Consistent Positive Associations and Method-Dependent Rankings of Perceived Biophilic Dimensions in Four Ugandan Primary Schools

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ABSTRACT

Evidence from Sub-Saharan African primary schools remains limited concerning how different biophilic environmental dimensions relate to pupil well-being. This exploratory secondary analysis used 302 questionnaire records from four purposively selected government-sponsored primary schools in Mukono District, Uganda. Eight Emotional and Social Environment (ESE) items formed the outcome; Nature in the Space (NIS), Sensory Nature Stimuli (SNS), Nature of the Space (NOS) and Natural Analogues (NA) formed study-specific perceived-environment composites. All four domains showed positive bivariate associations with ESE (Spearman rho=.362-.425, all p<.001), providing a consistent overall pattern. In simultaneous regression, the domains jointly explained 26.6% of variance (adjusted R2=.256); NA (B=.175, p<.001) and NIS (B=.162, p=.003) retained unique associations. A school-fixed-effects sensitivity model, with School A as the reference and indicators for Schools B-D, supported NIS, NA and NOS after absorbing mean differences among the four institutions. Adding age retained the same three domains. ESE reliability was modest (alpha=.568), but a seven-item sensitivity analysis retained the central NIS and NA findings. The changing rank across analytical criteria is a substantive contribution: it indicates that several biophilic dimensions may contribute complementarily rather than forming a single universal hierarchy. Within the four participating schools, the findings support a multidimensional, context-sensitive approach and identify direct nature, spatial qualities and nature-referencing interiors as promising candidates for future intervention studies. Replication with validated measures, more institutions and age-appropriate sampling is required before wider design priorities are proposed.

Keywords: biophilic design; learning environments; pupil well-being; Uganda; environmental perception; model dependence

INTRODUCTION

School buildings shape more than the delivery of lessons. Daylight, ventilation, vegetation, views, materials and spatial qualities can influence whether pupils experience classrooms as comfortable, legible, stimulating or restorative. Biophilic design brings these features into one design framework by connecting built environments with natural elements, processes and spatial experiences (Browning et al., 2014; Kellert, 2018; Ryan et al., 2014). Research generally associates children's contact with nature with well-being and restoration, although effect sizes vary with the exposure, outcome and context examined (Arola et al., 2023; Chawla, 2015; Fisher, 2024).

What remains unresolved is how this evidence should guide priorities in ordinary, resource-constrained schools. Much biophilic-design research comes from comparatively well-resourced settings, while African evidence remains limited and often concerns universities or purpose-designed environments rather than public primary classrooms (Umeora et al., 2025). Ugandan education research has more commonly examined access, staffing and basic infrastructure, including overcrowding, lighting and ventilation (Asad, 2021; Ngware et al., 2016). Consequently, neither the relative relevance of different biophilic dimensions nor the transferability of constructs developed elsewhere can be assumed.

The policy context makes this question timely. The East African Schools Design Guide, developed through fieldwork in Uganda, recognises respect for nature and biodiversity as a school-design principle (Feilden Foundation, 2024). However, intentional biophilic provision is not yet a routine requirement in government-sponsored primary schools, so natural qualities often occur incidentally and unevenly. Mukono District provides an informative setting because rapid urbanisation coexists with rural and peri-urban communities (Mukono District Local Government, 2019; Uganda Bureau of Statistics, 2017). The four schools in this study represented one rural, two peri-urban and one urban setting.

For decision-makers, an important question is whether one environmental dimension should be prioritised or whether several dimensions make complementary contributions. Although this four-school dataset cannot establish investment priorities for Uganda or Sub-Saharan Africa, it can provide useful evidence on two linked issues: whether the domains show a consistent positive relationship with well-being, and whether their relative ordering remains stable when shared variance and school membership are handled differently. A bivariate association may change when overlapping domains enter the same model, while adjustment for school mean differences may reveal a different within-school pattern. Examining both convergence and variation therefore produces a more informative account than selecting a single leading domain.

The present analysis uses the same 302 pupil questionnaire records, the same eight ESE items and the same four perceived-environment item sets used in Marete (2025). The earlier article combined questionnaire and qualitative findings to address the broad relationship between perceived biophilic environments and well-being and reported an overall regression model. It did not compare bivariate, simultaneous and school-adjusted domain rankings, report ESE item diagnostics, or test age sensitivity. The present paper is therefore a transparent secondary reanalysis of overlapping measures, not an independent sample or replication. Composite scores were reconstructed directly from the archived item-level workbook using the scoring rules reported below. The estimates in this paper should be evaluated as the results of that specified reanalysis and should not be combined with the earlier estimates as independent evidence.

Within these four participating schools, the study asked: (1) how strongly was each perceived biophilic domain associated with ESE; (2) which domains retained unique associations when considered simultaneously; (3) how did the relative ordering change after adjustment for school mean differences; and (4) were the conclusions sensitive to ESE item composition and pupil age? By examining the consistency of direction alongside the stability of ranking, the study aimed to identify robust patterns that can inform future intervention research without treating this small institutional sample as a basis for national or regional priorities.

