Research Journal in Advanced Humanities

RJAH

https://doi.org/10.58256/qg9drw14

Open Access

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RESEARCH ARTICLE **Section:** *Digital Humanities*

Digital sustainability culture on campus: University students' awareness of eco-friendly technology and exposure to sustainability initiatives

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ABSTRACT

Guided by the Theory of Planned Behavior, the study surveyed 383 students, gauging their knowledge of eco-technologies, attitudes, perceived control, social norms, intentions, and levels of exposure. The survey incorporated open-ended prompts to gather more nuanced feedback. Using the Theory of Planned Behavior, 383 students completed a questionnaire assessing eco-technology knowledge, attitudes, perceived behavioral control, subjective norms, intentions, and exposure, alongside open-ended questions. The findings revealed that the students expressed robust eco-friendly attitudes, felt social support, believed they could act, and voiced firm intentions. Nonetheless, their factual understanding of eco-technology was only middling. All mean respondent ratings on campus engagement with environmental initiatives were below the midpoint of the benchmarks, and comments described uneven involvement with recycling programs, green infrastructure and other eco-initiatives. Results also showed that the students who had prior experience with sustainability initiatives outperformed their peers on every measured dimension. Exposure correlated positively and significantly with each dimension of awareness and was closely tied to the overall awareness index, confirming the expected link between exposure and awareness. The study underscores the importance of using the campus as a "living laboratory" and for intersecting but equitable sustainability exposure in the first year through curricular and co-curricular experiences.

KEYWORDS: digital sustainability culture, first-year university students, eco-friendly technology awareness, campus sustainability initiatives, theory of planned behavior

Research Journal in Advanced Humanities

Volume 7, Issue 1, 2026

ISSN: 2708-5945 (Print)

ISSN: 2708-5953 (Online)

ARTICLE HISTORY

Submitted: **16 September 2025**

Accepted: 09 **December 2025**

Published: 22 **March 2026**

HOW TO CITE

Aldawsari, N. D., Alghamdi, H. M., Abdellatif, M. S., & Abdelhafez, A. M. M. (2026). Digital sustainability culture on campus: University students' awareness of eco-friendly technology and exposure to sustainability initiatives. *Research Journal in Advanced Humanities*, *7*(1). https://doi.org/10.58256/qg9drw14

Published in Nairobi, Kenya by Royallite Global, an imprint of Royallite Publishers Limited

1. Introduction

Emerging environmental crises have thrust education, and higher education in particular, into the limelight as a major force for transitioning to more sustainable societies. Worldwide, the United Nations Sustainable Development Goals (SDGs) are being integrated into teaching and learning, research, and the way campuses operate, making them active labs of sustainability (Papavasileiou et al., 2025). In Saudi Arabia, environmental goals were included and tied to economic diversification in its Vision 2030, which established specific objectives to enhance waste management systems and recycling practices, as well as to control pollution and water use (Kingdom of Saudi Arabia, 2016).

Within this national agenda, university students represent a strategic group. Their knowledge of green technology and their readiness to embrace sustainability are key in achieving long-term change as future policymakers. Incoming students quickly absorb campus signals, from visible features such as solar arrays and recycling stations to the availability of sustainability courses and related activities. These early experiences can shape students' understanding of sustainability and their perceived role in addressing environmental issues, in line with SDGs (Agbedahin, 2019). However, there is still little research on what first-year Saudi students know about eco-friendly technologies, or how their awareness may be influenced by involvement in campus sustainability initiatives.

The majority of these (regional) studies target older or senior students, and all suggest a discontinuity between the sustainability discourse and the students' knowledge and experiences (Alsaati et al., 2020; Ezzeldin, 2023). Students frequently report positive attitudes toward environmental protection but show limited knowledge of everyday ecopractices and low participation in sustainable behaviors such as recycling (Alsaati et al., 2020). Prince Sattam bin Abdulaziz University (PSAU) has recently launched a "Green University" initiative, including plans to plant 100,000 saplings, form sustainability committees, promote sustainable transportation, and reduce energy consumption in line with Vision 2030.

It remains an open question how first-year students use green technologies, whether they are aware of supportive social norms and opportunities for environmentally sound behaviors, and to what extent their knowledge is a function of direct experience with sustainability initiatives. Addressing this gap is important for designing targeted interventions that anchor sustainability from the very start of students' university careers. Thus, the present study aims to investigate: (a) first-year PSAU students' cognitive, affective, normative and behavioural dimensions of eco-technology awareness; (b) differences in eco-technology awareness by each of gender, residence and previous exposure to sustainability-related topics; and (c) how exposure to campus sustainability initiatives relates to students with eco-technology awareness.

Key to the theoretical framework is the linkage of exposure, awareness, and behavioural intentions, which combine perspectives from the Theory of Planned Behaviour (Ajzen, 1991), the theory on environmental education (Agbedahin, 2019; UNESCO, 1978), and the Social Learning Theory (Bandura, 1986; Jacobi et al., 2016). This work has three main contributions. The first is its empirical evidence on eco-technology literacy levels among Saudi students in the first year of university, filling this gap and contributing to the Vision 2030 goal of well-rounded, environmentally literate citizens. Secondly, it presents and tests a model that links exposure to campus sustainability programs with eco-technology awareness and behavioural intentions, drawing on the framework of Planned Behaviour Theory, the environmental education literature, and social learning theory. Third, it has practical implications for how universities - particularly in Saudi Arabia - can organize first-year experiences (such as orientation and general education) to scaffold eco-friendly technology literacy and sustainable habits over time.

