

Sustainability Literacy, Readiness, and Engagement among Undergraduate Students: Evidence from a Philippine Higher Education Institution

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ABSTRACT

Sustainability education in higher education requires the development of not only sustainability knowledge but also competencies that enable students to understand complex systems, make value-informed judgments, collaborate effectively, and translate knowledge into action. This study examined sustainability literacy, readiness for sustainable development, and sustainability engagement among 321 undergraduate students at a Philippine higher education institution. Using a cross-sectional survey design, data were collected through an institutionally developed and pilot-tested instrument measuring environmental, social, and economic sustainability literacy; five readiness competencies; and sustainability attitudes and self-reported practices. Data were analyzed using descriptive statistics, analysis of variance, Pearson correlation, multiple regression, and exploratory moderation analysis. Overall sustainability literacy was moderate, with economic literacy emerging as the strongest domain and environmental literacy as the comparatively lowest. Students generally reported favorable readiness for sustainable development, although strategic competence was the lowest-rated competency, and sustainability attitudes were more favorable than self-reported practices. Overall sustainability literacy was not significantly associated with overall readiness. In the multivariable model, systems thinking, normative competence, interpersonal competence, and action preparedness showed significant positive associations with sustainability engagement, whereas the measured literacy domains did not contribute significant unique associations after adjustment for other variables. Group differences were observed for selected outcomes, particularly across academic colleges and levels of prior sustainability exposure. The findings demonstrate that sustainability literacy, readiness competencies, and engagement are related but empirically distinguishable educational outcomes. They suggest that literacy alone is insufficient as an indicator of students' broader sustainability preparedness and engagement. Higher education institutions should therefore adopt multidimensional assessment approaches and complement knowledge development with interdisciplinary, experiential, competency-based, and action-oriented learning opportunities.

Keywords: sustainability literacy; sustainability readiness; sustainability engagement; Education for Sustainable Development; higher education

INTRODUCTION

Sustainability has become a defining educational challenge as climate change, biodiversity loss, resource depletion, social inequality, and unsustainable production and consumption threaten progress toward the Sustainable Development Goals (SDGs). Higher education institutions are consequently expected not only to communicate sustainability principles but also to demonstrate that students acquire the knowledge, competencies, values, and behavioral readiness needed to participate in sustainable development. Education for Sustainable Development (ESD) has therefore shifted from activity-based advocacy toward measurable learning outcomes and competency development (UNESCO, 2017, 2020; Leicht et al., 2018).

This shift is especially relevant to universities participating in international sustainability benchmarking. The Times Higher Education Impact Rankings explicitly asks institutions, under SDG 17, whether they measure students' sustainability literacy. The requirement places student learning evidence alongside institutional policies, partnerships, and sustainability initiatives and reinforces the need for credible, repeatable, institution-wide assessment (Times Higher Education, 2024).

Contemporary sustainability literacy is multidimensional. It includes understanding environmental, social, and economic sustainability, but effective sustainability education also requires competencies that enable learners to interpret complex systems, evaluate values and trade-offs, collaborate with others, formulate strategies, and act. Brundiers et al. (2021) identify systems thinking, normative, strategic, and interpersonal competencies among the core capacities needed for sustainability. Research likewise shows that knowledge and favorable attitudes do not automatically become sustainable behavior because contextual, motivational, and institutional barriers can interrupt the transition from knowing to doing (Nielsen et al., 2021; Erguvan, 2024a). This competency-oriented interpretation is well established in sustainability education research, which emphasizes systems, anticipatory, normative, strategic, and interpersonal capacities as educational outcomes (Wiek et al., 2011; Cebrián & Junyent, 2015; Lozano et al., 2017).

Within Philippine higher education, institution-wide evidence on student sustainability learning outcomes remains comparatively limited. Although universities increasingly implement SDG-related courses, extension activities, greening initiatives, and community programs, the existence of such activities does not itself demonstrate student learning. This study addresses that institutional evidence gap by assessing sustainability literacy, readiness competencies, and engagement simultaneously and by examining how these outcomes vary across student characteristics and prior exposure. The institutional setting provides a bounded case through which the alignment between sustainability knowledge, competency development, and engagement can be examined while generating evidence for curriculum improvement and sustainability reporting (Sánchez-Carracedo et al., 2022; Sharma & Kelly, 2014; Figueiró & Raufflet, 2015).

The study's contribution lies in testing whether sustainability literacy can adequately represent the broader student outcomes that higher education institutions seek to develop through ESD. It analytically separates three dimensions that are often combined or treated as proxies for one another in institutional sustainability assessment: what students know (literacy), what they report being prepared to do (readiness competencies), and how sustainability is expressed in attitudes and self-reported practices (engagement) (Brundiers et al., 2021; Chen et al., 2022; Gericke et al., 2019). By examining these dimensions simultaneously, the study evaluates the frequently assumed progression from sustainability knowledge to competent action and engagement (Redman & Wiek, 2021; Wiek et al., 2011). The broader analytical value of this distinction is that an institution may obtain a favorable estimate on one dimension while overlooking weaknesses or strengths on another; consequently, literacy scores alone may provide an incomplete account of sustainability learning outcomes.

Against this background, the study sought to determine the sustainability literacy, readiness for sustainable development, and sustainability engagement of undergraduate students of Notre Dame of Dadiangas University and to examine how sustainability exposure and student characteristics relate to these outcomes. The inquiry was designed both as an institution-level diagnostic and as an empirical test of whether knowledge, readiness, and engagement behave as distinguishable dimensions of sustainability learning. The study considered academic program, year level, sex, and prior sustainability exposure as contextual characteristics; sustainability literacy across environmental, social, and economic domains; readiness through systems thinking, strategic competence, normative competence, interpersonal competence, and action preparedness; and engagement through sustainability attitudes and self-reported sustainable practices.

Accordingly, the study addressed five questions: (1) What are the respondents' levels of sustainability literacy, readiness for sustainable development, and sustainability engagement? (2) Do these outcomes differ according to college, year level, sex, and prior sustainability exposure? (3) How is sustainability literacy related to readiness? (4) Which profile, literacy, and readiness variables are independently associated with sustainability engagement in the multivariable model? and (5) Do student profile characteristics moderate the associations of

literacy and readiness with engagement? The analyses were intended to identify empirically supported priorities for institutional sustainability education rather than to establish causal pathways.

LITERATURE REVIEW

Education for Sustainable Development (ESD) has progressed from an emphasis on environmental awareness and isolated activities toward an educational agenda centered on measurable learning outcomes, competencies, and the capacity to act. This transition is important because the presence of sustainability programs cannot by itself establish that students have developed sustainability-related knowledge, values, or behaviors. Contemporary ESD therefore emphasizes critical thinking, ethical judgment, participation, and the ability to respond meaningfully to complex sustainability challenges (Leicht et al., 2018; UNESCO, 2017, 2020).

A central strand of the literature concerns sustainability competencies. Sustainability problems are complex, interconnected, and resistant to single-discipline solutions; consequently, students require capacities that extend beyond factual recall. Brundiers et al. (2021) identify systems thinking, anticipatory, normative, strategic, and interpersonal competencies as key capacities for sustainability. Redman and Wiek (2021) similarly emphasize competencies that support transformation toward sustainability. These perspectives provide the theoretical basis for treating readiness in the present study as a distinct construct that reflects students' capacity to use sustainability knowledge in analysis, ethical judgment, collaboration, strategy formation, and action.

Sustainability literacy itself is multidimensional. In this study, sustainability literacy is conceptualized across environmental, social, and economic domains, reflecting the three-pillar view of sustainable development. Environmental literacy concerns ecological systems, environmental protection, climate-related issues, and resource stewardship; social literacy concerns equity, participation, well-being, and responsibility; and economic literacy concerns sustainable production, consumption, and development. Purvis et al. (2019) trace the conceptual development of these three pillars, while Chen et al. (2022) demonstrate empirically that sustainability literacy is better understood through multiple dimensions of knowingness, attitudes, and behavior rather than as a single undifferentiated score.

