importance of localizing global EE strategies to ensure alignment with regional capacities and contexts. Initiatives such as the KIX Global Partnership [42] and studies by Tafese and Kopp [43] underscore the necessity of community-adapted learning models, particularly in the Global South, where socio-economic and infrastructural challenges often complicate the implementation of standardized educational frameworks. For instance, Idrissi [44] examines the perceptions of future STEM educators in Morocco regarding climate change education, revealing key insights that could inform curriculum design and pedagogical approaches. As demonstrated by Nicholson [45], participatory models can be powerful tools for bridging governance and equity gaps, fostering more inclusive environmental education practices. Moreover, hybrid learning approaches that integrate digital tools with health education have shown promise in sustaining youth engagement and enhancing the relevance of EE programs [46], [47]. Yaqin et al. [48] explore how hybrid learning models in post-pandemic education can be adapted to promote sustainability-related pedagogy, offering valuable lessons for the future of EE.

However, despite these promising approaches, several barriers hinder the full realization of EE's potential. Underfunded institutions, inadequate teacher training, and deep socio-territorial inequities remain significant challenges [14], [30]. These barriers limit the effectiveness and scalability of environmental education initiatives, particularly in rural and marginalized areas. Addressing these structural issues requires a holistic approach integrating policy reforms, targeted funding, and capacity-building initiatives to ensure equitable access to quality environmental education for all students.

This study responds to these gaps by examining whether and how participation in school-based environmental clubs has supported the durability of self-reported eco-responsible practices among Moroccan secondary school students following the COVID-19 pandemic. Specifically, it explores behaviors such as the responsible disposal of masks and gloves, awareness of vaccination-related medical waste, and water-saving practices. It also analyzes how territorial contexts, urban (Fez) vs. peri-urban (Sefrou, Tangier), shape these outcomes. The study identifies student engagement profiles using chi-square tests, one-way ANOVA, Principal Component Analysis (PCA), and cluster analysis. It offers evidence to support more inclusive, resilient, and context-sensitive environmental education frameworks in Morocco and similar Global South settings.

2. MATERIAL AND METHODS

This section outlines the methodology employed to ensure the rigor and reproducibility of the study, detailing the sampling procedures, study locations, data collection protocols, and analytical approaches. The research was conducted in three Moroccan cities: Tangier (Tangier-Tétouan-Al Hoceïma region), Fez, and Sefrou (Fès-Meknès region) to capture the diversity of urban and peri-urban contexts across two distinct areas. The research design, instruments, and statistical techniques are described in detail to enable precise replication of the investigation. Ethical approval and participant consent procedures are also specified, confirming adherence to international research standards.

2.1. Research Design and Study Period

This study employed a cross-sectional quantitative design between January and June 2024 to investigate self-reported eco-responsible practices and their associations with environmental club participation among Moroccan secondary school students. This design is particularly suited for capturing behavioral snapshots across groups and socio-territorial contexts in a post-pandemic setting [49], [50].

The study design aligns with recent meta-analytic evidence that structured climate change education enhances environmental knowledge, pro-social attitudes, and self-reported sustainable practices in secondary education contexts [51]**.** Structured self-report questionnaires and indicator-based analysis remain robust and valid for such cross-sectional investigations.

Methodological clarification**:** Although this cross-sectional design effectively captures associations and behavioral patterns among student groups in the post-pandemic context, it does not permit causal inference regarding the influence of environmental club membership. It remains plausible that students who are already environmentally conscious are more inclined to join such clubs, reflecting a potential self-selection bias. A longitudinal design better suited to track behavioral change over time was not feasible due to logistical and resource constraints following the pandemic. Therefore, all findings should be interpreted as correlational rather than causal. This limitation is further discussed in the Discussion section.

Cross-sectional research remains widely endorsed for comparing population subgroups statistically and exploring differences in the durability of self-reported environmental practices across urban and peri-urban areas [52], [53] Complementary methodological reviews emphasize that structured pedagogical environments, such as problem-based learning (PBL) and extracurricular initiatives, enhance student engagement and support the validity of survey-based cross-sectional research [52]. Additionally, using multivariate statistical techniques (PCA, ANOVA, clustering) strengthens the robustness and reproducibility of group-level comparisons in educational and ecological studies [53].

2.2. Sampling Sites and Strategy

This study was conducted in three Moroccan cities Fez, Sefrou, and Tangier, selected from two different administrative regions: Fès-Meknès (Fez and Sefrou) and Tangier-Tétouan-Al Hoceïma (Tangier). These urban and peri-urban locations were deliberately chosen to reflect territorial and socio-economic diversity, which may influence students' access to environmental education (EE) and extracurricular activities.

A stratified random sampling method was applied to ensure proportional representation across the selected cities, school levels, and demographic characteristics. Public secondary schools were randomly selected in each city, followed by randomly selecting students aged 15 to 19 across different grade levels. This approach minimized sampling bias and allowed for balanced data collection from a diverse student population.

Table 1. Sampling Details by City (N=433)

City	Region	Category	Freq.	Percentage
Fez	Fès-Meknès	Urban	126	29%
Sefrou	Fès-Meknès	Peri-urban	134	31%
Tangier	Tangier-Tétouan Al Hoceïma	Urban	173	40%

The final sample included 433 students, which meets recommended standards for multivariate statistical analyses such as Principal Component Analysis (PCA) and clustering, according to Hair et al. [54] a minimum of 300–400 participants is suitable for indicator-based classification. The stratified design also enables comparative analysis between cities and student subgroups (e.g., by club membership or knowledge level).