2. Literature Review and Theoretical Background

2.1 Literature Review

2.1.1 Eco-Friendly Technology Awareness in Higher Education

Eco-friendly technology awareness encompasses what students *know* about sustainable technologies and practices, how they *feel* about them, and how likely they are to *adopt* them in their daily lives. The construct encompasses knowledge of renewable energy, energy-efficient devices, recycling systems, low-carbon transport, and resource-efficient infrastructure. It also includes emotional involvement (worry, curiosity) and a declared willingness to adopt sustainable behavior. Environmental education has maintained that awareness is more

than recalling facts: it involves concern, responsibility for caring, and a willingness to take prioritized action to improve/maintain the environment (UNESCO, 1978). Accordingly, an environmentally aware student not only identifies eco-friendly technologies but also appreciates their importance and is inclined to use or promote them. Recently, studies have shown that even though the topic of sustainability is more present today in higher education institutions worldwide there still exist substantial gaps between students' sound knowledge and their skills to convert awareness into everyday practices (Alsaati et al., 2020; Leal et al., 2024; Vasconcelos et al., 2022). Alsaati et al. (2020) reported that students living in Eastern Province of Saudi Arabia are well-aware of the sustainability concepts, but they face challenges with 'doing', including segregating recyclables properly or choosing renewable resources and energy saving options. Ezzeldin (2023) observed that PSAU students are more attuned to the technological and economic facets of sustainability than to its social or environmental elements. Technological awareness likely reflects national and institutional emphasis on digital transformation and green innovation. By contrast, low scores on eco- and socio-sensitivity mean that they are less likely to appreciate the complexity of environmental systems and equity. These variations are related to discipline or prior experience. Students in STEM and environmental majors seem to score highest, with mixed reports regarding gender differences (Ezzeldin, 2023). Overall, researchers emphasize the move from simple concept-based knowledge to a universal eco-technology literacy covering all students regardless of their major or background.

2.1.2 Exposure to On-Campus Sustainability Initiatives

Universities increasingly treat campuses as "living laboratories" where operations, governance, and co-curricular activities are aligned to make sustainability visible and experiential. Infrastructure (solar panels, green buildings, recycling hubs), programmatic initiatives (environmental clubs, volunteer campaigns, hackathons) and institutional policies (on energy or waste) are some ways students experience sustainability. These types of experiences can complement formal education by connecting observed or on-the-ground knowledge to real life, from an experiential and place-based learning perspective (Amaral et al., 2020; Jacobi et al., 2016).

Evidence from various contexts shows that participation in sustainability initiatives is associated with higher sustainability awareness and stronger pro-environmental behavior. Papavasileiou et al. (2025), in a Greek case study, found that environmental clubs, research projects, ecoinnovation competitions, and green campus operations all significantly enhanced students' engagement with the SDGs. Active participation was associated with greater environmental literacy and a higher intention to engage in sustainable behaviors. In addition, a few institutional practices such as recycling programs, energy management policies and landscape activities were other predictors of higher environmental knowledge and attitudes towards sustainability (Christou et al., 2024; Pereira Ribeiro et al., 2021).

At PSAU, sustainability initiatives include the Green University project (tree planting and expanded green space), measures to promote sustainable mobility, and steps to reduce energy consumption in line with national agendas. A sustainability committee and participation in global university sustainability rankings support these efforts. But not all students are equally exposed to such programs, especially for first-year students who may be newcomers in navigating the campus. Ensuring that early exposure is broad and well-supported is therefore critical if campus initiatives are to influence awareness and behavior.

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2.2 Theoretical Foundations

2.2.1 Theory of Planned Behavior

The Theory of Planned Behavior (TPB) posits that behavioral intention is shaped by three main components: attitude toward the behavior, subjective norms, and perceived behavioral control (Ajzen, 1991). In the context of sustainability, attitudes refer to the extent to which students view eco-friendly practices and technologies as beneficial. Subjective norms are students' perceptions of others' expectations regarding their behaviour, from peers, faculty, and the institutional culture. Perceived behavioral control refers to students' perceived ability to perform sustainable behavior, given their resources and limitations. In the university context, the TPB has been used to explain energy conservation and other pro-environmental behaviors. Du and Pan (2021) concluded that attitudes and perceived behavioral control are important factors in explaining students' intentions to save energy in dormitories, and that individual moral norms reinforce the model. Exposure to sustainability action can affect all three components of TPB, information (which constructs attitudes), social cues and role models (pertaining to norms) and practical experience (a prerequisite of perceived control).

2.2.2 Environmental Education and Social Learning

Environmental Education (EE) and Education for Sustainable Development (ESD) conceptualize learning as a process that moves from developing awareness and knowledge to fostering positive attitudes, building relevant skills, and ultimately encouraging action (UNESCO, 1978; Agbedahin, 2019). The efficient EE balances cognitive, affective and behavioural domains in a coherent whole. It emphasizes applicability, experiential involvement, integration among disciplines. Students should interact with sustainability in real world situations and throughout the curriculum not just within specialized environmental courses. Higher education capitalised on this and situated advocacy for an institutional package of education – where teaching, research, campus and outreach is anchored in sustainability (Christou et al., 2024; McMillin & Dyball, 2009). Social Learning Theory (Bandura, 1986) enriches environmental education by highlighting that individuals learn through both direct instruction and the observation and imitation of others. By observing, at university, what other people (fellow students and staff) do with respect to recycling, saving energy and taking part in sustainability initiatives), students co-develop social norms over time (Jacobi et al., 2016). Mechanisms such as modeling, social reinforcement, and feedback loops help translate exposure into internalized values and habits. Sustainability ambassadors, peer educators, and public recognition for green initiatives deliberately leverage social learning processes (Jacobi et al., 2016). Transformative learning models and whole system campus models highlight the importance of sustainability education to develop the ability to think critically, in systems, and undergo a change of identity; that is, from passive information processor into active partakers of social change (O'Grady, 2025; Rodríguez Aboytes & Barth, 2020; United Nations, 2015).