Empirical studies further show that sustainability knowledge is not necessarily uniform across domains. Kuehl et al. (2023) found substantial variation in what university students know about sustainability, reinforcing the value of domain-specific assessment. Erguvan (2024a) likewise argues for assessing cognitive and behavioral dimensions of sustainability literacy. Such findings justify the present study's separate measurement of environmental, social, and economic knowledge and its distinction between literacy, readiness, and engagement.

Another recurring issue is the gap between knowledge, attitudes, and behavior. Students may endorse sustainability principles while not consistently engaging in sustainable practices. Prior research indicates that convenience, cost, social norms, institutional conditions, and other contextual barriers can prevent attitudes from becoming behavior (Nielsen et al., 2021; Otto & Pensini, 2017). Wamsler (2020) consequently argues for sustainability education that supports broader personal and societal transformation rather than information acquisition alone. This literature supports the present study's decision to measure engagement through both sustainability attitudes and self-reported practices.

Curriculum integration and pedagogical quality also shape sustainability outcomes. Sustainability learning is generally stronger when it is embedded within formal curricula and reinforced over time rather than delivered through one-time lectures or optional activities. Hansen et al. (2021) illustrate both innovations and challenges in integrating and reporting the SDGs in higher education. Lozano et al. (2019) connect sustainability competencies with pedagogical approaches, while Wang et al. (2022) show that the way sustainability is taught influences students' competencies, sustainability mindset, and action. Accordingly, the present study treats sustainability exposure as more than simple contact with sustainability topics; it includes curricular, co-curricular, institutional, and community-based experiences.

Repeated exposure is particularly relevant because learning is strengthened through continued engagement and contextual practice. In the present study, sustainability exposure encompasses courses discussing the SDGs,

seminars and workshops, outreach programs, campus initiatives, environmental activities, media exposure, and personal sustainability practices. Leal Filho et al. (2024) emphasize student participation in implementing the SDGs in higher education, while Zenasni et al. (2024) highlight the importance of how ESD is conceptualized and experienced in educational settings. Together, these studies support examining whether prior exposure differentiates students' literacy, readiness, and engagement.

The literature also suggests that sustainability outcomes may vary across academic and demographic groups. Students in different academic programs may encounter different levels of curricular integration, pedagogical approaches, and opportunities to develop sustainability-related knowledge and competencies (Wang et al., 2022; Valdes-Ramirez et al., 2024). Wang et al. (2022), for example, found that the development of students' sustainability competencies was associated with how sustainability courses were delivered, highlighting the importance of pedagogical context in higher education. Recent large-scale evidence from STEM higher education likewise indicates variation in the development and assessment of sustainability competencies across academic programs and semesters, although differences according to gender, age, and nationality were not significant in that particular setting (Valdes-Ramirez et al., 2024). Other recent studies, however, have identified demographic differences. Erguvan (2024a) found gender-related differences in aspects of undergraduate students' sustainability literacy, while Yücel (2025) reported significant differences in sustainability literacy according to sex, college, and year level. These findings demonstrate that relationships between academic and demographic characteristics and sustainability outcomes are context-dependent rather than uniform across higher education settings. Accordingly, the present study includes academic program, year level, sex, and prior exposure as contextual profile variables rather than assuming that sustainability learning develops uniformly among students.

Measurement quality is essential when sustainability outcomes are used for curriculum improvement, quality assurance, or institutional reporting. Boateng et al. (2018) emphasize rigorous procedures for developing and validating measurement instruments, while Hair et al. (2022) discuss reliability and construct assessment in multivariate research. Recent research has likewise emphasized the systematic assessment of sustainability competencies among university students (Valderrama-Hernández et al., 2026). This concern is especially important for institutional sustainability reporting, where claims about student learning should be supported by defensible evidence rather than by descriptions of activities alone.

Finally, sustainability assessment increasingly intersects with institutional accountability. The present study positions baseline measurement as a mechanism for identifying weaker domains, comparing student groups, targeting interventions, and monitoring improvement. Higher education institutions are increasingly expected to connect sustainability commitments with demonstrable educational outcomes, making systematic assessment of literacy, readiness, and engagement relevant not only to research but also to curriculum development and institutional sustainability strategy (Hansen et al., 2021; O'Byrne et al., 2021; Žalėnienė & Pereira, 2021). Taken together, the literature supports an integrated model in which sustainability knowledge provides a cognitive foundation, readiness represents the competencies needed to mobilize that knowledge, and engagement reflects its affective and behavioral expression.

Conceptual Framework

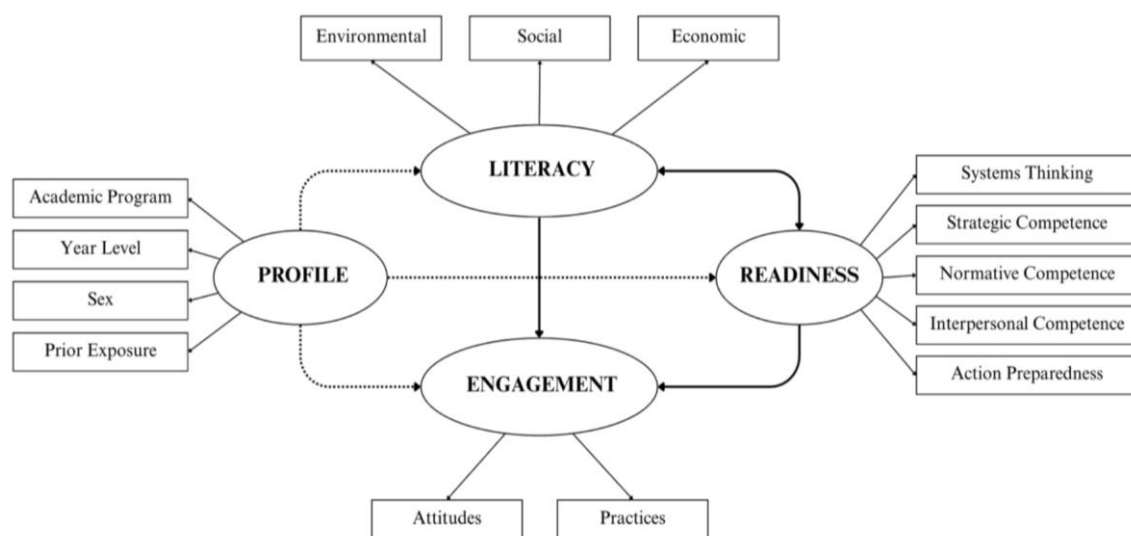
The study was grounded in ESD and competency-based sustainability education. The framework proposed that student profile characteristics—academic program, year level, sex, and prior sustainability exposure—may be associated with sustainability literacy, readiness, and engagement. Sustainability literacy covered environmental, social, and economic knowledge. Readiness was operationalized through systems thinking, strategic competence, normative competence, interpersonal competence, and action preparedness. Engagement comprised sustainability attitudes and self-reported sustainable practices.

The structural model in Figure 1 organizes the study around four major constructs: student profile, sustainability literacy, readiness for sustainable development, and sustainability engagement. Rather than treating these variables as parallel outcomes, the framework assigns them different conceptual roles. Profile variables represent the contextual conditions under which sustainability learning occurs; literacy represents what students know;

readiness represents what students are prepared and competent to do with that knowledge; and engagement represents the attitudinal and behavioral expression of sustainability learning. This layered structure follows the competency-based orientation of ESD, which links knowledge, values, skills, collaboration, and action (Brundiers et al., 2021; Redman & Wiek, 2021).

