

## Uncovering sustainability awareness profiles in higher education: A person-centered approach

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Received 13 August 2026 ▪ Accepted 18 October 2026

### Abstract

Sustainability awareness is generally treated as a single level to be raised, yet its components can vary independently of one another. This exploratory study identified subgroups of undergraduate students whose awareness follows distinct patterns and examined how those subgroups relate to demographic characteristics. Data were collected through an online survey from 597 undergraduate students across five faculties, on five dimensions covering personal knowledge and efficacy, educational experience, individual practices and engagement, institutional perception, and global concerns and ethics. The five-dimension structure was supported by exploratory structural equation modeling, with a scaled Chi-square of 268.02 on 185 degrees of freedom, CFI = .991 and RMSEA = .027, and scalar measurement invariance held across gender, age group, faculty, academic year and level of first exposure for the specifications tested. Latent profile analysis, estimated from multiple starting values after the default initialization was found to return to a local optimum, identified four profiles: moderate awareness (37.7%), high comprehensive awareness (36.7%), low practices and engagement (13.2%), and low personal knowledge (12.4%). Profile membership showed no association of practical size with any demographic variable, and effects of medium size were excluded by equivalence testing. Sustainability awareness is therefore distributed in qualitatively distinct patterns that do not follow conventional demographic lines. Because items were administered in a fixed order within visually separated blocks, construct and presentation format are confounded, and both the instrument and the profile structure require independent replication with randomized item order before they can be regarded as established.

**Keywords:** sustainability awareness, education for sustainable development, latent profile analysis, person-centered approach, higher education

## INTRODUCTION

Sustainability is a multidimensional concept that brings environmental, economic and social concerns together. The deepening of global challenges such as climate change, biodiversity loss and resource depletion has placed sustainable development among the highest priorities on the agenda of societies (Velenturf & Purnell, 2021). Higher education institutions carry a particular

responsibility in this process, since universities prepare future decision makers by integrating sustainability principles into their curricula and campus practices (Lozano et al., 2015; Ralph & Stubbs, 2014). Hence, it is not surprising to see that a substantial body of research has accumulated on what students know about sustainability and how they act upon it.

### Contribution to the literature

- This study measures students' perceptions of institutional and curricular sustainability provision on the same respondents, and within the same measurement model, as their own knowledge, practices and global concern, so that the configuration formed by all five dimensions can be examined within the individual rather than averaged across a campus.
- Latent profile analysis identified four configurations, two of which are defined by one dimension at the floor of the scale while the remainder sit near the sample mean: one group reports knowledge and perceived provision but almost no personal practice, and another reports perceived provision and practice but almost no personal knowledge. Neither corresponds to a demographic category, and equivalence testing excluded demographic effects of medium size.
- The study documents that the deterministic initialization routinely used to estimate latent profile models returned a local optimum in these data, and that a better-fitting solution located from multiple starting values agreed with it on only 72.9% of cases and did not reproduce one of its profiles. Person-centered findings reported without evidence that the optimum has been located may therefore be less secure than they appear.

Sustainability awareness refers to the extent to which individuals understand environmental, social and economic issues and demonstrate sensitivity towards them. In the literature this awareness is generally addressed through its cognitive, affective and behavioral dimensions (Kagawa, 2007; Shephard, 2008). The cognitive dimension concerns comprehension of the origins and effects of environmental problems, the affective dimension a sense of responsibility towards the environment, and the behavioral dimension the integration of sustainable practices into daily life. Shephard (2008) notes that the essence of sustainability education lies more in effectiveness than in cognitive outcomes. However, whether this three-part distinction fully reflects the diversity of students' experiences remains open to question. Kuehl et al. (2023) tested whether sustainability knowledge exhibits a consistent underlying structure and found no such structure across two separate samples.

A more detailed account becomes necessary once it is recognized that these components can vary independently of one another. A student may possess a high level of environmental knowledge and still find the university's sustainability practices inadequate (Dagiliūtė et al., 2018). Similarly, a student who has acquired sustainability experience during the educational process may not reflect that experience in daily habits. This gap between knowledge and behavior is among the most frequently emphasized issues in the field. Kollmuss and Agyeman (2002) argue that linear models assuming knowledge translates directly into behavior are fallacious, and Steg and Vlek (2009) further point out that the same person may be inconsistent across behavioral domains. Hence, it can be said that awareness may exist not at a single level but in different patterns across dimensions.

The whole institution approach offers a framework within which these interdependencies can be located. Reviewing 104 international documents, Holst (2023)

synthesizes the approach as a continuous and participative process of organizational learning directed at institutional coherence on sustainability, consistently linking the formal and the informal or hidden curricula across seven areas of action: governance, curriculum, campus, community, research, communication and capacity building. Hopkinson et al. (2008) had earlier argued along the same lines that student learning about sustainable development is best understood as the product of a formal, an informal and a campus curriculum operating together, and that campus management decisions should therefore be treated as educational opportunities rather than as operational matters. Mogren et al. (2019) operationalized the approach for schools through four organizational dimensions, namely a holistic vision, routines and structures, professional knowledge creation, and practical pedagogical work, and found that teachers in schools actively implementing education for sustainable development perceived greater organizational coherence than their counterparts elsewhere.

The empirical case for the framework is now reasonably strong. Holst et al. (2024) developed a whole institution approach scale and administered it to 2,985 learners and educators across school, vocational and higher education in Germany, finding that the degree to which learners experience the approach was the strongest of the predictors examined of how sustainably they act beyond the educational institution. Torsdottir et al. (2024) showed that student participation within such an approach is itself differentiated, identifying four distinct pathways through which students experience involvement in decision making at their school. Hence, it can be said that what the institution does, and what students perceive it to be doing, belongs inside any account of how sustainability awareness develops rather than alongside it.

A gap nonetheless remains. Whole institution research characteristically measures coherence at the

level of the institution, or aggregates learner responses to produce an institutional score, and what has been examined far less often is whether coherence is experienced uniformly by the students within a single institution. Ralph and Stubbs (2014) found that universities tend to address sustainability primarily through greening campus operations rather than through holistic transformation, and Lozano et al. (2015) showed that signing a declaration does not guarantee implementation. Dagiliūtė et al. (2018) found no difference in sustainability perceptions between students at a self-declared green university and students elsewhere, identifying campus activities and communication rather than formal declarations as the operative factors. Lad and Akerlof (2022) underline that no agreed instrument assesses sustainability literacy and sustainability culture simultaneously. These findings raise a question that an institution-level score cannot answer: within one university, do all students experience the same coherence between what they are taught, what they see the institution doing, and what they themselves know and practice?

The measurement literature reflects this imbalance. The sustainability consciousness questionnaire developed by Gericke et al. (2019) is the field standard and operationalizes knowingness, attitudes and behavior across the three pillars of sustainability; it has since been adapted in a range of national contexts. Biasutti and Frate (2017) validated a twenty-item scale of attitudes towards sustainable development with Italian undergraduates, and Salahange et al. (2024) reported a thirty-six item instrument covering knowledge, attitude, willingness to act, behavior and self-efficacy. Instruments addressing the institution also exist, and several of them are answered by students rather than by administrators: the sustainable university factors scale of Nejati and Nejati (2013), the curricular insertion scale of Aginako et al. (2021) and the questionnaire of Dagiliūtė et al. (2018) all collect student ratings. The distinction that matters here is not who responds but what the responses are taken to measure. In these instruments the student is a respondent about the institution, and the ratings are aggregated to characterize a campus or to compare campuses; the measurement target is the institution even though the unit of observation is the student. What is not modelled is the student's perception of institutional provision as one facet of that same student's own awareness, estimated jointly with what that student knows, practices and feels. The contribution of the present instrument is therefore not the measurement of institutional perception, which already exists, but the placement of institutional and curricular perception on the same respondent and in the same measurement model as personal knowledge, individual practices and global concern, so that the configuration formed by all five can be examined within the individual rather than averaged across individuals. Budak et al.