2.3. Data Collection Procedures and Instruments

Data for this study were collected using a structured, paper-based questionnaire administered within participating schools under the supervision of trained facilitators. The instrument consisted of four sections: demographics, environmental knowledge, self-reported eco-responsible practices, and health-related expertise. Self-reported eco-responsible practices included properly disposing of pandemic-related waste (e.g., masks, gloves), water conservation behaviors, and awareness of vaccination-related medical waste risks. The vaccination-related medical waste awareness item was deliberately excluded from the composite score of eco-responsible practices, as it reflects a cognitive dimension rather than a behavioral one. Instead, this item was analyzed separately as an indicator of students' cognitive engagement, particularly related to environmental club participation and overall ecological knowledge, which enhanced the internal consistency of the eco-responsible practices scale while preserving the relevance of the awareness variable within the post-pandemic educational context [55]–[57].

Before full-scale deployment, the instrument was piloted with 40 students to assess clarity, consistency, and reliability, yielding a Cronbach's alpha coefficient of 0.79, indicating acceptable internal consistency. To minimize social desirability bias, the survey was administered anonymously, with facilitators emphasizing no "right" or "wrong" answers and ensuring participants were fully confidential. As with most self-reported environmental studies, the results reflect students' perceptions of their behaviors, which may not fully align with their actual practices [58]. Participation was voluntary, with informed consent obtained from all participants and legal guardians, following international ethical standards [59].

2.4. Operationalization of Variables

To ensure clarity and precision in the statistical analyses, the key variables of this study were carefully defined and operationalized. The following table outlines the specific variables used in this research, their definitions, operationalization strategies, and the relevant references guiding their measurement. These variables are essential for capturing students' engagement with eco-responsible behaviors and their environmental knowledge, providing the foundation for subsequent analyses.

Table 2. Operationalization of Variables

Variable	Definition/Description	Operationalization
Environmental Club Membership	A binary categorical variable indicating membership in an environmental club.	1 = member, 0 = non-member
Self-Reported Eco-Responsible Practices	Two dichotomous behavioral indicators reflecting eco-responsible behaviors.	- Responsible disposal of pandemic-related waste (e.g., masks, gloves) - Water conservation
Awareness of Vaccine-Related Medical Waste	Cognitive awareness indicator reflecting knowledge of the risks associated with vaccination-related medical waste.	Analyzed separately as a cognitive awareness item and excluded from the eco-responsible practices score.
Eco-Responsible Practices Score	Composite score reflecting engagement in self-reported eco-responsible practices, focusing on behavior rather than perceptions or knowledge.	The mean of the two behavioral indicators is responsible waste disposal and water conservation (range: 0–1).
Environmental Knowledge Score	Composite index reflecting environmental literacy and knowledge.	Correct responses to questions about pollution sources (air, water, soil) and ecological components (range: 0–5).
Behavioral Sustainability (Self-Reported Practices)	Dimension derived from the Eco-Responsible Practices Score, specifically reflecting behavioral sustainability.	Derived exclusively from the two behavioral indicators: responsible waste disposal and water conservation.

To maintain conceptual consistency, the Eco-Responsible Practices Score was recalculated using only the two behaviorally anchored items, responsible waste disposal and water conservation, while excluding the cognitive

awareness item. This distinction ensures that the score reflects concrete, self-reported environmental actions, rather than being influenced by perceptions or knowledge. By focusing solely on measurable behaviors, the internal validity of the measurement is strengthened, making the score a more accurate representation of actual eco-responsible practices.

As a result, the Principal Component Analysis (PCA) dimension labeled "Behavioral Sustainability (self-reported practices)" was derived exclusively from these two validated behavioral indicators. This table provides a comprehensive overview of the key variables in this study, outlining their definitions, operationalization strategies, and measurement methods. By clearly delineating how each variable was operationalized, this framework ensures the reliability and validity of the subsequent analyses, allowing for a more precise interpretation of the data.

2.5. Analytical Framework and Statistical Methods

All analyses were conducted using SPSS and R, following best practices in the behavioral sciences [60], [61]. The studies focused on the recalibrated Eco-Responsible Practices Score, which included only two validated behavioral indicators, responsible waste disposal and water conservation. At the same time, the cognitive awareness item was deliberately excluded. This adjustment underscored the conceptual distinction between concrete behavioral actions and mental engagement, strengthening the analytical model's internal consistency and interpretive validity.

The analytical framework comprised descriptive statistics to summarize participants' demographic characteristics, environmental club membership, and individual responses. Chi-Square (χ^2) tests were applied to examine associations between club membership and behavioral indicators, with statistical significance set at $p < 0.05$. A two-way ANOVA was then employed to assess differences in the Eco-Responsible Practices Score based on club membership and city of residence, including potential interaction effects; subgroup means and standard deviations were reported separately in the supplementary materials. To explore latent dimensions of engagement, Principal Component Analysis (PCA) with Varimax rotation was conducted, and the resulting component scores were subsequently used in K-Means Clustering to classify students into distinct engagement profiles.

2.6. Ethical Compliance

This study was approved by the Institutional Ethics Committee of Sidi Mohamed Ben Abdellah University (Fez, Morocco). Participation was voluntary, confidential, and compliant with the Helsinki Declaration [62].

3. RESULTS

This section presents the empirical findings from the survey of 433 Moroccan secondary school students across Fez, Sefrou, and Tangier, focusing on the role of environmental club participation in sustaining eco-responsible behaviors post-COVID-19. Results are organized by descriptive statistics, inferential tests (Chi-square and ANOVA), factorial analysis (PCA), and cluster analysis for student segmentation. Additional descriptive measures (means, standard deviations) and effect sizes are provided to enhance statistical clarity.

3.1. Descriptive Statistics of Participants

This section summarizes the demographic and behavioral characteristics of the 433 Moroccan secondary school students surveyed across Fez, Sefrou, and Tangier. The Behavioral Practices Score was recalculated to exclude the "awareness of vaccine-related medical waste" item, conceptually aligned with cognitive indicators. This ensures that the composite score now exclusively reflects self-reported behavioral practices.