2.3 Conceptual Framework

Based on these claims, this paper presents a conceptual framework that situates exposure to sustainability initiatives on campus as an important contextual factor in students' environmental technology awareness and behavioral intentions.

Exposure is conceptualized broadly to include:

- Participation in sustainability events, clubs, campaigns, and competitions
- Use or observation of green infrastructure (e.g., recycling points, solar panels)
- Encounters with sustainability content in first-year courses and digital communications

Eco-friendly technology awareness is treated as a multidimensional construct with:

- *Cognitive awareness*: factual and conceptual knowledge about ecotechnologies and related practices
- *Affective orientation*: concern, interest, and favorable attitudes towards eco-friendly technologies
- *Normative and control beliefs*: perceived social expectations and perceived capability to act sustainably
- *Behavioral intentions*: self-reported likelihood of engaging in pro-environmental behaviors

The framework hypothesizes that greater exposure to initiatives is associated with higher knowledge, more favorable attitudes, stronger subjective norms, higher perceived behavioral control, and stronger behavioral intentions. It further posits that awareness mediates the link between exposure and intention, consistent with the Theory of Planned Behavior and Environmental Education. Programs accomplish this primarily by influencing what students are being taught about eco-technologies, which is the supplied. These pathways are anticipated to be moderated by individual differences (e.g., preexisting sustainability experience) and contextual elements (e.g., exposure to and visibility of initiatives).

3. Methodology

3.1 Participants

The quantitative analysis relied on a survey administered at one point in time to 383 first year undergraduates at Prince Sattam bin Abdulaziz University in Saudi Arabia. All learners were in the first year at the time of data collection, and they answered all questions in Arabic. The sample included 224 male (58.5%) and 159 female (41.5%) students. Most students (n = 333; 86.9%) lived off campus, while 50 (13.1%) resided in on-campus housing. Pre-exposure to sustainability was measured by questioning the students as to whether they had belonged or belong to environmental clubs, community-driven projects and school-initiated sustainable

efforts. A total of 121 students (31.6%) reported such experience, whereas 262 (68.4%) indicated they had not. Participation was voluntary and anonymous, and the sample represents a broad cross-section of PSAU first-year students rather than a specific program or major - important given evidence that sustainability awareness varies by discipline and demographic group in Saudi higher education.

3.2 Research Questions

1- What is the level of awareness of environmentally friendly technology among first-year university students?
2- Are there statistically significant differences in awareness dimensions according to gender, type of residence, or sustainability experience?
3- What is the pattern of relationships between exposure to green initiatives and the level of awareness?

3.3 Data Collection and Analysis

3.3.1 Quantitative Data

Data were analyzed using IBM SPSS Statistics 25.0 (IBM Corp., 2017). The main constructs were operationalized as follows:

- *Objective knowledge of eco-friendly technology*: 12 true/false items (plus "I don't know"), scored 1 for correct and 0 for incorrect/ "I don't know"; total scores ranged from 0 to 12.
- *Affective attitudes perceived behavioral control, subjective norms, and behavioral intentions*: multi-item scales rated on 5-point Likert scales (1 = strongly disagree; 5 = strongly agree). Negatively worded items were reverse scored so that higher scores consistently indicated more positive attitudes, stronger perceived control, stronger perceived norms, or higher intentions.
- *Exposure to green initiatives*: 12 items rated on a 0–4 scale capturing the frequency of engagement with sustainability-related activities and infrastructure (0 = never; 4 = very often). Scores were summed (0–48), with 24 as the theoretical midpoint.
- *Overall awareness score*: composite index obtained by summing the five awareness-related dimensions (objective knowledge, attitudes, perceived behavioral control, subjective norms, and behavioral intentions).

To address Research Question 1 (levels of awareness dimensions), descriptive statistics (means, standard deviations, frequencies, and percentages) were computed. For Likert-type scales, observed means were compared with theoretical midpoints to classify levels as below, average, or above average. To address Research Question 2 (group differences), independentsamples t-tests were compared (Male vs. female students; off-campus vs. on-campus residents; and students with vs. without prior sustainability experience) across each awareness dimension, the exposure scale, and the overall awareness score. Statistical significance was set at $p < .05$, with $p < .01$ reported for stronger effects. For Research Question 3 (relationships between exposure and awareness), Pearson product–moment correlation coefficients were calculated among all continuous variables. Correlations were interpreted considering the conceptual framework and hypotheses derived from the Theory of Planned Behavior.

3.4.2 Qualitative Data

To complement the quantitative data, the survey included open-ended questions aligned with the conceptual framework (experiences of and exposure to sustainability initiatives on campus, understanding of eco-friendly technologies, attitudes and values regarding green technologies, perceived social norms and role models, perceived barriers and enablers to sustainable behavior, and intended sustainability-related actions). All first-year respondents were invited to answer these questions in Arabic. Responses ranged from brief statements to multi-paragraph reflections. An inductive–deductive thematic analysis was conducted. The research team read each response to gain an overall sense of emerging themes and coded line by line with descriptive labels (e.g., seeing solar panels, no recycling bins present; was influenced by peers; confused about energy storage; intending to reduce use of plastic).