(2026), reviewing the assessment instruments used in higher education, report that nearly half measure attitude while more complex constructs are targeted minimally. It is on this basis that the present study measures curricular provision and institutional perception alongside personal knowledge, habits and global concern within a single instrument.

A second consideration concerns the analytic approach rather than the instrument. The majority of research in the field adopts variable-centered methods, which ask how far environmental knowledge predicts attitudes or how attitudes influence behavior through correlation, regression and structural equation modelling. Such methods are not confined to homogeneous effects. Interaction terms, multigroup models, mixture regression and random-coefficient specifications can all represent heterogeneity, and variable-centered work frequently does so. The constraint is of a different kind: heterogeneity in these models must be specified in advance through a moderator or a grouping variable that the researcher has nominated, whereas the question of which configurations of several dimensions actually occur within individuals, and in what proportions, is not posed in that form. Person-centered approaches address that question directly, focusing on individuals' patterns of scores rather than on relationships between variables. Latent profile analysis is a person-centered technique that identifies subgroups whose members share similar patterns (Spurk et al., 2020). The two families are complementary rather than mutually exclusive, and they answer different questions; the present study adopts the person-centered approach because its question concerns configurations across five dimensions for which no prior grouping variable is available. Although its application to environmental constructs is relatively recent, it is gaining ground. Helm et al. (2022) identified adaptive and maladaptive coping profiles in the context of global environmental threats, and Ágoston et al. (2024) identified five profiles combining eco-emotions and pro-environmental behavior. A notable observation in the former study is that profile membership was associated with environment-specific rather than general demographic factors.

The study closest to the present one is that of Aleixo et al. (2021), who surveyed 1,257 Portuguese higher education students, extracted five factors through exploratory factor analysis, and derived four clusters through hierarchical cluster analysis of the resulting subscale means. Their work established that student perceptions of sustainable development are patterned rather than uniform. The present study builds on that foundation in three respects. A formal measurement model is estimated rather than a principal component solution, classification is model based with reported fit indices and entropy rather than read from a dendrogram, and measurement invariance is established

before any group comparison is made. Whether a model-based classification recovers a comparable structure in a different national context is itself a question worth answering.

The relationship between awareness and demographic variables has also been extensively studied without converging. Some studies report higher environmental awareness and sustainability behavior among female students (Al-Naqbi & Alshannag, 2018; Boned-Gómez et al., 2025), while others find no significant gender difference (Chen et al., 2022; Maoela et al., 2024), and similar inconsistencies apply to field of study and academic year (Chuvieco et al., 2018; Urbaniak et al., 2024). It is not possible to make a generalization from these conflicting results. The inconsistency itself suggests that demographic variables may produce different patterns across the dimensions rather than determining the overall level, which is a proposition a person-centered design is well placed to test.

Answering that question requires measuring what a student knows and practices alongside what that same student perceives of the curriculum and of the institution and analyzing the resulting configurations through a person-centered approach. Measuring both on the same respondent makes it possible to treat coherence as an individual experience rather than an institutional property. Coherence is used in this study in a restricted and operational sense. It refers to the correspondence, within one student, between the position that student occupies on the institutional and educational dimensions and the position that same student occupies on the personal dimensions, each expressed relative to the sample. A configuration in which the perceived-provision dimensions and the personal dimensions fall on the same side of the sample mean is read as coherent, in the sense that what the student reports of the institution and what the student reports of their own awareness are aligned. A configuration in which they diverge, one set at or above the mean while the other falls to the floor of the scale, is read as incoherent, and the direction of the divergence distinguishes one form of incoherence from another. Two qualifications follow this definition and are observed throughout. The first is that similar scores on distinct dimensions indicate correspondence between two reports, not agreement between a report and an external fact; no measure of actual institutional provision is obtained here. The second is that a profile plot displays configurations of scores and nothing more, so the coherence reading placed on it is an interpretation of those configurations rather than a measurement of institutional coherence or of its internalization. This study is an attempt to reveal those configurations and to examine their relationship with demographic characteristics, and it addresses three research questions.

First, into which latent profiles do undergraduate students cluster on the basis of their scores across the five dimensions? Second, in terms of the operational definition given above, what forms of correspondence and divergence between perceived provision and personal uptake do those configurations represent? Third, do the profiles differ by gender, age group, faculty, academic year and the educational level at which students first encountered the concept? The psychometric properties of the instrument are established as a precondition and reported in summary form, with supporting detail provided as [Supplementary Material](#).

## METHOD

### Research Design

The present study was designed as a cross-sectional survey. The survey model is a research design that aims to describe the attitudes, opinions or characteristics of a group regarding a particular topic as they are (Creswell, 2012). This design was adopted for two reasons. The first is that the study seeks to describe undergraduate students' perceptions of sustainability in their current state. The second is that it seeks to identify subgroups of students whose perceptions follow similar patterns, and to examine how these subgroups are distributed across demographic variables. No intervention or experimental procedure was applied, and the data were collected at a single point in time.

### Participants

The study group consisted of 597 undergraduate students enrolled at Nukus State Pedagogical Institute during the 2025-2026 academic year, and data were collected in the spring semester. The questionnaire was distributed through the university's institutional electronic mail list and an announcement placed in the student information system, so that it reached enrolled undergraduates across all faculties rather than the students of any one course, instructor or program; participation was therefore not concentrated in a particular recruitment group. Eligibility was limited to students currently enrolled in an undergraduate program at the institution. Because the announcement was circulated to the student body as a whole and could be forwarded, the number of students who saw it cannot be established, and a response rate cannot be calculated; the sample is a self-selected volunteer sample and is treated as such in the interpretation of the findings. Participation was voluntary, no incentive was offered, and students were informed about the purpose of the study before giving consent. Every item in the questionnaire was configured as a required field, so the returned records contain no missing values on any analyzed variable and no imputation was required. The

form did not restrict submission to one response per respondent, so repeated submission cannot be excluded by design, although distribution through an institutional list and the absence of any incentive make it unlikely. The data from 23 participants who provided monotonous or irregular responses were excluded prior to analysis, and the analyses were conducted on 597 data sets. Participants were drawn from five faculty groups: social sciences ( $n = 134$ , 22.4%), natural and environmental sciences ( $n = 125$ , 20.9%), education and fine arts ( $n = 117$ , 19.6%), engineering and technology ( $n = 112$ , 18.8%), and health sciences ( $n = 109$ , 18.3%). Male students constituted 69.3% of the sample ( $n = 414$ ) and female students 30.7% ( $n = 183$ ). In terms of academic year, first-year students formed the largest group ( $n = 195$ , 32.7%), followed by second-year ( $n = 155$ , 26.0%), fourth-year and above ( $n = 129$ , 21.6%) and third-year students ( $n = 118$ , 19.8%).

Two features of the data require disclosure. The instrument offered an age band of 27 years and above, but no participant selected it; the age variable therefore comprises three categories, namely 17 to 19 years ( $n = 174$ , 29.1%), 20 to 22 years ( $n = 200$ , 33.5%) and 23 to 26 years ( $n = 223$ , 37.4%). In addition, two items in the demographic section, employment status and willingness to accept a lower salary in order to work for an environmentally responsible employer, returned an identical response from all 597 participants. This was traced to a default option that appears to have been pre-selected in the online form and left unchanged. Neither item carries any variance and both were excluded from all analyses.