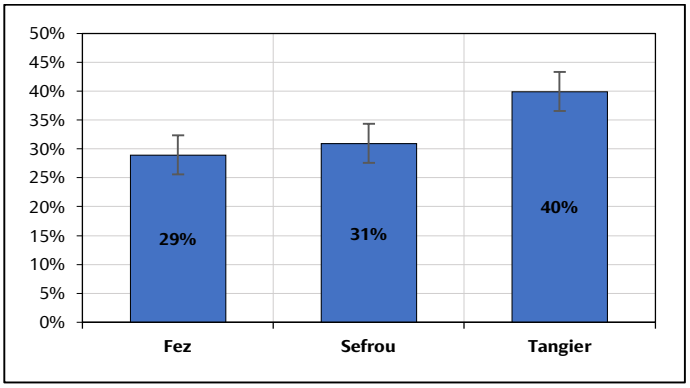

Figure 1. Proportional Distribution of Surveyed Secondary School Students Across the Cities.

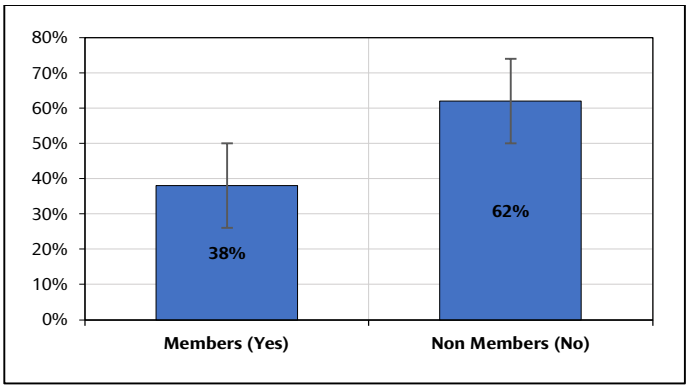

Figure 2. Proportion of surveyed secondary school students by participation in environmental clubs (membership status)

Figure 1 illustrates the territorial distribution of participants. Tangier accounted for 40% of the sample, followed by Sefrou (31%) and Fez (29%). This relatively balanced distribution ensures representation from urban (Fez and Tangier) and semi-urban (Sefrou) contexts, allowing for meaningful regional comparisons of environmental knowledge and engagement. This territorial heterogeneity strengthens the study's external validity and aligns with calls in the literature to contextualize environmental education geographically.

Figure 2 presents the proportions of students involved in environmental clubs. 38% of students reported active membership, while 62% reported no involvement. Although national policies encourage extracurricular engagement in

sustainability, the relatively low participation rate highlights structural barriers and limited accessibility of clubs in certain schools. This justifies further investigation into how club membership relates to behavioral and cognitive engagement. This study is cross-sectional, so the results are interpreted as associations rather than causality.

Table 3. Descriptive Characteristics of Participants (N=433)

Variables	Mean	SD
Age (in years)	16.20	1.40
Gender (% female)	52%	-
Club Membership (% Yes)	38%	-
Behavioral Practices Score (0–1)	0.63	0.18
Environmental Knowledge Score (0–5)	2.70	1.10

Table 3 summarizes the participants' descriptive characteristics. The average age was 16.2 years (SD = 1.4), with a nearly equal gender distribution (52% female). The recalibrated Behavioral Practices Score (M = 0.63, SD = 0.18) reflects moderate levels of self-reported sustainable behavior based on responsible waste disposal and water conservation. The Environmental Knowledge Score (M = 2.7 out of 5, SD = 1.1), aggregating key items on pollution and ecosystem components, suggests partial conceptual understanding. These indicators provide a baseline for interpreting the statistical patterns explored in the subsequent analyses.

3.2. Association Between Club Participation and Self-Reported Eco-Responsible Practices

To assess whether environmental club membership is associated with greater adoption of eco-responsible behaviors, Chi-square (χ^2) tests were conducted on three key indicators: (i) responsible disposal of pandemic-related waste (e.g., masks, gloves), (ii) water conservation practices, and (iii) awareness of risks associated with vaccination-related medical waste.

Results show statistically significant differences ($p < 0.001$) between club members and non-members across all indicators. Students affiliated with environmental clubs reported higher engagement in sustainable practices: 68.5% vs. 41.2% for responsible pandemic-related waste disposal, and 74.2% vs. 49.5% for water conservation. Similarly, awareness of vaccine-related medical waste risks was stronger among club members (61.7%) compared to their peers (38.3%).

Table 4. Differences in Eco-Responsible Practices and Environmental Awareness Between Environmental Club Members and Non-Members.

Indicators	Club Members	Non-Members	χ^2 (df = 1)	*p-value*	Cramer's V
Responsible Disposal of Pandemic-Related Waste	68.50%	41.20%	21.45	<0.001	0.22 (moderate)
Water Conservation Practice	74.20%	49.50%	19.34	<0.001	0.21 (moderate)
Awareness of Risks from Vaccination-Related Medical Waste	61.70%	38.30%	17.82	<0.001	0.20 (moderate)

Table 5. Two-way ANOVA Results Assessing the Effects of Environmental Club Participation and City on Students' Eco-Responsible Practices Scores.

Variables	Sum of Squares	df	Mean Square	*F-value*	*p-value*	Partial η^2 (effect size)
Club Participation	12.87	1	12.87	15.62	<0.001	0.034 (*minor to moderate*)
City	5.21	2	2.61	3.17	0.043	0.014 (*small*)
Interaction	3.44	2	1.72	2.09	0.087	0.010 (*small*)
Error	349.23	427	0.82	-	-	-

Effect sizes (Cramer's V = 0.20–0.22) indicate moderate associations, highlighting that club involvement is positively associated with behavioral engagement and environmental awareness.

These findings are consistent with broader literature on environmental clubs' role in fostering youth action-based and knowledge-based ecological commitment. Nevertheless, the study's cross-sectional nature precludes causal inference, a limitation further discussed in the conclusion.