Coding was predominantly inductive, with ongoing sensitivity to TPB constructs and to the cognitive,

affective, normative, and behavioral aspects of consciousness (Ajzen, 1991; Jacobi et al., 2016; UNESCO, 1978). The research team grouped similar codes into initial themes and compared these first to the raw data to verify their validity and distinctiveness. Coding was performed in Arabic; the translated extracts below were translated into English by a bilingual researcher and subsequently revised for brevity and clarity. Any disagreements were reconciled by recording the data and, in a subsequent stage, modifying the codebook based on those recordings to enhance trustworthiness. The latter themes are detailed in the qualitative findings and discussed alongside the quantitative results.

4. Results and Findings

4.1 Quantitative Results

4.1.1 Research Question 1: What is the level of awareness of environmentally friendly technology among first-year university students?

4.1.1.1 Dimension A: Objective Knowledge of Environmentally Friendly Technology

Table 1 presents item-level performance on the objective knowledge dimension.

Table 1: Distribution of student responses on the objective knowledge dimension (N = 383)

Item	Statement	Correct n	Correct %	Incorrect/Don't know n	Incorrect/Don't know %
1	LED lamps usually consume less electricity than incandescent lamps for comparable lighting.	245	64%	138	36%
2	A "smart" power strip can reduce device consumption in standby mode.	255	66.6%	128	33.4%
3	Recycling aluminium saves little energy compared with producing it from raw ore.	95	24.8%	288	75.2%
4	Solar panels generate electricity even on cloudy days (but at a lower level).	241	62.9%	142	37.1%
5	Low-flow outlets/faucets reduce consumption without affecting the user experience.	101	26.4%	282	73.6%
6	Composting helps reduce methane emissions compared with landfilling organic waste.	170	44.4%	213	55.6%
7	Double-glazed windows lose more heat than single-glazed windows.	119	31.1%	264	68.9%
8	Public transport and car sharing reduce an individual's emissions compared with driving alone.	222	58%	161	42%
9	Electronic waste does not contain recoverable materials and must be landfilled.	206	53.8%	177	46.2%
10	Induction cooktops are usually more efficient than conventional electric resistance stoves.	193	50.4%	190	49.6%
11	Turning lights off for short periods (e.g., 10 minutes) does not meaningfully save energy.	246	64.2%	137	35.8%
12	The energy performance label summarizes a building's expected energy consumption.	193	50.4%	190	49.6%

Note. Mean percentage of incorrect/"don't know" responses = 50.2%; mean percentage of correct responses = 49.8%.

On average, students answered roughly half the items correctly. Knowledge was stronger on widely publicized topics (LED lighting, smart power strips, solar panels) and weaker on less familiar or more technical issues (aluminium recycling, lowflow outlets, thermal performance of windows), suggesting partial and uneven ecotechnology literacy.

4.1.1.2 Dimension B: Affective Attitudes

Table 2: Means and standard deviations for affective attitude items (N = 383)

Item	Statement	N	M	SD	Level
1	Environmentally friendly technologies constitute an important part of modern university life.	383	3.89	1.04	Above average
2	Investing in green technologies on campus is a worthwhile use of resources.	383	3.93	0.87	Above average
3	I feel personal concern about the environmental issues addressed by green technologies.	383	2.99	0.91	Average
4	Improving green technologies enhances the quality of life, not only the environment.	383	4.01	0.91	Above average
5	I want to learn more about how green technologies work.	383	3.93	0.89	Above average

Item	Statement	N	M	SD	Level
6†	Green technologies are often overrated and impractical.	383	3.28	1.01	Above average
7	Adopting green technologies is part of my responsibility as a university student.	383	3.47	0.92	Above average
8	I prefer environmentally friendly options even if they cost more.	383	3.74	0.92	Above average
9	I feel proud when my university invests in visible green solutions.	383	4.08	0.88	Above average
10†	Green solutions often create more problems than they solve.	383	3.27	1.09	Above average

Total score: M = 36.60, SD = 4.74 (theoretical mean = 30).
† Reverse-scored items.

Students reported generally positive attitudes toward eco-friendly technologies, with all items at or above the midpoint and the total score clearly above average.

4.1.1.3 Dimension C: Perceived Behavioral Control

Table 3: Means and standard deviations for perceived behavioral control items (N = 383)

Item	Statement	N	M	SD	Level
1	I know practical steps I can take on campus to be more environmentally friendly.	383	3.61	1.01	Above average
2	I can easily find reliable information that helps me adopt green technologies.	383	3.57	0.98	Above average
3†	It is difficult for students here to act in an environmentally friendly way.	383	3.00	1.08	Above average
4	I feel able to change some of my daily habits to reduce my environmental footprint.	383	3.64	0.98	Above average
5	I can overcome common barriers (time/cost/availability) to acting sustainably.	383	3.54	0.91	Above average
6	If I decide to, I can take part in at least one sustainability activity this semester.	383	3.72	0.86	Above average

Total score: M = 21.10, SD = 3.31 (theoretical mean = 18).
† Reverse-scored item.
Perceived behavioral control was above average, indicating that students generally felt capable of acting sustainably and overcoming common barriers.

4.1.1.4 Dimension D: Subjective Norms

Table 4: Means and standard deviations for subjective norm items (N = 383)

Item	Statement	N	M	SD	Level
1	People who are important to me (friends/classmates) think I should behave sustainably.	383	3.43	1.09	Above average
2	I often see classmates using or talking about environmentally friendly technologies.	383	3.24	1.10	Above average
3	Faculty and administrators expect students to support sustainability initiatives.	383	3.77	0.96	Above average
4	Sustainable behavior is part of the "way of doing things" at this university.	383	3.79	0.93	Above average
5	If I do not behave sustainably here, others are likely to disapprove.	383	3.51	1.06	Above average

Total score: M = 17.76, SD = 3.47 (theoretical mean = 15).
Students perceived moderate to strong social support for sustainable behavior from peers, faculty, and the institution.