The adequacy of the sample was evaluated against two criteria. For the psychometric analyses, at least ten participants per item is recommended (Hair et al., 2019); the present sample provides approximately 24 participants for each of the 25 items. For latent profile analysis, samples of at least 200 to 300 participants are considered sufficient (Spurk et al., 2020). Hence, it can be said that the sample meets the requirements of both sets of analyses.

### Data Collection Tool

The Sustainability Perception and Awareness Scale was constructed for the present study by adapting items from previously validated instruments and supplementing them where those instruments did not cover the constructs of interest. Item generation proceeded in three stages. First, existing instruments measuring undergraduate sustainability awareness were reviewed, and two were selected as primary sources on the grounds of citation impact and construct coverage. The sustainability consciousness questionnaire operationalizes sustainability knowingness, attitudes and behavior across the environmental, social and economic pillars (Gericke et al., 2019). The questionnaire developed by Aleixo et al.

(2021) for Portuguese higher education students uniquely covers students' perceptions of institutional and curricular sustainability provision, and itself draws on Chuvieco et al. (2018) and Dagiliūtė et al. (2018).

Second, eleven items measuring perceived curricular provision, institutional commitment, climate concern and policy priority were adapted from Aleixo et al. (2021); six items measuring sustainable lifestyle practices and ethical orientation were adapted from the sustainability consciousness questionnaire; and one item measuring belief in personal efficacy was adapted from the perceived consumer effectiveness tradition (Ellen et al., 1991). All adapted items were rewritten for a uniform five-point agreement format and reworded for the higher education context.

Third, seven items were developed by the researchers on the basis of the general literature to cover constructs not represented in the source instruments. These address the perceived sustainability relevance of the student's own discipline, following Urbaniak et al. (2024) on disciplinary variation; the perceived encouragement of critical thinking by instructors; the diffusion of sustainable habits to peers and family, following Larson et al. (2015) on social environmentalism as a distinct behavioral domain; the university's role as a community exemplar and the visible sustainability of campus infrastructure, following Nejati and Nejati (2013); comparative appraisal of biodiversity loss; and a self-rated ability to articulate the relationship among the three pillars of sustainable development.

The final instrument comprises 25 items answered on a five-point Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree), distributed across five dimensions of five items each: personal knowledge and efficacy, educational experience, individual practices and engagement, institutional perception, and global concerns and ethics. Two of these labels were revised following the content validity panel, as explained below. The complete wording of all twenty-five items as administered, with the source of each, is provided in [Table S1](#) in [Supplementary Material](#). The item pool consisted of 25 items and all were retained; because the items were derived deductively from previously validated instruments and from the theoretical definitions of the five dimensions, no item reduction stage was carried out at the development phase. Item performance was evaluated for the first time in the present administration.

The content validity of the draft instrument was examined by a panel of six experts. Three work in curriculum and instruction, one of them also in STEM education, one in educational sciences and two in English language education; the panel included no specialist in sustainability content and no psychometrician, a limitation discussed below. Each expert rated every item independently on two four-point

scales, relevance to the dimension under which the item was placed (1 = not relevant, 2 = somewhat relevant, needs major revision, 3 = quite relevant, needs minor revision, 4 = highly relevant) and clarity of wording (1 = not clear to 4 = highly clear), and was asked to name an alternative dimension for any item judged misplaced. The item-level content validity index was computed as the proportion of experts rating an item 3 or 4, and with six raters the retention criterion was set at .83, that is agreement among at least five of the six (Lynn, 1986). A modified kappa was computed for each item to adjust for chance agreement, with the chance proportion obtained as the binomial probability of the observed level of agreement under random rating. The panel was convened after the survey had been administered, so its judgements informed the interpretation and labelling of the dimensions and the agenda for a subsequent revision of the instrument but could not inform the version that students completed; this ordering is a limitation of the present study and is stated as such. Scale-level indices were .94 for relevance and .95 for clarity by the averaging method, with universal agreement on 19 of the 25 items. The complete item-by-expert ratings and the resulting indices are reported in [Table S13](#) in [Supplementary Material](#).

All twenty-five items were retained. For two of the three items falling below the criterion the panel's objection concerned the breadth of the dimension label rather than the placement of the item. Efficacy belief, raised in connection with A5, is a constituent of self-perceived action competence (Olsson et al., 2020) and conditions the path from knowledge to behavior (Ovais, 2023). Peer influence, raised in connection with C5, is one of four empirically distinct domains of pro-environmental behavior (Larson et al., 2015). Two dimension labels were therefore widened, from personal knowledge and awareness to personal knowledge and efficacy and from individual attitudes and habits to individual practices and engagement. The objection to A2 was different in kind: the panel held that an item naming the seventeen sustainable development goals measures familiarity with a specific policy framework rather than knowledge in a broader sense, and that objection is accepted as accurate rather than reinterpreted as a matter of labelling. The item is retained because the goals are the operational definition of sustainability literacy across the higher education assessment literature, including in the instruments from which this scale draws, so a knowledge dimension that omitted them would be narrower than the construct it is named for. Its empirical performance is sound, with the highest corrected item-total correlation in its dimension at .633 and a primary loading of .715 with no secondary loading above .10, and its mean of 3.42 is close to those of the other items in the dimension rather than concentrated at the lower end. What remains after retention is a genuine limitation of domain coverage,

namely that the knowledge dimension combines one policy-framework item with more general self-assessments, and that is a matter for revision and re-administration of the instrument rather than for post hoc deletion. The full rationale for each of the three items is given in [Table S11](#) in [Supplementary Material](#).

### Data Analysis

The data were analyzed in four consecutive stages. In the first stage, descriptive statistics were computed for each dimension. In the second stage, the measurement model was examined. Dimensionality was assessed through parallel analysis with 1,000 random datasets and Velicer's minimum average partial test, both computed on the polychoric correlation matrix. The five-factor structure was then tested using exploratory structural equation modeling with geomin rotation. ESEM allows each item to load on every factor while identifying a dominant factor for each item, which overcomes the restriction that confirmatory factor analysis places on cross-loadings (Asparouhov & Muthen, 2009). Because the items are ordinal, the diagonally weighted least squares estimator with robust corrections was used, and scaled fit indices are reported throughout. Internal consistency was estimated using Cronbach's alpha and McDonald's omega. A bifactor model was additionally estimated in order to test whether the five dimensions could be treated as facets of a single higher-order construct.

In the third stage, measurement invariance was tested for each grouping variable before any group comparison was made. Following Wu and Estabrook (2016), configural, threshold, threshold-and-loading, and threshold-loading-and-intercept models were estimated in sequence, and invariance was evaluated through change in scaled CFI and RMSEA, adopting values of at least minus .010 and no more than .015, respectively as criteria. Because rotational indeterminacy makes multigroup ESEM impractical for five grouping variables, the invariance sequences were estimated on the independent clusters confirmatory model rather than on the ESEM solution, and the fit values are therefore not directly comparable with those of the ESEM. Two adjustments were required before estimation was possible, and both created a gap between the specification tested for invariance and the specification used in the group comparisons. For academic year the two lowest response categories of each item were merged, because two item-by-group cells contained no observations and thresholds cannot be estimated in that situation; the invariance test for this variable therefore concerns a four-category rather than a five-category response scale. For first encounter the four categories collapsed into exposure during compulsory schooling and exposure afterwards, because the informal-sources category contained only 78 respondents, whereas the descriptive analysis in the

Findings retains all four categories. Neither gap is closed by the analyses reported here, and the invariance conclusions are accordingly restricted to the specifications actually estimated.