The framework proposes that sustainability literacy may be associated with readiness and engagement, while readiness represents the competencies through which sustainability understanding may be mobilized in practice. This distinction is important because sustainability challenges are complex and interconnected: factual knowledge is necessary, but competencies, values, collaboration, and perceived capacity for action may shape whether learners use that knowledge meaningfully (Brundiers et al., 2021; Redman & Wiek, 2021). Related empirical and conceptual work likewise supports distinguishing sustainability knowledge from broader consciousness, competencies, attitudes, and behavior (Gericke et al., 2019; Kuehl et al., 2023; Wang et al., 2022).

Figure 1. Structural Model of the Conceptual Framework



The profile construct comprises academic program, year level, sex, and prior exposure. These variables are not interpreted as sustainability competencies in themselves. Instead, they represent contextual characteristics that may shape access to sustainability content and experiences. Academic programs may differ in the extent to which environmental, social, and economic sustainability is embedded in disciplinary courses. Year level may represent cumulative opportunity for exposure, while prior exposure directly captures students' encounters with sustainability-related courses, seminars, outreach, campus initiatives, media, and personal practices. Sex is included as a demographic characteristic that may be associated with differences in sustainability attitudes or readiness, without presuming a predetermined direction of effect.

Sustainability literacy is modeled as the cognitive foundation of the framework and is represented by environmental, social, and economic literacy. The three dimensions are treated as related but distinguishable because sustainability requires simultaneous consideration of ecological integrity, social equity, and economic viability (Purvis et al., 2019). This structure permits the study to identify domain-specific strengths and weaknesses that would be obscured by an overall score alone. It also reflects evidence that students may demonstrate uneven sustainability knowledge across domains (Chen et al., 2022; Kuehl et al., 2023).

Readiness occupies a pivotal position in the model because it represents the transition from knowing to being capable of acting. It is operationalized through systems thinking, strategic competence, normative competence, interpersonal competence, and action preparedness. Systems thinking concerns the ability to recognize interconnections and consequences across environmental, social, and economic systems. Strategic competence concerns the capacity to formulate and evaluate pathways toward sustainability. Normative competence concerns values, ethical judgments, fairness, and responsibility. Interpersonal competence concerns communication and collaboration, while action preparedness reflects confidence and willingness to apply sustainability principles in

real situations. Together, these dimensions operationalize the proposition that sustainability education should develop capacities for action, not merely conceptual familiarity (Brundiers et al., 2021; Wamsler, 2020).

Engagement is positioned as the principal outcome and is expressed through attitudes and practices. Attitudes capture students' beliefs, values, responsibility, and willingness to support sustainability, whereas practices represent the behavioral enactment of these orientations in daily and institutional life. Separating the two dimensions is theoretically important because favorable attitudes may coexist with inconsistent practices. The framework therefore does not assume a simple linear knowledge-to-behavior pathway; instead, it allows readiness competencies and contextual conditions to help explain why knowledge may or may not become engagement (Nielsen et al., 2021; Otto & Pensini, 2017).

The arrows in Figure 1 represent hypothesized associations rather than demonstrated causal paths. Profile characteristics are linked to literacy, readiness, and engagement because students may encounter different sustainability learning opportunities. Literacy is linked to readiness and engagement because knowledge may provide a conceptual basis for competency development, attitudes, and practices, while readiness is linked to engagement because systems thinking, normative judgment, collaboration, strategy, and preparedness may accompany greater engagement. Accordingly, the arrows represent hypothesized associations examined through correlational and multivariable analyses rather than temporal or causal pathways.

Readiness is therefore conceptualized as a theoretically plausible intermediary construct between literacy and engagement rather than as an assumed statistical mediator. The study examines the relationships among these constructs empirically, while moderation analysis assesses whether the literacy–engagement and readiness–engagement associations vary across student profile characteristics.

Overall, the framework advances an integrated view of sustainability learning. It avoids equating sustainability education with knowledge acquisition and instead treats literacy, competency development, and engagement as connected but empirically distinguishable outcomes. This structure is particularly useful for institutional improvement because different findings imply different interventions: weak literacy points toward curricular content needs; weak readiness points toward competency-building pedagogies; and weak engagement points toward the need for authentic opportunities, enabling environments, and sustained participation. In this sense, the framework serves both an explanatory purpose for the study and a practical diagnostic function for institutional ESD planning.

METHODS

Research Design and Participants

A quantitative cross-sectional survey design was used to describe sustainability literacy, readiness competencies, and engagement and to examine group differences and statistical associations among these constructs. The target population comprised undergraduate students enrolled at NDDU during the summer term of academic year 2025–2026. Stratified random sampling, using college and year level as principal strata, yielded 321 respondents. Representation was nevertheless uneven: Health Sciences and Business students constituted most of the sample, whereas Education and Arts and Sciences contributed six respondents each; similarly, only 25 respondents were in the third or fourth year. The unequal subgroup sizes reduced the precision of subgroup estimates, particularly for Education, Arts and Sciences, and upper-year students. The design supports estimation of contemporaneous associations but not temporal or causal conclusions.

Table 1. Profile of the Respondents

Characteristic	Category	n	%
College	Health Sciences	141	43.9
	Business	98	30.5
	Engineering, Architecture and Technology	70	21.8

	Education	6	1.9
	Arts and Sciences	6	1.9
Year level	1st Year	164	51.1
	2nd Year	132	41.1
	3rd Year	20	6.2
	4th Year	5	1.6
Sex	Female	190	59.2
	Male	126	39.3
	Prefer not to say	5	1.6

Instrument and Data Collection

The structured questionnaire comprised four components. The first recorded academic program, year level, sex, and prior sustainability exposure. The second assessed sustainability literacy using 15 multiple-choice items, with five items each for environmental, social, and economic sustainability. The third assessed readiness through five-point Likert-type items representing systems thinking, strategic competence, normative competence, interpersonal competence, and action preparedness. The fourth assessed sustainability engagement through sustainability attitudes and self-reported practices. Scores were summarized within their respective domains and interpreted using the study's predefined scoring categories. Because the readiness and engagement measures were self-reported, their scores represent respondents' perceived competencies, attitudes, and practices rather than direct performance or behavioral observations.

The profile variables were included because disciplinary context, year level, and prior exposure may correspond to different opportunities to encounter sustainability concepts and practices. Higher-education research has documented variation in sustainability learning across disciplinary settings and emphasizes explicit curricular integration rather than assuming that competencies develop uniformly across student groups (Alm et al., 2022; Sánchez-Carracedo et al., 2022; Wang et al., 2022).

The instrument underwent expert review for content relevance, clarity, and construct alignment. In a pilot test of 78 respondents, the sustainability literacy test yielded KR-20 = .86, while Cronbach's alpha coefficients for the Likert-type measures ranged from .818 to .915, indicating satisfactory internal consistency. Fuller evidence of dimensionality and construct validity was not available and is acknowledged as a limitation of the instrument. Data were collected through classroom administration using a QR code linked to the survey. Participation was voluntary, informed consent was obtained, personally identifying information was not collected, and findings were reported in aggregate.

Data Analysis

Descriptive statistics summarized respondent characteristics and the observed levels of literacy, readiness, and engagement. Group differences were examined using Fisher's one-way ANOVA when the homogeneity-of-variance assumption was satisfied and Welch's ANOVA when it was not. Pearson's r was used to examine bivariate relationships between literacy and readiness dimensions. Multiple regression estimated the conditional associations of profile, literacy, and readiness variables with sustainability engagement, while moderated multiple regression tested whether the literacy–engagement and readiness–engagement associations varied across college, year level, sex, and prior-exposure groups. Statistical significance was evaluated at $\alpha = .05$. Because no multiplicity adjustment was applied, findings near the .05 threshold were considered in relation to the overall pattern of results. Because the analyses were based on cross-sectional observational data, regression and moderation coefficients were interpreted as conditional associations and statistical predictions rather than causal effects.