4.1.1.5 Dimension E: Behavioral Intentions

Table 5: Means and standard deviations for behavioral intention items (N = 383)

Item	Statement	N	M	SD	Level
1	I intend to participate in at least one sustainability-related event within the next three months.	383	3.60	1.08	Above average
2	I intend to choose environmentally friendly options when available (refillable bottles, public transport, etc.).	383	3.88	0.94	Above average
3	I intend to reduce my energy consumption in my accommodation or study spaces on campus.	383	3.84	1.05	Above average
4	I plan to learn more about a green technology related to my major or courses.	383	3.87	0.93	Above average
5	I intend to encourage my friends/classmates to adopt environmentally friendly practices.	383	4.05	0.90	Above average
6	I plan to join a club, project, or volunteer activity related to sustainability this year.	383	3.69	1.03	Above average

Total score: M = 22.98, SD = 4.10 (theoretical mean = 18).

Behavioral intentions were high across all items, suggesting that many first-year students are willing to engage in sustainable actions when opportunities arise.

4.1.1.6 Dimension F: Exposure to Green Initiatives

Table 6: Means and standard deviations for exposure to sustainability initiatives (N = 383)

Item	Activity	N	M	SD	Level
1	Attending a lecture, workshop, or seminar on sustainability.	383	1.43	1.41	Below average
2	Participating in an environmental club, campaign, or volunteering activity (planting, cleanup, etc.).	383	1.36	1.27	Below average
3	Taking part in a competition or hackathon related to sustainability or green innovation.	383	0.91	1.15	Below average
4	Noticing and reading sustainability posters or messages on campus.	383	2.00	1.46	Below average
5	Using recycling points/containers on campus correctly.	383	1.88	1.51	Below average
6	Using sustainability-supporting infrastructure (water refill stations, bicycle racks, etc.).	383	1.74	1.48	Below average
7	Seeing visible green infrastructure (solar panels, native planting) and knowing its purpose.	383	1.96	1.46	Below average
8	Being exposed to sustainability content within a first-year course.	383	1.41	1.32	Below average
9	Engaging with sustainability via university platforms or social media.	383	1.81	1.34	Below average
10	Discussing sustainability with classmates or faculty outside of lectures.	383	1.57	1.38	Below average
11	Performing a personal behavior because of a sustainability message you saw on campus.	383	1.55	1.40	Below average
12	Visiting a booth or exhibition presenting an environmentally friendly technology.	383	1.35	1.42	Below average

Total score: M = 19.02, SD = 10.72 (theoretical mean = 24).

Compared with their attitudes and intentions, students' exposure to sustainability initiatives was comparatively low, indicating limited and uneven engagement among first year undergraduates.

4.1.2 Research Question 2: Are there statistically significant differences in awareness dimensions according to gender, type of residence, or sustainability experience?

4.1.2.1 Differences by Gender

Table 7: Differences in awareness dimensions by gender (independent samples t-test)

Dimension	Males M	Males SD	Females M	Females SD	t	df	p	Higher group
Objective knowledge	6.02	2.74	5.85	2.50	0.632	381	ns	–
Affective attitudes	36.87	5.47	36.22	4.70	1.22	381	ns	–
Perceived behavioral control	21.48	3.28	20.55	3.27	2.71	381	0.01	Males
Subjective norms	18.12	3.74	17.28	2.98	2.35	381	0.05	Males
Behavioral intentions	23.17	4.27	22.69	3.83	1.10	381	ns	–
Exposure to initiatives	20.40	11.36	17.59	9.60	2.21	381	0.05	Males
Overall awareness score	125.72	21.32	120.20	17.52	2.68	381	0.01	Males

ns = not significant.

No significant gender differences appeared for objective knowledge, affective attitudes, or behavioral intentions. Male students reported much higher perceived behavioral control and subjective norms, had been exposed to sustainability initiatives more often, and were more aware of eco-economics in general than their female colleagues.

4.1.2.2 Differences by Residence

Table 8. Differences in awareness dimensions by residence type (independent samples t-test)

Dimension	Off-campus M	Off-campus SD	On-campus M	On-campus SD	t	df	p	Higher group
Objective knowledge	5.92	2.63	6.18	2.70	0.66	381	ns	–
Affective attitudes	36.80	5.10	35.28	5.48	1.94	381	ns	–

Dimension	Off-campus M	Off-campus SD	On-campus M	On-campus SD	t	df	p	Higher group
Perceived behavioral control	21.27	3.27	19.96	3.35	2.63	381	0.01	Off-campus
Subjective norms	17.83	3.55	17.40	2.90	0.82	381	ns	–
Behavioral intentions	23.10	4.03	22.12	4.48	1.58	381	ns	–
Exposure to initiatives	18.86	10.82	20.08	10.07	0.75	381	ns	–
Overall awareness score	123.78	20.33	121.02	17.61	0.913	381	ns	–

Residence was largely unrelated to awareness; only perceived behavioral control was significantly higher among off-campus students.