In the fourth stage, latent profile analysis was applied. LPA is a person-centered approach that identifies homogeneous subgroups on the basis of individuals' score patterns across observed variables (Spurk et al., 2020). Solutions with one through six profiles were estimated under four covariance structures, ranging from equal variances with covariances fixed to zero through to varying variances and covariances. Model selection considered the AIC, BIC and sample-size-adjusted BIC, entropy, the size of the smallest class, the bootstrapped likelihood ratio test, and the substantive interpretability of the profiles.

The relationship between profile membership and demographic variables was examined in two ways. The first was a Pearson Chi-square test on modal class assignment. The second was the three-step procedure of Bolck, Croon and Hagnaars, implemented as follows. The classification error matrix was obtained by averaging the posterior class probabilities within each modally assigned class, giving a four-by-four matrix whose rows are the expected posterior distributions for cases assigned to each class; this matrix is reported in [Table S14 in Supplementary Material](#). Each case was then assigned a vector of four BCH weights obtained from the corresponding row of the inverse of that matrix, so that a case contributes to every class in proportion to the inverse of the probability of being misclassified into it. The auxiliary model was the cross-tabulation of weighted class membership against the demographic variable, and the test statistic was a Pearson Chi-square computed on the weighted cell counts. It should be stated plainly that this yields a classification-error-weighted association test rather than a full likelihood-based three-step analysis with model-based standard errors; the weighting removes the attenuation produced by modal assignment, but the reference distribution remains the nominal Chi-square, and the resulting *p* values are therefore approximate. They are reported alongside the modal results for comparison rather than as a replacement for them.

Dimension-level group differences were examined through twenty-five one-way analyses of variance, one for each combination of the five dimension scores and the five grouping variables. Homogeneity of variance was assessed by Levene's test based on medians, which was significant for two of the twenty-five comparisons; for that reason the Alexander-Govern test, which does not assume equal variances, was computed for every comparison alongside the ordinary *F* test, and the two agree on every decision. Effect sizes are reported as eta squared with 90% confidence intervals (CI) obtained by inverting the noncentral *F* distribution, which is the appropriate interval for a squared multiple correlation

and is one-sided at the 95% level. For the association between profile membership and the demographic variables, Cramer's *V* was accompanied by a 95% percentile bootstrap interval based on 5000 resamples of the case-level data with the modal class assignment held fixed; the measurement model, the profile solution and the classification were not re-estimated within resamples, so the interval reflects sampling variability in the association given the classification rather than the full uncertainty of the sequence of analyses, and label switching does not arise because classes are not re-estimated.

Because several comparisons were expected to be null, these intervals were used for equivalence testing rather than for significance testing alone. An effect was regarded as excluded when the upper bound of the interval fell below the conventional benchmark for a medium effect, taken as  $f = .25$ , equivalently eta squared of .0588, for the dimension comparisons and as  $V = .17$  for a four-class by four-category table (Cohen, 1988). These bounds are conventional rather than substantive, and their educational relevance is limited to the following statement: an association at or above the medium benchmark would correspond to a demographic variable accounting for roughly 6% or more of the variance in a dimension score, which is the order of difference that might justify designing distinct provision for different demographic groups. Excluding effects of that size does not establish that no difference exists, only that no difference large enough to warrant demographically targeted provision was detected. Analyses were conducted in R using lavaan, semTools, psych and tidyLPA, with alpha set at .05.

### Ethical Considerations

The study was approved by the Ethics Committee of ABC University. Participation was voluntary and no incentive was offered. The first item of the online instrument presented a description of the study and asked participants to indicate whether they consented to take part; those who declined were directed out of the survey. No identifying information was collected, and responses were stored and analyzed only in aggregate form.

## FINDINGS

### Students' Perceptions of Sustainability

**Table 1** presents descriptive statistics for the five dimensions. Mean scores range from 3.39 to 3.50 on a five-point scale, and all fall above the midpoint of 3.00. The highest mean was obtained on personal knowledge and efficacy and the lowest on global concerns and ethics, though the difference between the two is only 0.10 of a scale point. All five distributions are negatively skewed, with skewness between minus .64 and minus

**Table 1.** Descriptive statistics for the five dimensions (N = 597)

| Dimension                           | Mean | Median | SD   | Minimum | Maximum | Skewness | Kurtosis |
|-------------------------------------|------|--------|------|---------|---------|----------|----------|
| Personal knowledge and efficacy     | 3.50 | 3.60   | 0.78 | 1.20    | 5.00    | -0.84    | 0.40     |
| Educational experience              | 3.49 | 3.60   | 0.76 | 1.00    | 5.00    | -0.81    | 0.54     |
| Individual practices and engagement | 3.46 | 3.60   | 0.79 | 1.00    | 5.00    | -0.87    | 0.51     |
| Institutional perception            | 3.44 | 3.60   | 0.79 | 1.00    | 4.80    | -0.69    | 0.04     |
| Global concerns and ethics          | 3.39 | 3.60   | 0.85 | 1.00    | 5.00    | -0.64    | -0.23    |

Note. SD: Standard deviation; Standard error of skewness = .100; Standard error of kurtosis = .200

**Table 2.** Fit of the five-dimension solution and four alternative models (N = 597)

| Model                            | $\chi^2$ | df  | CFI  | TLI  | RMSEA | SRMR |
|----------------------------------|----------|-----|------|------|-------|------|
| Five-factor ESEM                 | 268.02   | 185 | .991 | .985 | .027  | .022 |
| Six-factor ESEM                  | 205.62   | 165 | .995 | .992 | .020  | .019 |
| Five-factor ICM-CFA              | 579.37   | 265 | .964 | .960 | .045  | .053 |
| Six-factor ICM-CFA (reorganized) | 1,836.41 | 260 | .822 | .794 | .101  | .097 |
| Bifactor                         | 264.86   | 250 | .998 | .998 | .010  | .034 |

Note. Scaled indices are reported throughout; The six-factor ESEM is not retained because its additional factor contrasted item positions rather than content and the solution was improper; The bifactor model is not retained because its general factor accounted for only 20.1% of common variance

.87 and kurtosis between minus .23 and .54, indicating no substantial departure from normality.

### Content Validity and Measurement Model

Three items fell below the content validity criterion of .83, each with an item-level index of .67 and a modified kappa of .56: item A2, concerning knowledge of the seventeen sustainable development goals, item A5, concerning belief that one's own actions contribute to sustainable development, and item C5, concerning the encouragement of sustainable habits in others. For A5 and C5 the objection concerned the scope of the dimension label rather than the placement of the item, and the empirical structure supports that reading: they loaded .644 and .675, respectively on their own factor, with no secondary loading above .13. For A2 the objection concerned the specificity of the item itself and was accepted as such; it was retained on grounds of domain coverage set out in the method, and it loaded .715 on its own factor with no secondary loading above .10. Two dimension labels were revised as described in the method and all items were retained. Clarity was lowest for item D2, at .67, where panelists noted that the item combines lighting, recycling facilities and green space in a single judgement; this item is flagged for rewording in a subsequent version. Because the panel was convened after administration, none of these judgements could be acted on in the data reported here, and the instrument is presented as a provisional assembly requiring revision and independent re-administration rather than as an established measure.

Parallel analysis and Velicer's minimum average partial test both indicated five factors, and the polychoric eigenvalues dropped from 2.49 for the fifth factor to 0.70 for the sixth. The five-factor ESEM solution fitted the data well, with a scaled Chi-square of 268.02 on 185 degrees of freedom, CFI = .991, TLI = .985, RMSEA = .027 with a 90% CI of [.020, .034], and SRMR = .022.