RESULTS AND DISCUSSION

Sustainability Exposure and Literacy

As shown in Table 2, students reported broad exposure to sustainability-related experiences, although the intensity of exposure varied considerably by activity. Personal initiatives such as recycling, waste reduction, and energy conservation were the most frequently reported (95.95%), followed by environmental or community outreach programs (89.41%), environmental documentaries or videos (87.85%), tree planting or clean-up drives (86.29%), and courses discussing the SDGs or sustainability (82.87%). By contrast, membership in environmental or sustainability organizations (43.93%) and participation in government- or NGO-led sustainability programs (44.55%) were least common. Table 2 therefore suggests that students' sustainability learning occurs through multiple formal, co-curricular, informal, and personal contexts, but that sustained participation in organized and externally partnered activities remains comparatively limited.

Table 2. Number of Respondents with Prior Sustainability Exposure on Identified Indicators

Indicators	f	%
Courses discussing SDGs or sustainability	266	82.87
Sustainability seminars or workshops	219	68.22
Environmental or community outreach programs	287	89.41
Campus sustainability initiatives	266	82.87
Participation in tree planting or clean-up drives	277	86.29
Exposure through social media campaigns on sustainability	257	80.06
Watching documentaries or videos about environmental issues	282	87.85
Reading articles, books, or journals on sustainability	213	66.36
Involvement in school or community sustainability projects	255	79.44
Membership in environmental or sustainability organizations	141	43.93
Discussions with teachers or peers about sustainability issues	265	82.55
Participation in sustainability-related competitions (e.g., poster making, research)	188	58.57
Exposure through government or NGO-led sustainability programs	143	44.55
Integration of sustainability topics in other subject areas	258	80.37
Personal initiatives (e.g., recycling, reducing waste, conserving energy)	308	95.95

The breadth of exposure documented in Table 2 is educationally important because sustainability learning in higher education is not confined to formal coursework. Gramatakos and Lavau (2019) found that informal and student-led experiences can contribute to cognitive, practical, and affective learning, while Wang et al. (2022) showed that pedagogical contexts are associated with the development of sustainability competencies. Leal Filho et al. (2024) likewise emphasized active student participation in implementing the SDGs in higher education. In

this context, the high levels of participation in personal initiatives, outreach, environmental activities, media exposure, and sustainability-related coursework indicate that NDDU students encounter sustainability through several potentially reinforcing learning environments.

Table 2 further suggests that prior exposure is better understood in terms of the nature and context of students' experiences rather than merely the number of activities encountered. Formal coursework may provide the conceptual foundations needed to understand sustainability, while co-curricular activities, community outreach, campus initiatives, and informal learning offer contexts in which such knowledge can be applied and connected to real-world concerns. This complementary role of formal and experiential learning is supported by Gramatakos and Lavau (2019), who found that informal learning communities can link sustainability knowledge with practical and affective development, and by Wang et al. (2022), who emphasized the role of pedagogical approaches in cultivating sustainability competencies. Accordingly, the varied forms of exposure reported in Table 2 may provide distinct but complementary learning experiences that contribute to students' sustainability readiness and engagement.

The lower participation rates in sustainability organizations and government- or NGO-led programs shown in Table 2 also identify a concrete area for institutional development. Although students were widely exposed to individually accessible and university-related activities, fewer participated in sustained organizational or external partnership settings. Such settings can provide authentic opportunities for collaboration, problem solving, shared responsibility, and action. This interpretation is consistent with Leal Filho et al. (2024), who highlighted student participation in university SDG implementation, and Gramatakos and Lavau (2019), who demonstrated the value of learning beyond the formal curriculum. NDDU may therefore strengthen the depth of sustainability exposure by connecting coursework and campus initiatives more deliberately with student organizations, community extension, government agencies, NGOs, and longer-term sustainability projects.

Table 3. Distribution of Students According to Level of Literacy

Range of Scores	f	%
0 to 7	48	14.9
8 to 11	144	44.9
12 to 15	129	40.2
Total	321	100.0

Note. Low – 0 to 7; Moderate – 8 to 11; High – 12 to 15

Table 3 shows considerable variation in students' sustainability literacy. Although the largest proportion of respondents was classified at the moderate level (44.9%), a substantial 40.2% attained the high-literacy range, while 14.9% were classified as having low sustainability literacy. Thus, the distribution does not characterize the student population as uniformly moderate; rather, it reveals differentiated levels of sustainability knowledge, with more than four in five students (85.1%) demonstrating at least moderate literacy and approximately two in five reaching the high category. At the same time, the presence of nearly one in seven students in the low-literacy group indicates that important knowledge gaps remain within a segment of the population.

The relatively large proportion of students in the high-literacy category may reflect the increasing visibility of sustainability issues across formal education, institutional initiatives, media, community activities, and other learning environments. However, the coexistence of moderate and low literacy groups indicates that exposure to sustainability-related information does not necessarily result in comparable levels of knowledge among students. Sustainability literacy is multidimensional and may vary according to students' educational experiences and their familiarity with environmental, social, and economic dimensions of sustainable development. Kuehl et al. (2023) similarly emphasize the importance of assessing sustainability knowledge systematically rather than

assuming that exposure or favorable attitudes necessarily correspond to adequate understanding. Null and Asirvatham (2023) likewise illustrate the value of measuring students' sustainability literacy to identify variation in knowledge and areas requiring further educational attention.

These findings have practical implications for sustainability education. The sizeable high-literacy group suggests an existing knowledge base upon which more advanced, interdisciplinary, and application-oriented sustainability learning can be developed. Conversely, the 14.9% classified at the low level points to the need for opportunities that strengthen foundational sustainability knowledge, while the 44.9% in the moderate category represents a substantial group for whom instruction may focus on deepening and integrating existing understanding.

The domain-level results in Table 4 clarify the pattern observed in Table 3. Economic sustainability obtained the highest mean ($M = 3.73$) and was interpreted as high, whereas social sustainability ($M = 3.46$) and environmental sustainability ($M = 3.17$) were both moderate. The contrast reinforces the multidimensional character of sustainability literacy: an overall score can conceal meaningful differences in what students know across environmental, social, and economic domains (Chen et al., 2022; Kuehl et al., 2023). For institutional assessment, Table 4 is therefore more diagnostically useful than the overall literacy score alone because it identifies both a relative strength in economic sustainability and a comparatively lower performance in environmental sustainability.

Table 4. Sustainability Literacy by Domain

Domain	No. of items	Mean	Interpretation
Environmental sustainability	5	3.17	Moderate
Social sustainability	5	3.46	Moderate
Economic sustainability	5	3.73	High
Overall	15	10.36	Moderate*

Note. Low – 0.00 to 2.33; Moderate – 2.34 to 3.67; High – 3.68 to 5.00

*See Note in Table 3

The moderate overall literacy reported in Tables 3 and 4 is important because sustainability literacy involves more than familiarity with sustainability terminology. Chen et al. (2022) conceptualized sustainability literacy through knowingness, attitudes, and behavior, while Kuehl et al. (2023) demonstrated that sustainability knowledge comprises multiple concepts rather than a homogeneous body of information. More recent assessment work has also argued that conventional surveys and knowledge tests can be complemented by performance-based approaches that capture higher-order application of sustainability understanding (Massara, 2026). Accordingly, the present results provide an institutional baseline of measured knowledge, while students' broader capacity to reason through complex sustainability problems extends beyond what these measures capture.