4.1.2.3 Differences by Sustainability Experience

Table 9: Differences in awareness dimensions by sustainability experience (independent samples t-test)

Dimension	No experience M	No experience SD	Sustainability experience M	Sustainability experience SD	t	df	p	Higher group
Objective knowledge	5.86	2.60	6.12	2.73	0.88	381	ns	–
Affective attitudes	36.14	4.95	37.58	5.53	2.53	381	0.05	Experience
Perceived behavioral control	20.83	3.36	21.69	3.13	2.36	381	0.05	Experience
Subjective norms	17.40	3.33	18.59	3.65	3.13	381	0.01	Experience
Behavioral intentions	22.70	4.01	23.58	4.26	1.95	381	ns	–
Exposure to initiatives	18.32	10.10	20.65	11.85	1.97	381	0.05	Experience
Overall awareness score	121.27	18.19	128.22	22.87	3.19	381	0.01	Experience

Students with prior sustainability experience scored significantly higher on affective attitudes, perceived behavioral control, subjective norms, exposure to initiatives, and overall awareness. However, objective knowledge and behavioral intentions did not differ significantly.

4.1.3 Research Question 3: What is the pattern of relationships between exposure to green initiatives and the level of awareness?

Table 10: Correlations among awareness dimensions and exposure to initiatives (N = 383)

Variable	1	2	3	4	5	6	7
1. Objective knowledge	1.00	0.39**	0.29**	0.25**	0.32**	0.19**	0.488**
2. Affective attitudes	–	1.00	0.53**	0.39**	0.59**	0.14**	0.66**
3. Perceived behavioral control	–	–	1.00	0.56**	0.63**	0.23**	0.69**
4. Subjective norms	–	–	–	1.00	0.58**	0.25**	0.65
5. Behavioral intentions	–	–	–	–	1.00	0.22**	0.72**
6. Exposure to initiatives	–	–	–	–	–	1.00	0.73**
7. Overall awareness score	–	–	–	–	–	–	1.00

$p < 0.01$.

Exposure to initiatives was positively and significantly correlated with all awareness dimensions, particularly with the overall awareness score. Students who reported greater exposure also tended to have higher knowledge, more positive attitudes, stronger perceived control and norms, and stronger intentions.

4.2 Qualitative Results: Students' Narratives of Exposure, Awareness, and Action

The thematic analysis yielded six themes that illuminate and contextualize the quantitative results.

4.2.1. Uneven Exposure to Sustainability Initiatives

Students reported significant variations in their exposure to campus sustainability. Some reported almost no visible initiatives:

> *"I haven't joined any activities, and none of my friends have either, because the administration hasn't encouraged or directed students toward such activities."*

Others recounted multiple activities and facilities, including treeplanting campaigns, cleanup events, recycling bins, solar panels, and awareness messages on screens and social media:

> *"The most important sustainability-related things I've noticed are waste-sorting bins, awareness campaigns about saving water and electricity, solar panels on some buildings, and a student club that focuses on the environment."*

These divergent accounts clarify why exposure scores fall below the average, showing that opportunities exist but are not consistently experienced by first year students.

4.2.2. Partial but Technology-Focused EcoTech Understanding

Solar power was the most ubiquitous for students' examples of green technology they felt they could understand:

> *"A green technology I am familiar with is solar. I heard about it in classes and projects that show how the light of the sun is turned into electricity."*

However, many acknowledged gaps, especially around energy storage and system design:

> *"I know solar panels convert sunlight into electricity, but I still don't know how the extra energy is stored and used later."*

Some students admitted to a minimal understanding of eco-technologies. This aligns with the objective knowledge results, which show stronger performance on highly visible technologies (solar panels, LEDs) than on everyday practices (recycling metals, lowflow fixtures, building energy performance).

4.2.3. Positive Values but Mixed Evaluations of University Practice

Most students had a positive view regarding the investment of PSAU in green energies and related it to ecological protection and the rise of consciousness:

> *"I rate the investment in green technologies by the university as very good because it does things like recycling, using solar energy to light buildings, and saving water."*

Others, however, perceived efforts as limited or still emerging:

> *"The university is trying, but it is still at the beginning of the road to sustainability."*

These mixed views mirror the quantitative pattern of strong affective attitudes but belowaverage exposure: students value sustainability and approve of investment where they see it, yet many experience implementation as partial or insufficient.

4.2.4. Peers and Faculty as Key Social Referents

Participants reported friends and faculty as the primary drivers of their environmentally sustainable behaviors, highlighting subjective norms and social learning.

> *"My classmates are the most influential, especially when they separate waste or use reusable bottles. Seeing them do that pushes me to copy them."*

> *"Members of the teaching staff are the most influential, because they set a practical example by saving resources and encouraging us to join environmental activities."*

Several respondents saw administrators, faculty, and peers as playing complementary roles (policies and

infrastructure from the administration, modeling and encouragement from faculty, and day-to-day norms from classmates), echoing wholeinstitution models of sustainability.

4.2.5. Structural and Social Barriers to Sustainable Action

Despite strong intentions, students acknowledged tangible obstacles that limit their capacity to engage in sustainable practices.

The most common were infrastructural gaps (especially insufficient or inconvenient recycling bins and waterrefill points) and limited awareness:

> *"The biggest obstacle I face is the lack of waste-sorting bins everywhere on campus, which makes it hard to commit to recycling."*

> *"The main obstacle is a lack of awareness about the importance of conserving resources and how to do it."*

Time pressure, perceived indifference from others, and lack of incentives were also mentioned. These barriers help account for the gap between students' relatively high perceived behavioral control in theory and their lower levels of actual exposure to sustainability initiatives in practice.

4.2.6. Everyday Intentions and Small Steps

When asked about what they would do, most students suggested small-scale and realistic actions, such as using less plastic, saving on resources, or participating in a sustainability initiative:

"This coming semester, I am going to use a reusable water bottle and not buy plastic bottles."