Standardized primary loadings ranged from .644 to .967 and all were significant at  $p < .001$ . The structure showed a clear simple pattern: across all 125 loadings the largest secondary loading was .143. Correlations among the five factors ranged from .057 to .214. Internal consistency was adequate for every dimension, with alpha coefficients between .834 and .851 and omega coefficients between .836 and .860. Full loading and reliability tables are provided in [Table S3](#), [Table S4](#), and [Table S5](#) in [Supplementary Material](#).

The correlations among the five factors, ranging from .057 to .214, are lower than would be expected among facets of a single higher-order construct and require comment. Two readings are available. The dimensions may be close to independent, in which case a single construct label is inappropriate. Alternatively the near-orthogonality may be a consequence of the presentation format, since the items were administered in five visually separate blocks and respondents may have answered each block with reference to the block rather than to the item. These data cannot separate the two readings, and the matter is returned to the discussion.

**Table 2** compares the five-dimension solution with four alternatives. A six-factor ESEM fits marginally better on every index, which is expected in exploratory rotation because an additional factor cannot worsen fit, but the sixth factor carried no primary loadings and its largest values were negative on the first item of four dimensions and positive on the later items, that is, a contrast between item positions rather than a substantive factor. The solution was also improper, with one standardized loading of 1.024 implying negative residual variance. A six-factor confirmatory model corresponding to a content-based reorganization of the items was clearly inferior. The bifactor model produced the best fit of all, yet the general factor accounted for only 20.1% of the common variance, with omega hierarchical of .504 for the total composite against subscale omegas

**Table 3.** Fit indices for one- through six-profile solutions (N = 597)

| Profiles | Log-likelihood  | AIC            | BIC            | SABIC          | Entropy     | Smallest class | BLRT p          |
|----------|-----------------|----------------|----------------|----------------|-------------|----------------|-----------------|
| 1        | -3,536.3        | 7,092.7        | 7,136.6        | 7,104.8        | -           | 100%           | -               |
| 2        | -3,335.0        | 6,711.9        | 6,804.1        | 6,737.5        | .732        | 36.7%          | < .01           |
| 3        | -3,289.2        | 6,642.4        | 6,782.9        | 6,681.3        | .782        | 12.4%          | < .01           |
| <b>4</b> | <b>-3,251.5</b> | <b>6,589.0</b> | <b>6,777.9</b> | <b>6,641.4</b> | <b>.791</b> | <b>12.4%</b>   | <b>&lt; .01</b> |
| 5        | -3,225.0        | 6,558.1        | 6,795.2        | 6,623.8        | .730        | 9.0%           | < .01           |
| 6        | -3,199.7        | 6,529.5        | 6,814.9        | 6,608.6        | .792        | 6.7%           | < .01           |

Note. The retained solution is shown in **bold**; BLRT: Bootstrapped likelihood ratio test; Results for all four covariance structures are given in [Supplementary Table S6](#)

**Table 4.** Dimension means by profile (N = 597)

| Profile                         | Knowledge | Education | Practices | Institution | Global | n (%)      |
|---------------------------------|-----------|-----------|-----------|-------------|--------|------------|
| 1. High comprehensive awareness | 3.96      | 3.91      | 3.92      | 3.91        | 3.98   | 219 (36.7) |
| 2. Moderate awareness           | 3.53      | 3.12      | 3.55      | 3.06        | 2.96   | 225 (37.7) |
| 3. Low practices and engagement | 3.55      | 3.31      | 1.92      | 3.36        | 3.31   | 79 (13.2)  |
| 4. Low personal knowledge       | 1.97      | 3.56      | 3.46      | 3.23        | 3.04   | 74 (12.4)  |

Note. Knowledge: Personal knowledge and efficacy; Education: Educational experience; Practices: Individual practices and engagement; Institution: Institutional perception; Global: Global concerns and ethics; The values are observed means of the groups formed by modal class assignment, not model-estimated class means; the two differ by at most 0.07 of a scale point on any dimension. Profiles are numbered in the order discussed in the text

between .652 and .735. Hence, it can be said that the instrument is multidimensional and that a total score is not interpretable; the five dimension scores were used in all subsequent analyses.

Measurement invariance was supported at the scalar level for every specification tested. The largest absolute change in CFI across the fifteen comparisons was .003, and every change in RMSEA was zero or negative. The full sequences are reported in [Table S7](#) in [Supplementary Material](#). Three qualifications limit what this establishes. The sequences were estimated on the independent clusters confirmatory model rather than on the ESEM, so they test invariance of a model that is not the one used to characterize the dimensions. For first encounter the test was conducted on the two-category collapsed version of the variable, whereas we compare four categories, so equivalence across those four categories has not been demonstrated. For academic year the test was conducted on items whose two lowest response categories had been merged, which is not the scoring used elsewhere. In addition, changes in fit indices within the adopted cut-offs are evidence against substantial differential item functioning in the aggregate, not proof of its absence at the level of individual items. The dimensions can therefore be regarded as measured equivalently across the groups and under the scoring actually tested, and the untested gaps are recorded as a limitation.

### Determination of the Number of Profiles

**Table 3** presents the enumeration results for the model with varying variances and covariances fixed to zero, which produced the lowest BIC of all 24 solutions examined. Because the default initialization of this model class is deterministic and was found to converge on a suboptimal solution, every solution reported here

was selected as the best of 800 starting values under the screening described in the method. The indices do not converge on a single answer. The BIC reached its minimum at four profiles, 5.0 points below the three-profile solution and 17.3 points below the five-profile solution, so unlike the AIC and the sample-size-adjusted BIC it does identify an optimum interior rather than improving indefinitely. The AIC and the sample-size-adjusted BIC continued to improve through six profiles, and the bootstrapped likelihood ratio test, computed with 100 replications, was significant at every step including six profiles against five, so neither provided a stopping rule. The size of the smallest class fell from 12.4% at four profiles to 9.0% at five and 6.7% at six. Entropy was .791 at four profiles and did not improve materially thereafter.

The four-profile solution was retained on the basis of the BIC minimum, the size of the smallest class, and the interpretability of the resulting profiles. The adjacent three-profile solution was examined as a sensitivity analysis. It reproduced the high comprehensive awareness and low practices and engagement profiles almost exactly, with 218 of 219 and 73 of 79 cases, respectively and merged the moderate awareness and low personal knowledge profiles into a single class of 305. Because that merger averages away a configuration in which personal knowledge sits at the floor of the scale while educational and institutional perceptions sit near the sample mean, the four-profile solution was preferred. Classification quality was adequate, with average posterior probabilities of .870, .885, .899 and .894 for the four profiles, all above the .80 criterion.