While the chi-square analyses provided insight into specific eco-responsible behaviors and awareness indicators across club membership status, a broader perspective is necessary to examine how these patterns interact with institutional and territorial factors. To this end, the following section presents a multivariate analysis based on an integrated Eco-Responsible Practices Score, offering a more holistic view of students' sustainable engagement across urban contexts and participation levels.

3.3. ANOVA on Eco-Responsible Practices Score

To further investigate students' sustainable engagement, a two-way analysis of variance (ANOVA) was performed on the Eco-Responsible Practices Score, which ranges from 0 to 5. This score was constructed based on two core behavioral indicators: the responsible disposal of pandemic-related waste and self-reported water conservation. These indicators reflect tangible, action-oriented practices particularly relevant in post-pandemic environmental behavior.

The ANOVA model (presented in Table 5) examined the main effects of environmental club membership, city of residence (Fez, Sefrou, Tangier), and their interaction on students' eco-responsible behavior scores. This analysis aimed

to assess the influence of these factors on students' engagement in sustainable practices.

For consistency throughout the manuscript, the Eco-Responsible Practices Score used in the ANOVA (Tables 5 and 6) is based on a 0–5 scale. In earlier sections (Table 3), a 0–1 binary scale was employed for descriptive frequency reporting of individual behaviors. The current score aggregates and scales these behaviors, enabling parametric analysis for a more detailed data exploration.

Table 6. Means and Standard Deviations of Eco-Responsible Practices Scores.

City	Club Status	Mean Score	Standard Deviation
Fez	Members	4.21	0.66
	Non-Members	3.74	0.78
Sefrou	Members	4.10	0.61
	Non-Members	3.62	0.81
Tangier	Members	4.02	0.72
	Non-Members	3.58	0.75

The results demonstrate a statistically significant main effect of environmental club participation on Eco-Responsible Practices Scores, $F(1, 427) = 15.62$, $p < 0.001$, with a small to moderate effect size (partial $\eta^2 = 0.034$). This finding suggests that environmental club membership robustly predicts students' engagement in sustainable behaviors. Additionally, the results reveal that club membership is a more influential determinant of students' self-reported sustainable practices than their geographic location. This underscores the significant role of school-based environmental clubs in promoting consistent engagement with eco-responsible behaviors, irrespective of regional differences.

The city of residence also demonstrates a significant, though smaller, effect, $F(2.427) = 3.17$, $p = 0.043$, partial $\eta^2 = 0.014$, indicating that territorial context has a modest influence on behavioral responses. This may reflect variations in infrastructure, environmental programs, or local awareness campaigns across different cities. However, no significant interaction effect was observed between club participation and city, $F(2.427) = 2.09$, $p = 0.087$, partial $\eta^2 = 0.010$, suggesting that the benefits of club participation are consistent across the three cities. These results imply that the positive impact of environmental clubs on students' eco-responsible behaviors is generalizable across diverse geographic contexts.

These findings reinforce the importance of institutional engagement, specifically through environmental club participation, as a central driver of promoting sustainable practices among youth. They also highlight the need to investigate regional disparities in future policy and educational strategies. The results confirm the robustness of the 0–5 engagement score across regions and club membership status, demonstrating statistically significant differences with clearly reported effect sizes. To explore these behaviors in greater depth, the following section utilizes Principal Component Analysis (PCA) to identify the key dimensions of student engagement, followed by a clustering approach to segment the student population into distinct ecological behavior profiles. This multidimensional analysis provides a deeper understanding of how practices, knowledge, and institutional participation interact within and across groups.

3.4. Principal Component Analysis (PCA)

To uncover the latent structure of student engagement, a Principal Component Analysis (PCA) was performed on five standardized variables: responsible disposal of pandemic-related waste, awareness of vaccination-related medical waste risks, water conservation, environmental knowledge, and ecological club participation. The analysis employed Varimax rotation to improve the interpretability of the factor solution. Before extraction, data suitability was confirmed by the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, which yielded a value of 0.703, indicating acceptable adequacy, and Bartlett's Test of Sphericity ($\chi^2 = 413.54$, $df = 10$, $p < 0.001$), which demonstrated sufficient intercorrelation among the variables to justify factor analysis.

Two principal components were extracted, accounting for 65.4% of the total variance. The first component, labeled Eco-Responsible Practices, explained 43.2% of the variance and reflected behavioral engagement, with high loadings on water conservation (0.80), responsible disposal of pandemic-related waste (0.78), and awareness of risks from vaccination-related medical waste (0.75). The second component, Awareness and Participation, explained 22.2% of the variance and represented cognitive and institutional engagement, driven primarily by environmental club participation (0.79) and ecological knowledge (0.72). The PCA correlation circle (Figure 3) illustrates a near-orthogonal relationship between these two axes, suggesting that behavioral practices and cognitive/institutional engagement form distinct yet complementary dimensions of environmental commitment.

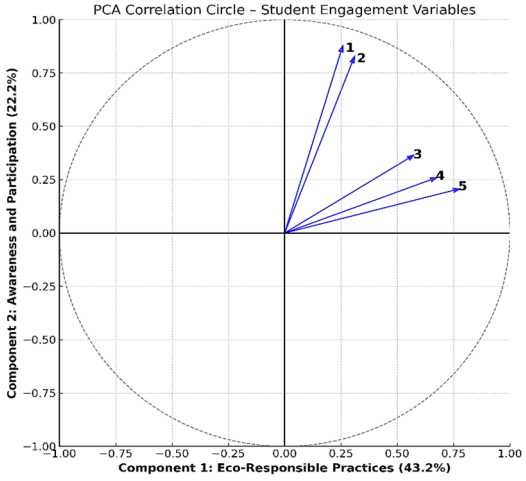

Figure 3. PCA Correlation Circle of Student Engagement Dimensions (1. Club participation; 2. Environmental knowledge; 3. Awareness of vaccination-related medical waste risks; 4. Responsible disposal of pandemic-related waste; 5. Water conservation)

These findings imply that students may engage in sustainable practices without strong cognitive support or institutional affiliation. Nevertheless, the most committed students typically combine both dimensions, integrating proactive behaviors with strong knowledge and active participation. This dual pattern of engagement is further explored in the subsequent cluster analysis. From a practical perspective, the results highlight the importance of environmental education strategies that simultaneously activate behavioral practices and reinforce cognitive and institutional support. In particular, school-based environmental clubs are pivotal in transmitting environmental knowledge, fostering more profound behavioral commitment, and shaping ecological identity.