> *"I guess I would try to be more cautious when it comes to turning off the lights and air-conditioning, on days that I leave my classroom or room."*

Several students stated an intention to start or join sustainability activist campaigns; others (fewer in number) had no action plans - explanations fell along lines of starting things being unfamiliar territory, or nothing is happening on this front within the institution. These stories are consistent with high behavioral intention scores and demonstrate that a significant number of first-year students were ready to act once provided with appropriate campus climates.

4.3 Integrating Qualitative and Quantitative Findings

The qualitative evidence reinforces the survey results:

- *Awareness and attitudes*: Students demonstrate strong pro-environmental values and interest in eco-technologies, yet their knowledge remains moderate and uneven, particularly regarding less visible or less publicized technologies.
- *Exposure*: Stories of high and low exposure account for the sub-optimal mean exposure score despite a very strong willingness to act.
- *Norms and social learning*: Peers and faculty constitute the primary referent group, thereby reflecting the influence of subjective norms and the tenets of social learning theory.
- *Barriers*: Infrastructure and knowledge barriers constrain the translation of intentions into behaviour; this explains why exposure is relatively low.

5. Discussion

The focus of this study was to investigate first-year students' knowledge and exposure to eco-friendly technology at PSAU, their awareness of each other's effects, and their effects on each other, based on TPB, environmental concern, and social learning theory literature. Three broad patterns emerge.

5.1 EcoTechnology Awareness: Strong Dispositions, Partial Knowledge

In relation to Research Question 1, first-year students reported strongly positive attitudes, norms, perceived behavioral control, and behavioral intentions, but only moderate objective knowledge. They answered about

half of the knowledge items correctly, performing better on widely publicized technologies (e.g., solar panels, LEDs, smart power strips) and worse on less familiar issues (e.g., aluminium recycling, lowflow outlets, building energy performance). Qualitative data show a similar pattern: solar energy is the default reference point, while other technologies and everyday eco-practices remain less well understood. This combination of power and positive intent also resonates with research suggesting that, when it comes to sustainability, university students care in principle, even if they do not understand it systemically (Alsaati et al., 2020; Leal et al., 2024; Vasconcelos & Sebastião, 2022). It is positive from an ESD point of view that the first-year students at PSAU are open-minded and well-motivated, yet a concern that their eco-technology literacy remains sporadic when they begin their university education. In the absence of focused educational interventions, an attitude may be insufficient to influence not only effective decisions but also to sustain long-term actions (Biasutti, 2015; Shephard, 2008).

5.2 Exposure as a Key Lever

Findings related to Research Question 3 indicate that overall exposure to sustainability initiatives is below average, yet it shows a strong and positive association with all dimensions of awareness, especially the composite awareness score. Students who report more frequent engagement with sustainability activities and infrastructure tend to have higher knowledge, more favorable attitudes, stronger perceived norms and control, and stronger intentions. Qualitative data highlight that exposure is uneven: some firstyears see almost no sustainability activities; others experience a campus that clearly functions as a "living lab". These findings align with the theoretical framework and support the Theory of Planned Behavior.

Exposure seems to function as context, through which attitudes (by highlighting benefits and values), subjective norms (with the effect of role models and expectations), and perceived behavioral control (by providing exposure to opportunity for practicing sustainable behaviors) are influenced by intentions (Ajzen, 1991; Du & Pan, 2021). They are also consistent with studies on green campuses and sustainability-related extracurricular activities, which found a positive correlation between active involvement and both literacy in sustainability issues and sustainable behavior (Amaral et al., 2020; Papavasileiou et al., 2025; Pereira Ribeiro et al., 2021). In addition, the strong correlations between exposure and overall awareness, combined with qualitative accounts of infrastructural and informational barriers, suggest that increasing and equalizing exposure, particularly during the first year, could be an efficient way to raise eco-technology awareness across the cohort.

5.3 Group Differences and the Role of Prior Experience

Regarding Research Question 2, gender differences were small but significant. Male students reported greater behavioral control, stronger subjective norms, and greater exposure to sustainability initiatives than female students, but there was no difference in general awareness. However, Knowledge, attitude, and behavioral intentions showed no significant differences between male and female students. This observation is, to some extent, consistent with previous Saudi studies that found male students outperforming in various sustainability aspects and may indicate differences in disciplinary pathways, mobility, or involvement (Ezzeldin, 2023). The absence of gender differences in knowledge and attitudes indicates that both male and female firstyears receive similar informational cues but may differ in opportunities or social support for action.

Prior sustainability experience before university was linked to higher levels of attitudes, perceived behavioral control, subjective norms, exposure to initiatives, and overall awareness. However, it was not associated with higher objective knowledge or behavioral intentions. This supports the idea from environmental education and social learning that experiential engagement fosters stronger dispositions and a sense of agency that carry over into new contexts (Jacobi et al., 2016; Qureshi, 2020). Students with such experience enter PSAU better prepared to recognize and benefit from campus sustainability opportunities, highlighting the importance of continuity between school-level sustainability education and university-level initiatives. Residence (on vs. offcampus) showed minimal effects; only perceived behavioral control differed significantly, favoring off-campus students. This suggests that, in this setting, residential context is less important than prior experience and patterns of engagement in shaping awareness.