### Sustainability Awareness Profiles

**Table 4** presents the dimension means for each profile, and [Figure 1](#) displays their trajectories.

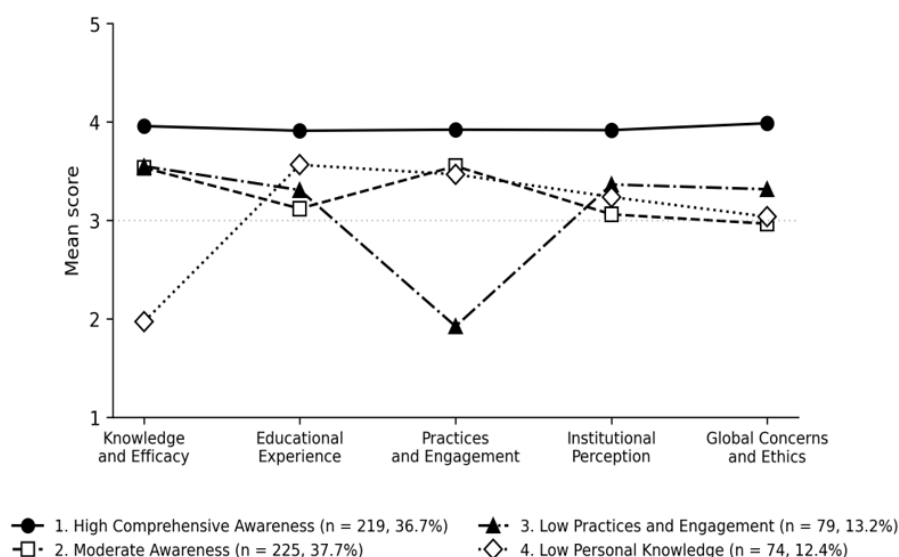


**Figure 1.** Dimension means by profile (created by the authors)

Profile 2, moderate awareness, is the largest group at 37.7% and sits near or below the sample mean throughout, though not uniformly: personal knowledge and individual practices (3.53 and 3.55) stand above educational experience, institutional perception and global concerns (3.12, 3.06 and 2.96). Profile 1, high comprehensive awareness, is almost as large at 36.7% and follows a high and level trajectory across all five dimensions, with means between 3.91 and 3.98 and no dimension distinguishing it from the others. Together these two groups account for nearly three-quarters of the sample and differ mainly in level rather than in shape.

The two smaller profiles are distinguished by shape rather than level. Profile 3, low practices and engagement, comprises 13.2% of the sample and reports individual practices at 1.92 while its other four dimensions range from 3.31 to 3.55, at or slightly above the sample mean. Profile 4, Low Personal Knowledge, comprises 12.4% and reports personal knowledge and efficacy at 1.97 while its other four dimensions range from 3.04 to 3.56. Each is therefore defined by a single dimension at the floor of the scale against an otherwise unremarkable profile, and the two deficits are on different dimensions.

The deficits that define the third and fourth profiles are carried by the whole dimension rather than by any single item. For students in the low practices and engagement profile the first practices item averages 1.75 and the remaining four average 1.97; for students in the low personal knowledge profile the first knowledge item averages 1.78 and the remaining four average 2.01. In every non-deficit block of both profiles the first item stands between 0.58 and 0.88 of a scale point above the remaining four, whereas inside the deficit block it falls 0.22 and 0.23 of a point below them, which is the ordinary pattern described below, so the reversal within the deficit block is not an artefact of that pattern. These

profiles therefore describe a consistent position across a dimension rather than an isolated response to one item.

### Sensitivity of the Profile Structure to Item Position

The first item presented in each dimension attracted substantially higher endorsement than the remaining four, with differences between 0.51 and 0.56 of a scale point and between 23 and 28 more percentage points selecting 4 or 5. The same first items also carried the highest loadings in the ESEM solution, between .883 and .967 against .644 to .754 for the remaining twenty items. Because item order was fixed and the dimensions were presented as visually separated blocks, construct and presentation format are confounded in this design.

To assess the consequences, the dimension scores were recomputed from the remaining four items and the enumeration was repeated under the same multi-start procedure. Under this specification the Bayesian information criterion reached its minimum at two profiles rather than four, and entropy for the four-profile solution fell from .791 to .569. Forcing a four-profile solution and matching it to the retained solution through optimal assignment yielded agreement of 61.0%, and none of the four deficit or high-level patterns was reproduced in recognizable form. The reduction in reliability that accompanies this operation was quantified rather than assumed. Removing the first item lowers coefficient alpha to between .774 and .803 across the five dimensions, with a mean of .785, against .834 to .851 for the full five-item scores. Removing any one of the other four items lowers alpha to a mean of .812, with the individual means for removing the second, third, fourth and fifth items being .809, .806, .816 and .816. The first item is therefore the single most costly item to remove in every dimension, but the additional cost relative to the average alternative removal is .027 of a reliability coefficient, which is small. Shortening each

**Table 5.** Association between profile membership and demographic variables (N = 597)

| Variable        | $\chi^2$ modal | df | p    | Cramér's V | 95% CI       | $\chi^2$ BCH | p    |
|-----------------|----------------|----|------|------------|--------------|--------------|------|
| Gender          | 2.82           | 3  | .421 | .069       | [.030, .166] | 3.82         | .282 |
| Age group       | 9.50           | 6  | .147 | .089       | [.061, .163] | 13.19        | .040 |
| Faculty         | 11.06          | 12 | .524 | .079       | [.072, .151] | 14.51        | .269 |
| Academic year   | 11.40          | 9  | .249 | .080       | [.065, .144] | 14.64        | .101 |
| First encounter | 4.43           | 9  | .881 | .050       | [.048, .123] | 5.91         | .749 |

Note. Modal: Chi-square computed on modal class assignment; BCH: Bolck, Croon, and Hageaars three-step weighting, which corrects for classification error; The smallest expected cell frequency under modal assignment was 8.1; The four categories of first encounter are retained here, whereas the invariance test for this variable used the collapsed two-category version

score from five items to four is thus a genuine but modest part of the explanation, and because content, position and score length change together this diagnostic cannot isolate a position effect from a content effect. What it does establish is that the four-profile structure reported here is conditional on the full item set as administered, and that replication with randomized item order is necessary before the structure can be treated as a property of the construct rather than of the instrument. The comparison of all five single-item removal sets is reported in [Table S15](#) in [Supplementary Material](#), and the remaining figures in [Table S8](#) and [Table S10](#) in [Supplementary Material](#).

A second sensitivity analysis removed the three items that fell below the content validity criterion and repeated the analysis on the remaining twenty-two. The measurement model was unaffected, with five factors again indicated and a largest secondary loading of .126, though internal consistency for personal knowledge and efficacy fell from .834 to .771 with three items remaining. The profile solution was again perturbed. The BIC now favored three profiles rather than four; forcing four gave agreement of 77.4% with the retained solution under optimal matching and entropy of .671. The low practices and engagement profile survived with its deficit intact, but the low personal knowledge profile did not, its defining dimension rising from 1.97 to 2.89 once two of its five items were removed. Taken with the item-position diagnostic, two independent perturbations of the item set both altered the profile structure, and the four profiles reported here are accordingly a description of this sample under this instrument rather than an established typology. Details are given in [Table S12](#) in [Supplementary Material](#).

### Sensitivity of the Profile Solution to Starting Values

The profile solution reported above required a departure from the default estimation procedure, and the reason is reported here because it bears on how the solution should be read. Mixture models of this class are commonly estimated with a deterministic initialization derived from model-based agglomerative hierarchical clustering, which returns the same answer on every run. That reproducibility is a property of the initialization rather than evidence that the solution is well determined. Re-estimating the same model on the same

data from 800 starting values located a better-fitting solution, with a log-likelihood of -3251.5 against -3258.9 for the default and the same 43 free parameters, giving a BIC of 6777.9 against 6792.6. The better solution was returned by 144 of 790 admissible starts and was the modal outcome; the default solution is a genuine local optimum, since starting the algorithm from its own class assignments returns to it. The same was true for three profiles.

The two solutions do not agree substantively. Agreement under optimal one-to-one assignment is 72.9%, and the default solution contains a profile characterized by institutional perception at the floor of the scale which the better-fitting solution does not recover, its members distributing across the moderate and deficit profiles. The solution reported in this paper is the better-fitting one throughout, and every enumeration figure in [Table 3](#) was obtained under the same multi-start procedure.

Two implications follow. The first is practical: the number of profiles is better determined under multi-start estimation than it appeared under the default, since the BIC now shows an interior minimum rather than a shallow one. The second is a caution. If the substantive description of a sample can turn on the starting values of an estimation algorithm, then a profile solution reported without evidence that the optimum has been located is weaker evidence than it appears, and this applies to the present solution as much as to any other. We report the comparison so that readers can see how much of the interpretation rests on the optimization, and we regard it as a further reason, alongside the item-order confound, to treat these profiles as provisional pending independent replication.