The relatively stronger economic literacy in Table 4 represents a comparative strength within the measured domains rather than evidence of comprehensive sustainability understanding. A higher score in one domain does not necessarily demonstrate an integrated understanding of sustainable development, which requires students to recognize relationships and trade-offs among ecological integrity, social well-being, and economic activity. The multidimensional perspectives advanced by Chen et al. (2022) and Kuehl et al. (2023) support interpreting the economic result as a relative strength within an overall literacy profile that still requires development across domains.

Conversely, the environmental literacy mean in Table 4 was the lowest of the three domains. This result deserves particular attention because environmental knowledge provides a foundation for understanding climate change,

biodiversity loss, resource use, ecological interdependence, and the environmental consequences of human decisions. The present data do not establish why environmental literacy was weaker; however, plausible explanations include differences in curricular emphasis, disciplinary exposure, and opportunities to apply environmental concepts. These possibilities offer plausible directions for follow-up investigation, but the present data do not establish them as causes. For NDDU, the result supports strengthening environmental content while explicitly connecting ecological issues with their social and economic consequences (Chen et al., 2022; Kuehl et al., 2023).

These findings reinforce the importance of intentional curricular integration. Erguvan (2024a) demonstrates that sustainability literacy can be meaningfully assessed within undergraduate coursework, while Erguvan (2024b) found that content-based instruction can influence students' sustainability literacy. Together with Chen et al. (2022) and Kuehl et al. (2023), this literature suggests that sustainability literacy can be developed and monitored as an educational outcome rather than treated as incidental knowledge. Repeated assessment across programs and cohorts would allow NDDU to determine whether curricular and co-curricular interventions are producing measurable improvement in environmental, social, and economic sustainability understanding.

Readiness for Sustainable Development

As presented in Table 5, mean readiness scores were favorable across all five measured competencies. Normative competence had the highest mean ($M = 4.68$), followed by systems thinking ($M = 4.43$), interpersonal competence ($M = 4.36$), action preparedness ($M = 4.30$), and strategic competence ($M = 4.03$). These descriptive rankings show the relative pattern of the competency means, with normative competence emerging as the highest and strategic competence as the lowest measured dimension. Substantively, the pattern indicates strong self-reported normative orientation alongside a comparatively lower mean for strategic competence, consistent with competency frameworks that distinguish ethical judgment, systems thinking, strategy, and collaboration (Brundiers et al., 2021; Redman & Wiek, 2021; Wiek et al., 2011).

Table 5. Readiness for Sustainable Development

Readiness dimension	Mean	SD	Interpretation
Systems thinking	4.43	0.71	Agree
Strategic competence	4.03	0.84	Agree
Normative competence	4.68	0.63	Strongly Agree
Interpersonal competence	4.36	0.79	Agree
Action preparedness	4.30	0.75	Agree

The generally favorable readiness profile supports competency-based approaches to ESD in which systems thinking, values or normative judgment, strategic thinking, interpersonal competence, and implementation-oriented capacities are treated as central learning outcomes (Faham et al., 2017; Brundiers et al., 2021; Redman & Wiek, 2021; Valderrama-Hernández et al., 2026). Studies of sustainability education further indicate that these competencies are strengthened when students encounter interdisciplinary, transformative, and authentic learning experiences rather than content transmission alone (Brundiers et al., 2021; Vasques et al., 2022; Wang et al., 2022).

Table 5 also reveals an important internal contrast: strategic competence was the lowest readiness dimension ($M = 4.03$), although it remained within the favorable range. Students therefore appeared stronger in ethical orientation and recognition of interconnected systems than in the strategic capacity to formulate and evaluate pathways toward sustainability. This pattern suggests a pedagogical priority rather than a deficiency. Experiential, problem-based, interdisciplinary, and project-based learning can provide students with

opportunities to design interventions, compare alternatives, work with stakeholders, and evaluate the consequences of proposed solutions (Lozano et al., 2017, 2019; Thian et al., 2026; Wang et al., 2022).

Sustainability Engagement

Table 6. Sustainability Engagement

Dimension	Mean	SD	Interpretation
Sustainability attitudes	4.66	0.62	Strongly Agree
Sustainability practices	4.31	0.81	Often

Table 6 reports a higher mean for sustainability attitudes ($M = 4.66$) than for self-reported practices ($M = 4.31$). The observed mean difference suggests that favorable sustainability attitudes were more strongly expressed than the corresponding self-reported practices among the respondents. The pattern is nevertheless compatible with literature showing that favorable sustainability orientations do not necessarily correspond to equally strong behavioral enactment because motivation, efficacy, social norms, and enabling conditions may intervene (Null & Asirvatham, 2023; Perrault & Clark, 2018).

Because practices were self-reported and not independently verified, social-desirability and recall effects may have influenced the reported frequency of sustainable behavior. Even with this limitation, the pattern is educationally meaningful because it suggests that positive attitudes alone are insufficient. Higher education interventions should create authentic opportunities and enabling conditions through which students can enact sustainability commitments in everyday academic and campus contexts. Research likewise indicates that sustainability competencies and engagement develop through interacting influences of knowledge, motivation, agency, and educational experience (Núñez et al., 2024; Wang et al., 2022). Triangulation with observed behavior or institutional participation indicators could provide a more comprehensive account of sustainability practices in subsequent research.

Differences across Student Groups

Table 7. Group Differences in Literacy, Readiness, and Engagement

Grouping variable	Outcome	F	df1	df2	p	Interpretation
College	Literacy	5.23	4	316	< .001	Significant
	Readiness	2.59	4	316	.037	Significant
	Engagement	3.17*	4	20.8	.035	Significant
Year level	Literacy	0.46	3	317	.714	Not significant
	Readiness	0.86	3	317	.460	Not significant
	Engagement	0.12	3	317	.950	Not significant
Sex	Literacy	3.03*	2	10.7	.090	Not significant
	Readiness	4.68	2	318	.010	Significant

	Engagement	1.29	2	318	.276	Not significant
Prior exposure	Literacy	6.27*	2	101	.003	Significant
	Readiness	15.04	2	318	< .001	Significant
	Engagement	8.37	2	318	< .001	Significant

Note. Fisher's or Welch's* ANOVA was used according to the homogeneity-of-variance test reported in the study.

Table 7 summarizes the group-comparison results, with Fisher's one-way ANOVA or Welch's ANOVA applied according to the homogeneity-of-variance assumption. Significant overall differences across colleges were found for sustainability literacy, $F(4, 316) = 5.23$, $p < .001$, and readiness, $F(4, 316) = 2.59$, $p = .037$. Because homogeneity was not satisfied for engagement, Welch's ANOVA was used and likewise indicated an overall college difference, $F(4, 20.8) = 3.17$, $p = .035$. The omnibus results indicated heterogeneity across academic units, although specific pairwise differences were not examined. This distinction is especially important because college representation was highly uneven. The pattern is compatible with disciplinary variation in curricular emphasis, pedagogy, and opportunities for sustainability-related experience (Alm et al., 2022; Sánchez-Carracedo et al., 2022), but those mechanisms were not directly tested. Accordingly, the college findings are interpreted as evidence of overall institutional heterogeneity rather than as a ranking of academic units.

Year level did not significantly differentiate sustainability literacy, $F(3, 317) = 0.46$, $p = .714$, readiness, $F(3, 317) = 0.86$, $p = .460$, or engagement, $F(3, 317) = 0.12$, $p = .950$. Thus, no year-level differences were detected in this cross-sectional sample. In contrast, prior sustainability exposure differed significantly across all three outcomes.