This Principal Component Analysis (PCA), conducted on standardized scores from 433 students, revealed two distinct and orthogonal dimensions of environmental engagement. The first component, Eco-Responsible Practices, accounted for 43.2% of the variance and reflected behavioral engagement, with strong loadings on waste management, water conservation, and awareness of medical waste risks. The second component, Awareness and Participation, explained 22.2% of the variance and captured cognitive and institutional engagement, represented by environmental knowledge and club participation.

The corresponding figure illustrates the near-orthogonal relationship between these two components, indicating that behavioral practices and cognitive or institutional dimensions are distinct and complementary aspects of environmental commitment. To enhance readability within the constraints of academic publishing formats, individual items are represented by numeric labels (1–5) in the figure, with the decoding provided in the caption. Both axes are labeled with component names and explained variance, ensuring interpretability.

The visualization concisely synthesizes engagement profiles, distinguishing between practical eco-actions and cognitive or institutional involvement. Subsequent cluster analysis further examines these dual forms of engagement, exploring how students combine behavioral practices with broader awareness and participation.

3.5. Cluster Analysis of Student Profiles

A K-means cluster analysis used the component scores derived from the principal component analysis (PCA) to identify meaningful subgroups among students based on their environmental engagement.

The optimal number of clusters (k = 3) was determined using the elbow method, which revealed a clear inflection point in the within-cluster sum of squares. This selection was further supported by the three-cluster solution's theoretical interpretability, which aligned with the two PCA components: Component 1 (Eco-Responsible Practices) and Component 2 (Awareness and Participation).

The final model explained 72% of the between-group variance, indicating the robustness of the classification and its ability to differentiate the student profiles meaningfully. The three identified clusters represent distinct levels of engagement:

- The Sustainably Engaged group (25%) demonstrates high behavioral and cognitive engagement levels. These students exhibit excellent scores in eco-responsible practices (M = 4.5 ± 0.5), strong environmental knowledge (M = 4.3 ± 0.6), and a very high rate of club participation (92%). This profile represents the most holistically engaged students, integrating awareness, motivation, and action.
- The Latently Engaged group (50%) comprises the most significant cluster. Students in this group report moderate levels of engagement across all indicators: practices (M = 3.1 ± 0.7), knowledge (M = 3.0 ± 0.8), and club participation (28%). The revised label more accurately reflects their latent engagement potential, highlighting structural constraints such as limited access to clubs and unequal institutional opportunities without implying a lack of intent or attitude.
- The Unconcerned group (25%) shows consistently low engagement across all dimensions. These students score low in eco-responsible practices (M = 2.0 ± 0.6), exhibit limited environmental knowledge (M = 2.1 ± 0.7), and participate minimally in clubs (5%). This profile likely represents students disconnected from or unaware of environmental education initiatives. Their marginal position underscores the need for targeted outreach and support strategies to address the gaps in engagement.

Table 7. Cluster-Derived Student Profiles Based on Self-Reported Practices, Knowledge, and Club Membership

Profiles	Samples	Club Participation	Mean Practices Score	Mean Knowledge Score
Sustainably Engaged	25%	92%	4.5 ± 0.5	4.3 ± 0.6
Latently Engaged	50%	28%	3.1 ± 0.7	3.0 ± 0.8
Unconcerned	25%	5%	2.0 ± 0.6	2.1 ± 0.7

As presented in Table 7, the Sustainably Engaged group (25%) is distinguished by its high behavioral and cognitive engagement levels. This is reflected in exceptional scores for eco-responsible practices (M = 4.5) and environmental knowledge (M = 4.3), along with a very high rate of club participation (92%). These students demonstrate a comprehensive form of engagement, integrating action and awareness.

The Latently Engaged group (50%), the largest subgroup, reports moderate scores across all indicators and exhibits limited institutional support, with only 28% participation in environmental clubs. The revised label better captures their latent potential for engagement while acknowledging the contextual barriers that hinder its activation, without resorting to negative connotations often associated with terms such as "opportunists." This group likely consists of students with the potential for increased engagement, but are constrained by factors such as limited access to structured environmental programs.

Finally, the Unconcerned group (25%) displays consistently low levels of environmental engagement across all measured dimensions. This group has minimal participation in environmental clubs (5%), low self-reported eco-responsible practices (M = 2.0), and limited ecological knowledge (M = 2.1). These students appear largely disengaged from structured environmental education efforts, potentially due to a lack of exposure, insufficient institutional support, or low intrinsic motivation. Their position at the margins of both behavioral and cognitive engagement highlights the urgent need for targeted outreach strategies to re-engage this subgroup and mitigate the educational disparities in sustainability awareness.