### Profile Membership and Demographic Variables

[Table 5](#) presents the relationship between profile membership and the five demographic variables. Under modal class assignment none of the five was significantly associated with profile membership, and Cramer's V ranged from .050 to .089. Because entropy of .791 implies classification uncertainty that modal assignment discards, the analyses were repeated using BCH weighting. This raised every Chi-square value, and for age group the association reached the conventional threshold, Chi-square = 13.19, df = 6, p = .040, where the

modal test had returned  $p = .147$ . Three considerations bear on how much weight that single result can carry. It is one of five tests and is not corrected for multiple comparisons. It is not reproduced under modal assignment. And, as stated in the method, the weighted test is an approximate procedure whose reference distribution remains the nominal Chi-square rather than one derived from a full likelihood-based three-step model. It is reported here rather than suppressed, but it is treated as a signal worth testing in a replication rather than as an established age effect. The full cross-tabulations underlying the table are given in [Table S17](#) in [Supplementary Material](#).

The equivalence analysis places a bound on what these results mean. Across the five tests of profile membership the upper limit of the 95% bootstrap interval for Cramer's  $V$  ranged from .123 to .166, so associations of medium size or larger, which for four profiles begin at .17, can be ruled out, and this holds for age group as well as for the four null comparisons. At the level of the dimension means, of the twenty five analyses of variance twenty four returned no significant difference. The exception was personal knowledge and efficacy across academic year,  $F(3, 593) = 2.99$ ,  $p = .030$ , eta squared = .015, confirmed under unequal variances by the Alexander-Govern test,  $p = .026$ ; it is likewise uncorrected for multiple testing, and one significant result in twenty five is close to chance expectation. Across all twenty five comparisons eta squared ranged from .000 to .015 and the upper limit of the 90% CI reached .031 at its highest, which corresponds to an  $f$  of .18, so effects of medium size, an  $f$  of .25, are excluded throughout. The full table of twenty five comparisons is given in [Table S16](#) in [Supplementary Material](#). What these analyses support is therefore the absence of demographic associations of practical size, with two uncorrected marginal results that a replication should examine, rather than the absence of any demographic association whatsoever.

## DISCUSSION

This study examined undergraduate students' perceptions of sustainability across five dimensions and identified individual differences through a person-centered approach. Sustainability awareness proved to exist not at a single level but in qualitatively distinct patterns, and those patterns did not follow the demographic lines along which the field has conventionally searched for them.

Four profiles emerged, and the two largest differ mainly in level. The high comprehensive awareness profile follows a high and level trajectory across all five dimensions, and the moderate awareness profile sits near or below the sample mean throughout, with personal knowledge and individual practices somewhat above educational experience, institutional perception

and global concerns. Together they account for nearly three-quarters of the sample. The two smaller profiles differ in shape rather than level, each defined by one dimension at the floor of the scale against an otherwise ordinary configuration, and the dimensions concerned are different ones.

Read through the whole institution framework, and within the operational definition of coherence given in the Introduction, the profiles represent different relations between what students report of institutional and curricular provision and what they report of their own knowledge and practice. These are readings of score configurations rather than observations of provision, and they are offered as interpretations to be tested rather than as findings. The high comprehensive awareness configuration is one in which the two sets of reports correspond at a high level. In the moderate awareness configuration, personal knowledge and practice sit above perceived provision. The correspondence therefore holds at a lower level, with the institutional side the weaker of the two. Sevim and Pala (2026) compared Turkish and German students and found engagement linked more strongly to the perceived institutional role than to specific campus practices, so what this configuration registers may be the visibility of institutional commitment rather than its extent. The two deficit configurations are the ones in which the sets diverge, and they diverge in opposite directions: in low practices and engagement personal knowledge and perceived provision are intact while practice is on the floor, and in low personal knowledge perceived provision and practice are intact while knowledge is on the floor. Holst (2023) describes the object of a whole institution approach as coherence between the formal and the informal curricula. What these configurations suggest is that the correspondence students report between provision and their own position is not a single institutional state but takes several forms within one university, and that an institution-level average would report one number and conceal all of them. Whether any of these configurations reflects the institution's actual provision cannot be determined here, since provision itself was not measured and no institutional self-assessment was obtained.

The two smaller profiles are the more informative ones, since each is defined by a deficit on a single dimension while the remainder sit near the sample mean. Students in the low personal knowledge profile report educational experience and institutional perception at or above average while personal knowledge falls to the floor. One reading is that exposure reported in educational and institutional contexts has not become internalized knowledge, which is the configuration the whole institution literature would predict where provision exists but is not taken up; the data are consistent with that reading without establishing it, since exposure itself was not measured

independently of the student's report. Students in the low practices and engagement profile present the complementary case, reporting knowledge, educational experience and institutional perception near or above the mean while individual practices fall to the floor. This is the configuration the knowledge-to-behavior literature describes. Kollmuss and Agyeman (2002) argue that linear models assuming knowledge translates into behavior are fallacious, and Steg and Vlek (2009) note that the same person may be inconsistent across behavioral domains. Shafiei and Maleksaeidi (2020) add that students may express interest in sustainability yet be unable to act on it, citing practical constraints, established habits and declining motivation. None of this is established here: no behavior was observed, and the practices score combines reported habit, willingness and advocacy, so the configuration is a pattern consistent with those arguments rather than evidence that translation has failed in any individual. The labels used for both profiles describe the position of a self-report score and should not be read as establishing factual ignorance, passivity, or an absence of action.

Both deficits are carried by the whole dimension rather than by any single item, which matters for their interpretation. For students in the low practices and engagement profile the mean of the four practices items after the first is 1.97, and for students in the low personal knowledge profile the mean of the four knowledge items after the first is 2.01. In both cases the first item of the deficit block sits below the remainder, at 1.75 and 1.78, respectively, reversing the pattern found in every other block, which is how a highly discriminating item behaves at the lower end of a distribution. These profiles therefore describe a consistent position across a dimension rather than an isolated response to one item.

The absence of any significant association between profile membership and the five demographic variables is the finding that most requires interpretation. Three complementary lines of evidence bear on it, and they are complementary rather than independent, since all three are computed on the same respondents, the same instrument and the same administration, so an artefact common to the instrument would affect all three together. Measurement invariance was established at the scalar level for every specification tested, which weighs against an explanation in terms of differential item functioning without excluding it; the test was conducted on a confirmatory rather than an ESEM specification, on collapsed categories for two of the five variables, and at the level of aggregate fit rather than individual items, so differential functioning that is item-specific or confined to the untested categories remains possible. Dimension means differed in only one of twenty five comparisons, with eta squared between .000 and .015 and an upper confidence limit of .031 at its highest, so effects of medium size are excluded. And profile membership itself showed no significant association with the

grouping variables under either modal assignment or the BCH weighting, although four of the five BCH probabilities fell between .06 and .10, so the evidence is of no association of practical size rather than of no association whatsoever. Helm et al. (2022) reported a comparable result, finding that profile membership in their study was associated with environment-specific rather than general demographic factors. It is not possible to generalize about the effect of demographic characteristics on awareness patterns from a single sample. What can be said is that no association of practical size was detected at any of the three levels examined. Whether psychological variables such as personal values or motivation account for profile membership is a question this design cannot answer. Perceived efficacy is the one such variable that was measured, by item A5, but it is a constituent of one of the profile indicators and cannot therefore serve as an independent predictor of the profiles it helps to define; establishing its role would require an external efficacy measure administered alongside the instrument. This is offered as a direction for research rather than as an inference from these data.