Welch's ANOVA indicated variation in literacy, $F(2, 101) = 6.27$, $p = .003$, while readiness, $F(2, 318) = 15.04$, $p < .001$, and engagement, $F(2, 318) = 8.37$, $p < .001$, also differed across exposure groups. The results indicate differences across exposure groups, although their direction requires group-specific comparisons and the cross-sectional design precludes causal inference. Nevertheless, the consistency of the exposure pattern across literacy, readiness, and engagement is compatible with research emphasizing explicit curricular integration, authentic learning, and sustained opportunities for competency development (Alm et al., 2022; Sánchez-Carracedo et al., 2022; Vasques et al., 2022).

Differences according to sex were outcome-specific. Sustainability literacy did not differ significantly across sex categories under Welch's ANOVA, $F(2, 10.7) = 3.03$, $p = .090$, and sustainability engagement likewise showed no significant difference, $F(2, 318) = 1.29$, $p = .276$. Readiness showed an overall difference, $F(2, 318) = 4.68$, $p = .010$. Given the marked subgroup imbalance, particularly the five respondents who selected "Prefer not to say," the readiness difference warrants cautious interpretation.

Relationship between Literacy and Readiness

Table 8. Correlations between Sustainability Literacy and Readiness

Readiness variable	Environmental	Social	Economic	Overall literacy
Systems thinking	.02 (.776)	.01 (.817)	-.01 (.926)	.01 (.870)
Strategic competence	-.04 (.528)	-.10 (.066)	-.09 (.107)	-.10 (.067)
Normative competence	.08 (.169)	.18 (< .001)	.15 (.009)	.18 (< .001)
Interpersonal competence	.07 (.249)	.04 (.484)	.03 (.597)	.06 (.326)

Action preparedness	.03 (.611)	.05 (.425)	.05 (.407)	.05 (.347)
Overall readiness	.03 (.557)	.03 (.543)	.02 (.664)	.04 (.487)

Note. Values represent Pearson's correlation coefficients (r), with the corresponding p -values reported in parentheses.

Table 8 shows that most literacy–readiness correlations were close to zero and nonsignificant. Overall literacy was not significantly associated with overall readiness ($r = .04$, $p = .487$). Normative competence was the principal exception, with small positive correlations with social literacy ($r = .18$, $p < .001$), economic literacy ($r = .15$, $p = .009$), and overall literacy ($r = .18$, $p < .001$). Although statistically significant, these correlations were small in magnitude, indicating only limited correspondence between literacy and normative competence. Considered alongside the predominantly negligible correlations in the table, the pattern suggests that measured sustainability knowledge and readiness competencies largely operated as distinct dimensions in this sample. Overall, the results support empirical distinction between measured knowledge and self-reported readiness competencies (Ariza et al., 2021; Gericke et al., 2019).

The weak overall association in Table 8 also refines the study's conceptual 'bridge' proposition. Readiness may be understood as a theoretically plausible and educationally important pathway between sustainability knowledge and engagement, but the present cross-sectional results do not establish statistical mediation. Competency frameworks treat knowledge as one component of a broader capacity involving systems analysis, values, strategic thinking, collaboration, and implementation (Brundiers et al., 2021; Redman & Wiek, 2021). The present findings therefore support combining cognitive instruction with values clarification, systems analysis, teamwork, decision-making, and authentic action rather than expecting knowledge alone to generate readiness.

Predictors of Sustainability Engagement among Students

Table 9. Multiple Regression Model of Sustainability Engagement

Predictor	B	SE	95% CI		t	p	β
			Lower	Upper			
Intercept ^a	1.256	0.212	0.840	1.673	5.937	< .001	—
College:							
2 – 1	−0.094	0.051	−0.194	0.007	−1.839	.067	−0.183
3 – 1	−0.070	0.062	−0.192	0.052	−1.124	.262	−0.135
4 – 1	0.083	0.152	−0.217	0.383	0.544	.587	0.161
5 – 1	−0.096	0.153	−0.398	0.206	−0.627	.531	−0.187
Year Level:							
1 – 2	0.045	0.045	−0.042	0.133	1.019	.309	0.088
3 – 2	0.049	0.088	−0.124	0.223	0.556	.578	0.095
4 – 2	0.163	0.167	−0.166	0.492	0.977	.329	0.317
Sex:							
1 – 0	0.050	0.047	−0.041	0.142	1.081	.281	0.098
2 – 0	0.046	0.166	−0.280	0.373	0.278	.781	0.090

Prior Exposure	−0.015	0.017	−0.048	0.018	−0.910	.363	−0.095
Environmental	−0.0006	0.022	−0.043	0.042	−0.028	.977	−0.001
Social	−0.008	0.018	−0.044	0.027	−0.465	.642	−0.022
Economic	0.009	0.018	−0.026	0.044	0.497	.619	0.023
Systems Thinking	0.199	0.056	0.088	0.310	3.535	< .001	0.225
Strategic Competence	0.030	0.044	−0.057	0.117	0.675	.500	0.042
Normative Competence	0.202	0.054	0.095	0.309	3.716	< .001	0.225
Interpersonal Competence	0.163	0.056	0.053	0.274	2.902	.004	0.205
Action Preparedness	0.115	0.055	0.007	0.223	2.086	.038	0.144

Note. B = unstandardized regression coefficient; SE = standard error; CI = confidence interval; β = standardized regression coefficient. ^aReference level. Model summary: $R = .74$, $R^2 = .55$, adjusted $R^2 = .52$.

Categorical coding: College—1 = Health Sciences (reference), 2 = Business, 3 = Engineering, Architecture and Technology, 4 = Education, 5 = Arts and Sciences; Year Level—1 = 1st year, 2 = 2nd year (reference), 3 = 3rd year, 4 = 4th year; Sex—0 = Female (reference), 1 = Male, 2 = Prefer not to say.

As shown in Table 9, the regression model accounted for 55% of the observed variance in sustainability engagement ($R = .74$, $R^2 = .55$; adjusted $R^2 = .52$), indicating substantial explanatory capacity within the present sample. In interpreting the categorical predictors, Health Sciences, 2nd year, and Female served as the reference categories; consequently, the reported coefficients for the remaining categories represent adjusted differences from these reference groups. Prior exposure did not significantly predict engagement ($B = -.015$, $SE = .017$, 95% CI $[-.048, .018]$, $\beta = -.095$, $p = .363$). Likewise, none of the college contrasts was statistically significant: Business versus Health Sciences ($B = -.094$, $p = .067$), Engineering, Architecture and Technology versus Health Sciences ($B = -.070$, $p = .262$), Education versus Health Sciences ($B = .083$, $p = .587$), and Arts and Sciences versus Health Sciences ($B = -.096$, $p = .531$). Year level was also nonsignificant, with Year Levels 1, 3, and 4 showing no significant differences from the reference group, 2nd year, with p -values .309, .578, and .329, respectively. Similarly, male students and those who preferred not to report their sex did not differ significantly from female ($p = .281$ and $p = .781$, respectively). The three sustainability literacy domains—environmental ($B = -.001$, $\beta = -.001$, $p = .977$), social ($B = -.008$, $\beta = -.022$, $p = .642$), and economic ($B = .009$, $\beta = .023$, $p = .619$)—also showed no significant unique associations with engagement after adjustment for the other predictors. In contrast, systems thinking ($B = .199$, $SE = .056$, 95% CI $[.088, .310]$, $\beta = .225$, $p < .001$), normative competence ($B = .202$, $SE = .054$, 95% CI $[.095, .309]$, $\beta = .225$, $p < .001$), interpersonal competence ($B = .163$, $SE = .056$, 95% CI $[.053, .274]$, $\beta = .205$, $p = .004$), and action preparedness ($B = .115$, $SE = .055$, 95% CI $[.007, .223]$, $\beta = .144$, $p = .038$) were significant positive predictors of engagement. Strategic competence was not significant ($B = .030$, $SE = .044$, 95% CI $[-.057, .117]$, $\beta = .042$, $p = .500$). Among the significant predictors, normative competence and systems thinking showed the largest and nearly identical standardized unique associations with engagement, followed by interpersonal competence and action preparedness. Overall, the pattern suggests that sustainability engagement was more consistently associated with selected sustainability competencies than with prior exposure, demographic or academic profile characteristics, or measured environmental, social, and economic sustainability literacy. These coefficients represent conditional associations within the fitted multiple-regression model and should not be interpreted as evidence of causal effects.