5.4 Theoretical Implications

The findings provide empirical evidence to support a TPB-guided, campus-wide conceptualization of

sustainability education. First, results confirmed that exposure to the messages was strongly associated with Theory of Planned Behavior constructs and general awareness, suggesting that campus interventions can affect not only students' knowledge but also their perceptions of norms and capacity (Ajzen, 1991; Du & Pan, 2021). Second, they exemplify how the triad of cognitive, affective, and behavioral focus in environmental education pans out in practice, where students have strong affective and even intentional components, whereas their cognition needs further development as well as being provided with more structured opportunities for behaviors (Agbedahin, 2019; UNESCO, 1978). Third, the qualitative results indicate that the Social Learning Theory constructs of modeling and social reinforcement are relevant, with peers and faculty as important referents (Bandura, 1986; Jacobi et al., 2016). The findings therefore support calls for wholeinstitution, transformative approaches to sustainability in higher education, in which governance, operations, curricula, and student life are aligned and mutually reinforcing (Christou et al., 2024; McMillin & Dyball, 2009; O'Grady, 2025; Rodríguez Aboytes & Barth, 2020).

5.5 Practical Implications for First-Year Sustainability Education

For PSAU and similar institutions, several practical implications arise:

1. *Guaranteeing structured first-year exposure:* Embedding sustainability into orientation programs, general education courses, and first-year seminars can ensure that all new students (not only the self-selected) encounter eco-friendly technologies and sustainability initiatives early (Hay & Eagle, 2020; Gorman, 2025; Vasconcelos et al., 2022).
2. *Making the campus a visible "living lab":* Expanding and clearly signposting green infrastructure - such as recycling stations, waterrefill points, and solar installations - and linking them to measurable environmental indicators (e.g., energy or water savings) can reinforce informal learning and signal institutional commitment (Amaral et al., 2020; Pereira Ribeiro et al., 2021).
3. *Activating cocurricular opportunities:* Clubs, campaigns, and competitions indicate that the potential in this population is not being harnessed. First-year-friendly environmental clubs, volunteering opportunities, and SDG-themed hackathons can offer high-impact experiential learning experiences that develop skill sets (Qureshi, 2020; Papavasileiou et al., 2025; Surendran et al., 2023).
4. *Removing structural barriers and providing incentives:* Structural barriers must be dismantled, and incentives must be created by making environmental facilities more accessible, visible, and usable (e.g., recycling bins, refill stations), as well as through targeted communication and small incentives (e.g., competitions, recognition). Thus, students can be supported in translating intentions into action.
5. *Addressing equity in exposure:* The advantages students with prior sustainability experience enjoy, along with gender differences in perceived control and norms, point to possible inequities in access to sustainability learning. Monitoring participation across groups and implementing targeted outreach, particularly for females, students outside STEM disciplines, and those with limited prior exposure, would foster more inclusive outcomes (Leal et al., 2024).

5.6 Limitations and Future Research

The study has several limitations. A cross-sectional design and self-reported knowledge prevent the researchers from drawing causal inferences; longitudinal or quasi-experimental studies would be needed to evaluate how exposure and understanding increase over time, as well as the effects of interventions on knowledge and behavior. As the data were obtained from a single Saudi university, the generalizability of the findings is limited. There is a need to compare such work across organizations and regions to distinguish between context-specific patterns and those that may apply more generally. Moreover, behavioral intentions are informative but not identical with behavior itself. These could be combined in future research with behavioral measures, for instance, participation records or more direct observations of recycling activities, together with more detailed assessments of SDG-related learning (Leal et al., 2024; Vasconcelos et al., 2022). Lastly, the fact that this scale of objective knowledge focuses on a few eco-technologies only ultimately diminishes the sustainability literacy per se; indeed, framing broader socio-political and economic dimensions as part of it would give a more comprehensive vision of what sustainability is (Christou et al., 2024; McMillin & Dyball, 2009).

6. Conclusion

This study offers an integrated quantitative and qualitative examination of first-year students' awareness of eco-friendly technologies at PSAU and how this awareness relates to their exposure to campus sustainability initiatives. First-year students express favourable attitudes, supportive norms, perceived behavioural control, and strong intentions to engage in sustainable behaviour. Students are only moderately knowledgeable about sustainability and encounter sustainability topics less often than the average individual. However, those who have had more contact with or experience of sustainability exhibit above-average awareness across many levels. These findings underscore the importance of structured, equitable exposure to sustainability initiatives during the first year of university, as part of a broader whole institution approach to Education for Sustainable Development. By intentionally designing first-year curricula, co-curricular opportunities, and campus operations to function as a "living lab" for sustainability, universities in Saudi Arabia and beyond can help close the gap between sustainability rhetoric and practice, supporting the ambitions of Vision 2030 and the global 2030 Agenda for Sustainable Development.

Conflict of Interest

There is no conflict of interest.

Funding

"The authors extend their appreciation to Prince Sattam bin Abdulaziz University for funding this research work through the project number (PSAU/2025/01/34327)"

Institutional Review Board Statement

Ethical review and approval were waived for this study due to voluntary participation of the sample where all members had more than 18 years old. The data were collected anonymously and confidentially.

Informed Consent Statement

Participants were informed about the aims of the study and agreed to allow the research team to use the data to write this paper.

Data Availability Statement

Data is contained within the article.

Acknowledgments

The authors extend their appreciation to Prince Sattam bin Abdulaziz University for funding this research work through the project number (PSAU/2025/01/34327).

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Authorship contribution

All authors contributed to the literature research, data collection, analysis, and interpretation of the collected data.

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Abbreviations

The following abbreviations are used in this manuscript:

PSAU Prince Sattam bin Abdulaziz University
SDG Sustainable Development Goals
TPB Theory of Planned Behavior
EE Environmental Education
ESD Education for Sustainable Development.

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