Comparison with Aleixo et al. (2021) is instructive, and the comparison has become more informative than it first appeared. Their hierarchical cluster analysis of Portuguese students produced four clusters from five factors, and the present analysis also retains four profiles, but the correspondence should not be pressed. Cluster analysis of the kind they used has no model-based criterion for the number of groups and no measure of classification uncertainty, and the present study found that even a model-based procedure with an established default can settle on a suboptimal solution. What the two studies share is the finding that student perceptions of sustainable development are patterned rather than uniform. Whether the particular patterns correspond across the two national contexts is not something either study can establish on its own.

Several limitations qualify these findings. The data were collected from students at a single university using a cross-sectional design and from a self-selected volunteer sample for which no response rate can be computed, which limits generalizability and leaves open the possibility that students with an interest in sustainability were more likely to respond. The instrument relies on self-report, and subjective and objective knowledge do not always coincide (Liobikiene & Poskus, 2019); Heeren et al. (2016) report that students' confidence about sustainability concepts may exceed their actual knowledge, so the mean on personal knowledge should be read as a self-perception. The instrument contains no reverse-worded items, so acquiescent responding was uncontrolled, and because the form did not restrict respondents to a single submission, repeated participation cannot be excluded by design. A further limitation concerns item

presentation. The items were administered in five visually separate blocks in a fixed order, and the first item of each block attracted markedly higher endorsement than the remaining four, with differences between 0.51 and 0.56 of a scale point. Because construct and presentation format are confounded in this design, the recovered structure requires replication with randomized item order; the consequences of this confound are reported in the Findings and in [Table S8](#), [Table S10](#), and [Table S15](#) in [Supplementary Material](#). Two explanations for the pattern that the present data cannot separate should be named. A primacy or anchoring effect, in which the first item of a block is answered more readily and more positively than those that follow, and a content explanation, in which the first item of each block happens to be the most general and therefore the most endorsable statement in its set, both predict what was observed. Distinguishing them requires an administration in which order is randomized while content is held constant. Finally, the content validity panel was drawn from curriculum and instruction, educational sciences and language education, and included no specialist in sustainability content and no psychometrician. The panel was therefore well placed to judge wording, answerability and educational fit, but less well placed to judge whether the five dimensions cover the sustainability domain adequately, and its judgements were collected after administration rather than before, so none of them could be acted on in the version students completed. Three items fell below the retention criterion, and the objections raised to them, that A5 measures perceived efficacy rather than knowledge, that C5 measures interpersonal advocacy rather than personal habit, and that A2 measures familiarity with a specific policy framework, indicate revisions that a subsequent version of the instrument should incorporate. No pilot administration or cognitive interviewing was conducted. For all of these reasons the contribution of this study is exploratory, and both the instrument and the profile structure are presented as provisional and in need of independent replication rather than as established.

## CONCLUSION

The findings reveal that sustainability awareness is distributed among students not at a uniform level but in distinct patterns. The classification of students into four profiles on the basis of their scores across five dimensions demonstrates that groups with similar overall levels may sit at the floor of the scale on different dimensions, a diversity that the averages produced by variable-centered approaches conceal. Demographic variables showed no association of practical size with profile membership: all five comparisons were null under modal assignment, one of five reached the conventional threshold under the approximate weighted

analysis without being reproduced under modal assignment, and the equivalence bounds exclude associations of medium size throughout. That result constrains what can be concluded rather than supplying an alternative explanation. No comparative test of demographic against psychological predictors was conducted here, because no psychological variable was measured independently of the profile indicators, and the relative explanatory value of the two classes of variable therefore remains an open question for designs that measure both.

This study is an attempt to measure sustainability awareness multidimensionally and to analyze it through a person-centered approach. Because each profile represents a different configuration of scores, each suggests a different pedagogical response, and the responses are not interchangeable. The proposals that follow are hypotheses for evaluation rather than findings, since the present design measures perceptions at one point in time and tests no intervention; what the data establish is that the configurations differ, not that any particular response to them would work. For the low personal knowledge group, the configuration suggests that what is absent is the link between institutional practice and personal meaning rather than exposure as such, and a testable response would be assessment requiring students to analyze their own institution's sustainability performance through the concepts of their discipline, following the argument of Hopkinson et al. (2008) that campus decisions should be treated as educational opportunities. Whether additional exposure would help this group is not established by these data and would itself have to be tested. For the low practices and engagement group, knowledge and perceived provision are present while reported practice is not; Olsson et al. (2020) locate the difference in confidence in one's own influence and willingness to act, which are developed through action-oriented teaching rather than through additional content, and that proposition is testable here but untested. For the moderate awareness group, the largest at more than a third of the sample, the institutional and educational dimensions sit below the personal ones, and Torsdottir et al. (2024) identify distinct pathways through which students experience participation, whether leadership, teaching, community connection or formal representation, which offers a candidate diagnostic for where the shortfall lies; whether the shortfall is in provision or in its visibility cannot be separated here, since no measure of actual provision was obtained. The high comprehensive awareness group represents a potential resource, and its members are plausible candidates for the peer roles that a participative whole institution approach requires. Each of these proposals specifies an intervention and an outcome that a pilot study could evaluate: a discipline-anchored campus audit assignment evaluated against change in the personal knowledge dimension, action-

oriented teaching evaluated against change in practices and in an external measure of action competence, and an institutional communication or participation intervention evaluated against change in institutional perception. Until such evaluations exist, profile membership should not be used to allocate educational support to individual students, since the classification has not been validated against any outcome, its stability across administrations has not been established, and the present study has shown it to be sensitive both to the composition of the item set and to the starting values of the estimation.

Three priorities follow for future research, and the first two should precede any applied use of the profiles. The instrument requires re-administration with randomized item order and independent validation in a separate sample, since the structure reported here was recovered from the same respondents whose data defined it and a further model fitted to those same respondents would not constitute validation. Profile membership requires replication before it is treated as a stable property rather than a description of this sample. Beyond these, psychological variables predicting profile membership should be measured externally to the instrument, and longitudinal designs should track whether students move between profiles over the course of a degree. Replication in other institutional and national contexts would establish how far the profiles identified here are contextual.

**Author contributions:** **AKP:** conceptualization, methodology, project administration, supervision, writing – original draft, writing – review & editing; **IKP:** conceptualization, formal analysis, investigation, methodology, visualization, writing – original draft; **ZKK:** conceptualization, formal analysis, methodology, visualization, writing – review & editing; **BRK:** formal analysis, investigation, writing – original draft, writing – review & editing; **SZS:** methodology, visualization, writing – original draft, writing – review & editing; **ÚAU:** investigation, visualization, writing – original draft, writing – review & editing. All authors agreed with the results and conclusions.

**Funding:** No funding source is reported for this study.

**Ethical statement:** This study was approved by the Ethics Committee at Nukus State Pedagogical Institute. Participation was voluntary and no incentive was offered. The first item of the online instrument presented a description of the study and asked participants to indicate whether they consented to take part; those who declined were directed out of the survey. No identifying information was collected, and responses were stored and analyzed only in aggregate form. All participants gave informed consent before taking part.

**AI statement:** AI-powered (Claude Opus 5) tools were used solely for proofreading, grammar checking, and editing to enhance the clarity and readability of the final text. All intellectual content, interpretations, conclusions, and scientific contributions are the sole responsibility of the authors.

**Declaration of interest:** No conflict of interest is declared by the authors.

**Data sharing statement:** Data supporting the findings and conclusions are available upon request from the corresponding author.

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