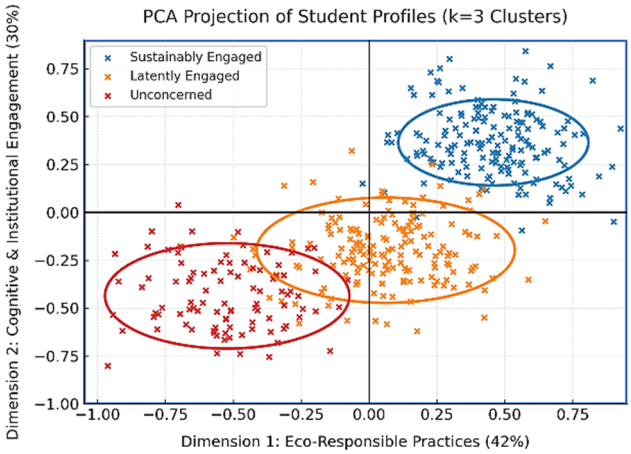

Figure 4. PCA-Based Projection of Student Engagement Profiles Along Eco-Responsible Practices and Cognitive & Institutional Engagement Dimensions (k = 3 Clusters, N = 433)

This PCA scatterplot projects student engagement profiles across two principal components: Eco-Responsible Practices on the x-axis (42% of the variance) and Cognitive & Institutional Engagement on the y-axis (30%). Together, these dimensions explain 72% of the total variance, providing a robust factorial solution that underpins the reliability of the cluster segmentation. Figure 4 illustrates the coexistence of distinct ecological engagement profiles and the dynamic pathways through which students may shift between them, pointing to actionable strategies for tailored environmental education.

The Sustainably Engaged cluster (blue), concentrated in the upper-right quadrant, represents students who consistently integrate ecological behavior with strong knowledge and institutional participation. Their position demonstrates the synergy of proactive habits such as waste management and water conservation with cognitive awareness and active involvement in environmental clubs. This profile reflects a deeply rooted ecological identity and suggests a group of potential peer leaders who can model sustainable practices.

In contrast, the Unconcerned cluster (red) lies in the lower-left quadrant, with uniformly low scores on both behavioral and cognitive dimensions. These students appear disengaged and detached from sustainability efforts, making them a priority for intervention strategies. The cluster's compactness suggests homogeneity in their disinterest, which may stem from either lack of exposure, competing priorities, or limited personal relevance of environmental issues.

The Latently Engaged cluster (orange), located near the origin of the factorial space, is more dispersed and partially overlaps with other clusters. This distribution highlights its transitional nature: students in this group show moderate behavioral or cognitive engagement but lack consistent reinforcement across both dimensions. Their positioning suggests contextual constraints such as limited resources, sporadic club activities, or insufficient training rather than intentional disengagement. Importantly, their overlap with the Unconcerned group identifies a "zone of risk," where students could either slide into complete disengagement or, with institutional and pedagogical support, progress toward the sustainably engaged profile.

The spatial separation and overlap of the three clusters underscore the need for differentiated educational strategies. For the Sustainably Engaged, reinforcement through leadership opportunities may deepen ecological identity. For the Latently Engaged, targeted interventions such as enhanced resource access, mentorship, or structured club activities could catalyze their transition into sustainable commitment. Meanwhile, the Unconcerned require foundational awareness-building programs, leveraging social influence and contextual relevance to spark initial engagement.

3.6. Territorial Distribution of Student Profiles

A cross-tabulation analysis was conducted to examine the distribution of the three student engagement profiles, Sustainably Engaged, Latently Engaged, and Unconcerned, across the participating cities of Fez, Sefrou, and Tangier. The results revealed a statistically significant association between territorial context and engagement profile membership (χ^2 = 12.67, df = 4, p = 0.013). This finding suggests that their local educational and socio-institutional environments significantly influence students' environmental engagement patterns.

Table 8. Territorial distribution of Student Engagement Profiles Across Fez, Sefrou, and Tangier

City	Sustainably Engaged	Latently Engaged	Unconcerned
Fez	29%	48%	23%
Sefrou	22%	54%	24%
Tangier	24%	49%	27%

In Fez, 29% of students were classified as Sustainably Engaged, the highest proportion among the three cities. This indicates a more substantial alignment between behavioral practices, cognitive awareness, and participation in environmental clubs. This may reflect a more robust institutional integration of environmental education initiatives and the presence of more active club structures within the urban school context.

In contrast, Sefrou exhibited the most significant proportion of Latently Engaged students (54%). Despite some signs of environmental interest and occasional pro-environmental behaviors, these students face structural limitations, such as insufficient club support, lack of training, and uneven access to awareness tools, which hinder sustained engagement. These findings underscore the vulnerabilities of semi-urban contexts, where institutional resources are often inconsistent.

While demonstrating a relatively balanced distribution of engagement profiles, Tangier showed the highest proportion of Unconcerned students (27%). This may point to challenges in reaching specific student populations in larger urban environments, where competing interests, high population density, and fragmented awareness initiatives could limit the effectiveness of environmental education efforts.

Although no causal conclusions can be drawn from this cross-sectional and self-reported dataset, these territorial disparities reinforce the importance of contextualized approaches to environmental education. Tailoring pedagogical tools, club structures, and awareness strategies to meet each territory's specific needs and institutional capacities, whether urban or semi-urban, may help bridge engagement gaps and foster more inclusive, long-lasting environmental behaviors.

The results from the descriptive statistics, principal component analysis, clustering, and territorial cross-tabulations provide a multidimensional understanding of Moroccan secondary school students' environmental engagement in the aftermath of the COVID-19 pandemic. Identifying three distinct student profiles, each characterized by varying degrees of behavioral practices, cognitive awareness, and institutional participation, offers a nuanced framework for interpreting how environmental education is internalized across socio-territorial contexts.

Moreover, the significant territorial disparities observed in the distribution of these profiles emphasize the role of local institutional structures, resource availability, and contextual constraints in shaping student engagement. Urban centers like Fez appear more conducive to sustained environmental involvement, while semi-urban or structurally fragmented settings, such as Sefrou, present more pronounced limitations. These findings warrant critical reflection on the' effectiveness, equity, and contextualization of current educational strategies.

In the following discussion, we explore these results' theoretical and practical implications, assess the validity of our research hypotheses, and position our findings within the broader literature on environmental education and behavioral change. This integrative analysis lays the foundation for targeted recommendations to enhance the inclusivity and long-term impact of environmental education in Morocco.