The finding that systems thinking, normative competence, interpersonal competence, and action preparedness significantly predicted sustainability engagement, while environmental, social, and economic literacy did not, is

consistent with competency-oriented approaches to Education for Sustainable Development. These approaches conceptualize sustainability learning as extending beyond the acquisition of factual or disciplinary knowledge to include capacities for understanding complex systems, making value-informed judgments, collaborating with others, and translating knowledge into action. Brundiars et al. (2021) identify systems thinking, values or normative thinking, interpersonal competence, and implementation-related capacities as interconnected competencies needed to address complex sustainability challenges. Similarly, Redman and Wiek (2021) emphasize that sustainability transformations depend on combinations of systems, values, interpersonal, intrapersonal, implementation, and other competencies rather than knowledge alone. The results of the present study are consistent with these frameworks, as the significant predictors of engagement reflect students' capacities to recognize interconnections, evaluate sustainability values and priorities, work collaboratively, and prepare themselves to act on sustainability concerns.

The positive association of systems thinking with engagement is theoretically important because sustainability challenges involve interconnected ecological, social, economic, and institutional systems whose consequences cannot readily be understood through isolated disciplinary knowledge. Systems-thinking competence enables learners to recognize relationships, feedback processes, multiple perspectives, and consequences across interacting systems and is consequently regarded as a foundational component of sustainability problem solving (Brundiars et al., 2021; Redman & Wiek, 2021). Higher-education competency frameworks similarly place systems thinking alongside normative, interpersonal, anticipatory, and strategic competencies as capacities required for analyzing sustainability problems and developing viable responses. The present result therefore suggests that students' engagement with sustainability is associated not simply with possessing sustainability information but with their perceived capacity to recognize how sustainability issues and possible responses are interconnected.

The comparable standardized association for normative competence ($\beta = .225$) further suggests that engagement has an important value-oriented dimension. Normative or values-thinking competence concerns the capacity to recognize, articulate, negotiate, and critically evaluate sustainability values, principles, goals, and trade-offs (Brundiars et al., 2021; Redman & Wiek, 2021). Sustainability decisions frequently involve competing interests and questions of equity, responsibility, justice, and desirable futures; consequently, knowing environmental, social, or economic facts does not by itself determine how learners evaluate such choices. The significant association observed in Table 9 is therefore consistent with the proposition that sustainability engagement involves not only cognitive understanding but also the capacity to make value-informed judgments about sustainability problems and possible courses of action.

The significant contribution of interpersonal competence ($\beta = .205$) also reinforces the inherently social and collaborative character of sustainability engagement. Complex sustainability problems generally require communication, negotiation, coordination, perspective taking, and collaboration across disciplinary, professional, institutional, and community boundaries. Interpersonal competence is consequently included among the core sustainability competencies in established higher-education frameworks (Brundiars et al., 2021; Redman & Wiek, 2021). Its independent association with engagement in the present study suggests that students' capacity to interact and work with others may be particularly relevant when sustainability moves from individual awareness toward collective participation. This finding supports pedagogical approaches that place students in collaborative, interdisciplinary, and community-oriented contexts rather than treating sustainability primarily as individually acquired content.

The positive association between action preparedness and engagement provides an additional connection between competency and action-oriented perspectives in ESD. Research on action competence conceptualizes meaningful sustainability education as developing not only knowledge of sustainability problems but also students' confidence, willingness, and perceived capacity to participate in addressing them. Olsson et al. (2022), using a three-wave longitudinal design, found that students' experiences of ESD were associated with the development of action competence over time, supporting the view that action-related capacities are educational outcomes that can be deliberately developed. Research in higher education has likewise found that an action-competence teaching model can support knowledge of sustainability problems together with confidence and willingness to act (Xing & Ironsi, 2024). Evidence from Norway further indicates that students' experiences of

influencing society were positively related to multiple components of action competence, including knowledge of action possibilities, confidence in one's influence, and willingness to act (Torsdottir et al., 2024). These findings provide a useful interpretive context for the present result: students who perceive themselves as better prepared to act may also be more likely to express sustainability through attitudes and self-reported practices.

The nonsignificant literacy coefficients do not imply that sustainability knowledge lacks educational relevance; rather, literacy did not account for unique variation in engagement after adjustment for readiness and profile variables. This distinction corresponds with the broader movement in ESD away from an information-deficit assumption in which increasing knowledge is expected, by itself, to produce sustainable action. Longitudinal research on action competence has explicitly described this shift from information-centered education toward the development of competencies that enable learners to act on complex sustainability problems (Olsson et al., 2022). Research on young people's sustainability action similarly demonstrates that relationships among knowledge, perceived efficacy, action competence, private-sphere behavior, and collective sustainability action are complex rather than uniformly linear; action competence may relate differently to different forms of sustainability behavior, and knowledge does not automatically translate into collective action (Oinonen et al., 2024).

Taken together, Tables 8 and 9 provide the study's principal analytical contribution. Overall literacy and overall readiness were only weakly related ($r = .04$, $p = .487$), and the literacy domains did not explain unique variation in engagement once readiness competencies and other variables were included in the multivariable model. By contrast, systems thinking, normative competence, interpersonal competence, and action preparedness showed significant conditional associations with engagement. The findings therefore do not support using sustainability literacy as a sufficient proxy for students' broader preparedness or engagement in this sample. Instead, they support a multidimensional view in which cognitive knowledge, perceived competencies, and engagement are conceptually connected but empirically distinguishable outcomes. This interpretation is consistent with contemporary sustainability-competency frameworks in which disciplinary knowledge remains necessary but operates alongside capacities for systems analysis, value-informed judgment, collaboration, and action (Brundiers et al., 2021; Redman & Wiek, 2021).

This distinction has implications beyond the present institution because sustainability assessment can produce different conclusions depending on what is measured. A literacy-only assessment may identify knowledge strengths and deficits but may not reveal whether students perceive themselves as able to analyze complex systems, negotiate values, collaborate, or act. Conversely, favorable self-reported competencies should not be interpreted as evidence of strong factual knowledge or observed sustainable behavior. The present findings therefore support assessment designs that retain these dimensions separately and use their pattern jointly to guide curriculum and program evaluation. In educational practice, this means complementing knowledge-focused instruction with authentic tasks in which students analyze interconnected systems, confront sustainability trade-offs, collaborate across perspectives, evaluate alternatives, and participate in action-oriented projects (Birdman et al., 2022; Kalla et al., 2022).

The regression coefficients represent conditional associations rather than causal effects. The cross-sectional design does not establish temporal ordering, and the readiness and engagement measures rely substantially on self-report. Moreover, because competencies may reinforce one another, the unique regression coefficients should not be interpreted as indicating that one competency operates independently of the broader competency system. Contemporary competency frameworks instead emphasize their integration in sustainability problem solving (Brundiers et al., 2021; Redman & Wiek, 2021). Longitudinal, intervention-based, and multi-institutional studies would therefore be valuable for determining whether changes in these competencies precede corresponding changes in observed sustainability engagement.

Moderating Effects of Student Profile

Table 10. Moderation of Literacy/Readiness Effects on Engagement

Predictor	Moderator	Estimate	SE	p	Interpretation
Overall literacy	College	-0.017	0.009	.073	Not significant
	Year level	-0.022	0.013	.094	Not significant
	Sex	0.011	0.019	.559	Not significant
	Level of exposure	-0.004	0.003	.211	Not significant
Overall readiness	College	0.041	0.042	.320	Not significant
	Year level	-0.005	0.059	.929	Not significant
	Sex	-0.150	0.067	.029	Significant
	Level of exposure	0.007	0.011	.545	Not significant

Table 10 presents the interaction estimates, standard errors, and significance tests for the moderation models. None of the examined profile variables significantly moderated the association between overall sustainability literacy and engagement: college ($B = -0.017$, $SE = 0.009$, $p = .073$), year level ($B = -0.022$, $SE = 0.013$, $p = .094$), sex ($B = 0.011$, $SE = 0.019$, $p = .559$), and level of exposure ($B = -0.004$, $SE = 0.003$, $p = .211$). Similarly, the readiness–engagement association was not significantly moderated by college ($B = 0.041$, $SE = 0.042$, $p = .320$), year level ($B = -0.005$, $SE = 0.059$, $p = .929$), or level of exposure ($B = 0.007$, $SE = 0.011$, $p = .545$). A significant readiness $\times$ sex interaction was observed ($B = -0.150$, $SE = 0.067$, $p = .029$), whereas the remaining moderation effects were nonsignificant. Given the multiple moderation tests and unequal subgroup sizes, the interaction is interpreted as exploratory.

The readiness $\times$ sex interaction indicates that the estimated readiness–engagement slope was not uniform across the numerical coding of the sex variable. The negative coefficient indicates variation in the estimated readiness–engagement slope across the coded sex categories; however, the specific group pattern cannot be determined without conditional slopes or predicted values. Statistical significance also does not establish practical importance or imply that sex causes differences in sustainability engagement. These qualifications are especially important because the sex categories were unevenly represented and because the interaction was one of several moderation tests. Replication with more balanced subgroup representation and examination of conditional slopes would clarify the form and practical magnitude of this interaction. More broadly, it is consistent with the possibility that sustainability engagement reflects the interplay of competencies, agency, motivation, educational experience, and social context rather than demographic characteristics in isolation (Núñez et al., 2024; Yang et al., 2026).

Implications for Sustainability Education and Assessment

The findings support a focused institutional response rather than an expansion of disconnected sustainability activities. First, the comparatively lower environmental literacy score and the overall college differences indicate a need to map sustainability learning outcomes across programs, strengthen environmental content where warranted, and preserve discipline-specific applications. At the same time, the multivariable results suggest that knowledge-oriented instruction should be complemented by learning experiences that explicitly develop systems thinking, normative judgment, interpersonal competence, and action preparedness. Constructive alignment among sustainability competencies, learning activities, and assessment can help make these outcomes visible

rather than leaving them implicit in the curriculum (Alm et al., 2022; Lewis & Bader, 2026; Redman & Wiek, 2021).

Second, the exposure findings and the descriptive difference between highly favorable attitudes and comparatively lower self-reported practices point to the value of authentic opportunities for participation. Interdisciplinary projects, community-based research, service-learning, campus sustainability audits, SDG-related capstones, student organizations, and partnerships with government, NGOs, communities, and industry can provide contexts in which students apply knowledge and exercise sustainability competencies. The campus itself can function as a learning environment when curriculum is connected with operations, student affairs, research, extension, internationalization, and community engagement (Alm et al., 2022; Thian et al., 2026). These recommendations derive from the observed associations; their effectiveness requires evaluation through longitudinal or intervention-based research.

Third, implementation depends on institutional and faculty capacity. Faculty development can support the translation of sustainability frameworks into discipline-specific outcomes, authentic tasks, and assessment strategies, while institution-wide curriculum mapping can identify duplication, omissions, and uneven opportunities across academic units. Recent higher-education research emphasizes both competence-based curriculum design and the organizational conditions needed for sustainability integration (Duran et al., 2026; Lewis & Bader, 2026; Vargas-Merino & Vivanco Aquino, 2026). The practical objective is not to replace sustainability knowledge with competencies, but to ensure that knowledge is developed alongside opportunities to reason, collaborate, and act.

Finally, the study supports a multidimensional and cyclical approach to institutional sustainability assessment. Literacy, readiness, and engagement should be monitored as separate but complementary outcomes because a favorable result on one dimension cannot be assumed to represent the others. Repeated assessment across cohorts can determine whether observed patterns change following curricular or co-curricular initiatives, while performance-based tasks, observed behavior, participation records, and qualitative evidence can complement self-report measures where feasible (Lewis & Bader, 2026; Massara, 2026). The present findings provide a baseline diagnostic of where sustainability knowledge, perceived competencies, and engagement converge or diverge and can inform subsequent evaluation of institutional initiatives.

Limitations of the Study

Several limitations qualify the interpretation of the findings. First, readiness and engagement were measured through self-report and may be affected by social-desirability, common-method, and recall biases; reported practices were not triangulated with observed behavior or institutional records. Second, subgroup sizes were markedly uneven across colleges, year levels, and sex, reducing the precision and stability of some omnibus comparisons and interaction estimates and limiting meaningful subgroup interpretation. Third, the cross-sectional design does not establish temporal ordering, causal relationships, developmental change, or mediation. Fourth, multiple group comparisons, correlations, regression coefficients, and moderation tests were evaluated without a multiplicity adjustment; consequently, isolated p-values near .05 should be treated cautiously. Fifth, although pilot internal-consistency estimates were satisfactory, fuller evidence regarding dimensionality and construct validity was not available, so the measures should not be treated as fully validated scales beyond the present institutional context. Finally, the significant readiness $\times$ sex interaction was not probed with conditional slopes or predicted values and is further constrained by unequal subgroup representation; it should therefore be regarded as exploratory. Future research should use longitudinal or repeated-cohort designs, more balanced or multi-institutional samples, stronger multidimensional validation, effect-size and assumption-focused reporting, objective or performance-based indicators, and qualitative evidence capable of clarifying how sustainability knowledge, competencies, and engagement develop and interact over time.

CONCLUSION

This study provides institution-level evidence that sustainability literacy, readiness competencies, and engagement are related conceptually but empirically distinguishable outcomes of Education for Sustainable

Development. Sustainability literacy was heterogeneous and moderate overall, with environmental literacy showing the lowest domain mean, while self-reported readiness and sustainability attitudes were generally favorable. Most literacy–readiness correlations were negligible, and the measured literacy domains did not explain unique variation in engagement in the multivariable model; systems thinking, normative competence, interpersonal competence, and action preparedness did. The central implication is therefore not that sustainability knowledge is unimportant, but that literacy alone may provide an incomplete proxy for students’ broader sustainability preparedness and engagement. Higher education assessment should distinguish what students know from the competencies they report and the ways sustainability is expressed in attitudes and practices. For educational practice, the findings support integrating knowledge development with interdisciplinary, experiential, competency-based, and action-oriented learning. These conclusions remain specific to a cross-sectional, single-institution sample and require confirmation through stronger construct validation, balanced and multi-institutional sampling, longitudinal designs, and behavioral or performance-based evidence.

Ethical Considerations

Ethical safeguards were applied throughout the study. Before data collection, respondents received an informed-consent statement explaining the study purpose, procedures, voluntary nature of participation, and right to decline or withdraw without penalty. The survey did not collect personally identifying information beyond the demographic variables required for analysis, and findings were reported in aggregate. Data were stored in password-protected files accessible only to the researcher and were used for academic and research purposes. Students were informed that participation would not affect their academic standing, grades, or access to institutional services. These procedures were intended to protect voluntary participation, privacy, confidentiality, and data security.

Conflict of Interest

The authors declare no conflict of interest in the conduct, analysis, interpretation, or reporting of this study.

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