4. DISCUSSIONS

4.1 Environmental Clubs as Vectors of Social Learning and Institutional Anchoring

Our findings offer compelling empirical support for the role of environmental clubs as institutional platforms that facilitate ecological engagement through mechanisms of social learning, peer modeling, and norm internalization. The profile of the "Sustainably Engaged" cluster, comprising 25% of the sample and including 92% of club-affiliated students, illustrates this vividly. These students report the highest levels of both eco-responsible practices and environmental knowledge, reinforcing theories of ecological self-efficacy and behavioral reinforcement through group affiliation [17], [63], [64].

The theoretical framework of Huoponen [17], which postulates that eco-clubs foster pro-environmental identity through structured peer influence and institutional continuity, finds direct resonance. Our results confirm that the presence of clubs enhances the durability of eco-responsible practices, even in the face of territorial inequalities. The moderate effect size ($\eta^2 = 0.034$) observed in our ANOVA supports the idea that club engagement exerts a more substantial influence on behavior than geographic context, a finding also echoed by Houmam et al. [63] and Chen et al. [36], who highlight the power of school-level initiatives to cultivate civic commitment and sustainable action.

To further contextualize this finding within broader civic education literature, it is worth noting that environmental clubs often function as incubators of democratic values and civic agency. As Westheimer and Kahne [65] emphasize, experiential civic learning opportunities, particularly those rooted in real-world problem-solving, to promote long-term engagement and collective efficacy among youth [66]. Similarly, Torney-Purta, Wilkenfeld, and Barber [67] demonstrate that participation in experiential, community-oriented educational activities fosters sustained civic engagement and political efficacy among adolescents. In the Moroccan context, these dynamics intersect with broader socio-economic challenges, including uneven access to academic resources and civic spaces, highlighted in DGAP's analysis of Morocco's migration, education, and employment landscape [29]. This reinforces the argument that environmental clubs can simultaneously cultivate ecological awareness and strengthen civic norms, bridging environmental action with social responsibility when embedded in school systems.

Thus, clubs should no longer be viewed as extracurricular luxuries but as core institutional levers in promoting ecological citizenship and fostering civic engagement, particularly in transitional or post-crisis settings.

4.2 The Latently Engaged: A Policy Priority in Unequal Settings

The most critical finding of this study concerns the most extensive and most complex profile: the "Latently Engaged" (50%). Despite moderate levels of engagement and awareness, this group exhibits low club affiliation (28%) and is disproportionately represented in semi-urban areas such as Sefrou (54%).

This pattern reflects broader structural constraints, territorial disparities, limited institutional investment, and digital divides, which are well documented in Moroccan and Global South contexts [14], [61], [68]. As shown by Timmis and

Valladares-Celis [69] and van de Wetering et al. [70], students in peri-urban zones often express environmental concern but lack access to tools and infrastructures necessary to translate intent into practice, despite evidence showing that well-structured environmental education programs can improve behavioral outcomes in youth.

These access-related challenges are closely linked to persistent digital inequalities that hinder students' ability to engage meaningfully with environmental education tools and hybrid learning modalities, particularly in structurally underserved regions. Recent reviews of Morocco's socio-educational challenges also highlight how systemic underinvestment and governance asymmetries compound exclusion, undermining the transformative potential of education [29].

This cluster aligns with the "missing middle" concept in education for sustainability [69], students with latent potential who remain under-engaged due to external constraints. This group risks becoming permanently marginalized without targeted support such as trained facilitators, mobile clubs, or hybrid delivery modes.

Addressing this gap is thus not only an issue of educational equity but a strategic imperative. Investing in this group could yield disproportionate returns in terms of engagement and resilience, especially in crisis-prone or underserved regions.

4.3 From Eco-Behavior to Socio-Ecological Resilience: Broader Implications

Beyond behavioral analysis, this study contributes to a more systemic understanding of how school-based environmental education fosters socio-ecological resilience, a particularly relevant concern after COVID-19.

The "Sustainably Engaged" cluster reported strong adherence to eco-health practices such as proper pandemic-related waste disposal and water conservation. These behaviors are not only environmental but also public health practices, pointing to a growing need for integrated educational responses that align environmental sustainability with crisis preparedness and health literacy [21], [43], [71].

Socio-ecological resilience is defined here as the capacity of interconnected human and natural systems to absorb shocks, adapt to change, and maintain long-term functionality [66]. In educational settings, this entails developing learners' ability to adapt to environmental and social disruptions by combining cross-disciplinary knowledge, emotional coping skills, and civic responsibility. Case studies compiled by the Pan American Health Organization [72] These examples illustrate how integrated health and environmental education initiatives have increased community resilience in diverse contexts, often through participatory, equity-focused, and context-sensitive approaches. They provide concrete models for how Moroccan environmental clubs could integrate public health and environmental objectives to foster resilience.

These findings echo global reflections on embedding adaptive capacities within education systems. As Naidu and Sargues [73] argue, building post-crisis resilience requires systemic reform, flexibility in delivery modalities, and an intentional shift toward equity-centered planning.

Recent international experiences from Ontario's hybrid EE implementation [74] to Southeast Asian community-based resilience programs [71] demonstrate how EE can be leveraged to maintain continuity in values and action during disruptive events. These examples highlight the need to evolve EE from a content-based model toward a cross-sectoral strategy, responsive to environmental, social, and health risks [29].

These findings resonate with broader analyses of educational strategies to foster socio-ecological resilience in times of crisis. As shown by Servant-Miklos [73], educational action research during the COVID-19 pandemic revealed the potential of environmental education to support adaptive learning, emotional well-being, and community-oriented practices in schools.

4.4. Methodological and Contextual Limitations

Firstly, the reliance on self-reported data introduces the risk of social desirability bias, which may lead to an overstatement of actual practices due to the well-known attitude–behavior gap [34], [47]. Although efforts were made to ensure anonymity, previous research has highlighted that adolescents often misreport socially desirable behaviors, particularly in sustainability and digital consumption. This tendency can inflate correlations and distort behavioral profiles [75]–[77]. Moreover, youth responses may be influenced by immediate social contexts or perceived expectations from educators. To mitigate this bias, future research could incorporate behavioral logs, ecological momentary assessments, or digital trace data to enhance the reliability of the findings.

Secondly, the cross-sectional design and self-selection bias limit the ability to draw causal inferences. It remains unclear whether participation in environmental clubs leads to eco-responsible behavior or if students who already exhibit such behaviors are more likely to join them. This limitation is standard in many environmental education (EE) studies [49]. To address this, longitudinal designs must clarify the causal relationships and trajectories between participation and behavior.

Another significant limitation is the geographic scope of the study. By focusing exclusively on three urban and peri-urban cities, the study omits perspectives from rural areas, which may differ significantly regarding access, perceptions, and environmental outcomes [30], [63]. Including rural areas in future research would help enhance the generalizability of the findings and capture a more comprehensive range of experiences and challenges.

This study did not capture several influential factors, including parental education and involvement, socio-economic status (SES), media exposure, digital access, and prior environmental experiences. Recent research highlights two critical, interrelated dimensions of adolescent behavior formation that were not considered: (a) peer influence, where social norms within friendship groups significantly shape youth attitudes and practices, particularly when reinforced through emotional bonding or identity-related mechanisms

[76]; and (b) social media exposure, where platforms such as TikTok, YouTube, and Instagram not only disseminate environmental knowledge but also influence behavioral intentions through algorithmic reinforcement, visual storytelling, and emotional contagion [77]. Excluding these dimensions may obscure key psycho-social dynamics behind eco-responsibility, particularly in the post-pandemic digital context. For instance, Meng et al. [77] found that exposure to environmental content on social media platforms like WeChat significantly enhances adolescents' intentions to engage in pro-environmental behaviors, mediated by attitudes and perceived behavioral control.

Lastly, measurement ambiguity arose in the early stages of data collection, including a cognitive item (awareness of vaccine-related waste) in the composite scores. This item blurred the line between knowledge and behavior, which could have confounded the results. Although this issue was corrected in the final analyses, future research should clearly distinguish between these dimensions to avoid construct overlap and ensure more precise measurement of knowledge and behavior.

4.5. Future Research Directions

Several avenues for future research are recommended to address the limitations identified in this study and further strengthen the field of environmental education (EE). One promising direction is using longitudinal and mixed-methods designs, allowing researchers to capture changes over time and explore the underlying motivations driving ecological behaviors. Such an approach could provide deeper insights into the dynamics of behavior change and the factors influencing it [30], [50].

Additionally, qualitative interviews and focus groups could be utilized to understand better the contextual factors shaping student choices, constraints, and cultural framing. These methods would allow for a more nuanced exploration of the personal and societal influences on students' engagement with environmental practices [50]. Another vital consideration is including rural and marginalized areas in research, which would enhance the generalizability of findings and contribute to a more equitable representation in EE studies. Research on these regions could provide valuable insights into how environmental education initiatives can be adapted to diverse contexts, ensuring inclusivity and accessibility [63].

Furthermore, future research should aim to integrate a broader range of variables, such as socio-economic status (SES), parental influence, peer dynamics, and digital media use, to model the whole ecology of behavior formation better. Understanding how these factors intersect will allow researchers to develop a more comprehensive framework for behavior change in the context of environmental education [78]. Lastly, there is a need for the impact evaluation of hybrid environmental education models, particularly in semi-urban or resource-constrained schools. This would assess the resilience benefits of integrating digital tools and health-related content into environmental education, helping to identify strategies for strengthening student adaptation in the face of multiple, interconnected crises [63], [69].

These future research directions are vital for building a contextualized, systemic, and inclusive model of environmental education. Such a model would equip youth with the knowledge and skills to act sustainably and empower them to adapt resiliently in an era marked by environmental, social, and economic challenges.

5. CONCLUSION

This study provides robust empirical evidence that environmental clubs are pivotal institutional mechanisms for promoting durable eco-responsible behaviors among Moroccan secondary school students in the post-COVID-19 context. Based on a representative sample of 433 students across Fez, Sefrou, and Tangier, the analysis reveals a significant and consistent association between club membership and the adoption of self-reported sustainable practices, including proper disposal of pandemic-related waste, water conservation, and awareness of vaccination-related medical waste risks (Cramer's $V \approx 0.20–0.22$).

Through Principal Component Analysis, two complementary dimensions of engagement were identified: Eco-Responsible Practices and Awareness/Participation, jointly accounting for 65.4% of the variance. Cluster analysis further distinguished three student profiles: Sustainably Engaged, Latently Engaged, and Unconcerned. Each reflects varying degrees of behavioral commitment, institutional support, and exposure to environmental education, with apparent territorial disparities.

These findings carry direct implications for education policy and practice. In particular, they emphasize the urgency of scaling and strengthening environmental clubs, especially in structurally disadvantaged settings such as peri-urban and underserved areas. Investing in trained facilitators, flexible pedagogies, and digital support systems can help overcome socio-territorial gaps and sustain youth engagement. Integrating health-environment modules into club activities further supports the development of resilient, eco-citizen behaviors in the face of contemporary and future crises.

Beyond its national scope, this research contributes to the global discourse on Education for Sustainable Development (ESD) by proposing a replicable model of how school-based environmental structures can serve as cross-cutting levers for behavioral change, public health awareness, and community resilience. It highlights the importance of contextualized, participatory, and inclusive approaches that center youth not merely as recipients of knowledge, but as active agents of transformation.

Ultimately, this study repositions environmental clubs from the periphery of extracurricular activity to the core of strategic educational planning. In an era of interlinked environmental, social, and health challenges, fostering context-sensitive, youth-led environmental engagement is no longer optional; it is foundational to cultivating adaptive, resilient, and civically responsible citizens. The evidence presented here offers a clear and urgent directive to

policymakers in Morocco and beyond: investing in environmental clubs is not just an educational choice, but a strategic investment in a more equitable, sustainable, and crisis-resilient future.

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