CONCEPTUAL AND ANALYTICAL RATIONALE

Nature in the Space (NIS) represents relatively direct experiences, including vegetation, daylight, views and air movement. Sensory Nature Stimuli (SNS) captures natural sound, scent, touch and thermal variation. Nature of the Space (NOS) concerns prospect, refuge, mystery, movement and legibility. Natural Analogues (NA) captures indirect evocations of nature through materials, colour, imagery, furniture and spatial arrangement. The groupings were adapted from established biophilic frameworks to language and conditions familiar to Ugandan primary pupils. They are therefore study-specific perceived-environment composites, not universal or fully validated scales.

Attention Restoration Theory and Stress Recovery Theory suggest that natural qualities can support effortless attention, emotional recovery and reduced stress (Kaplan, 1995; Ulrich et al., 1991). These mechanisms justify expecting positive associations, but they do not predict a fixed rank among multidimensional environmental qualities. Classroom experience is also shaped by teaching, peers, age, school organisation and settlement context. The analytical expectation was therefore convergence in direction, accompanied by possible variation in relative ordering across models.

METHODS

Design, setting and participants

This cross-sectional secondary analysis used questionnaire data collected within a convergent mixed-methods doctoral study in four purposively selected government-sponsored primary schools in Mukono District. Schools A and B were peri-urban, School C urban and School D rural. The item-level workbook contained 302 complete records: A=23, B=101, C=106 and D=72. Participants were aged 9-17 years (M=12.62, SD=1.16): 1 was aged 9, 6 were 10, 35 were 11, 101 were 12, 102 were 13, 43 were 14, 10 were 15, 1 was 16 and 3 were 17. The broad range reflects the archived survey sample and was not an intended age-stratified design. Because developmental and grade-placement differences could influence response interpretation, age was examined through correlation, covariate adjustment and a restricted 11-13-year sensitivity analysis. The four schools were selected for contextual variation and are not statistically representative of settlement categories, Uganda or Sub-Saharan Africa.

Relationship to Marete (2025). Both papers use the same 302 questionnaire records, ESE outcome items and four perceived biophilic item sets. Marete (2025) answered the broader mixed-methods question of whether perceived biophilic environments were related to pupil well-being and integrated qualitative findings. The present secondary reanalysis asks whether domain ordering is stable across bivariate, simultaneous and school-adjusted criteria, and adds item-level reliability and age sensitivity checks. It introduces no new participants and does not treat overlapping positive associations as independent confirmation. The current composites and models were recomputed directly from the archived item-level workbook using the procedures specified here.

Measures and data quality

Pupils answered 50 statements on a five-point scale from 1 (strongly disagree) to 5 (strongly agree). The questionnaire was developed for the doctoral study rather than adopted as a previously validated scale. ESE items were written with reference to the Positive Emotion and Relationships dimensions of the PERMA framework and addressed classroom welcome, expression of ideas, peer relations, teasing, comfort, temperature, lighting and safety. The perceived-environment items were mapped to Kellert's biophilic framework and related design patterns, then organised as NIS (10 items), SNS (10), NOS (13) and NA (9). Wording and sequencing were refined after piloting with 11-12-year-old pupils; the pilot indicated that simpler language and oral administration were needed, and pilot records were excluded from the present dataset. During the main study, items were administered orally to support comprehension. No items were reverse-scored. For each construct, the pupil's score was the arithmetic mean of its completed items: ESE (8), NIS (10), SNS (10), NOS (13) and NA (9). All records were complete and within the 1-5 response range.

Validity evidence is limited. Content representation was supported by the explicit mapping of ESE items to the selected PERMA dimensions and environmental items to the biophilic framework, while pilot testing provided evidence about comprehensibility and administration feasibility. The consistent positive correlations between all four environmental composites and ESE offer preliminary evidence of theoretically expected relationships, but they do not establish factorial, convergent or discriminant validity because all measures were collected from the same respondents at one time. No confirmatory factor analysis, criterion validation or measurement-invariance test was available. The four environmental scores and ESE should therefore be treated as study-specific composites rather than validated universal scales.

Internal consistency was ESE alpha=.568, NIS alpha=.715, SNS alpha=.726, NOS alpha=.704 and NA alpha=.718. The overall 50-item alpha was not used as evidence for the separate constructs because combining heterogeneous domains can conceal weak subscale performance. For ESE, corrected item-total correlations and alpha-if-item-deleted values were examined. The weakest item was 'There is little teasing in my classroom' (corrected item-total r=.104); omitting it increased alpha only from .568 to .598. Because removing an item after inspecting the same sample can capitalise on chance and narrow content coverage, the eight-item ESE remained the primary outcome. A seven-item score excluding that item was used only as a sensitivity analysis.

Analysis

Domain means and standard deviations were calculated from pupil-level composite scores. Spearman correlations described monotonic bivariate associations. The primary ordinary least-squares model entered NIS, SNS, NOS and NA simultaneously. Standardised coefficients were used only for within-model comparison, and variance-inflation factors assessed collinearity. The school-fixed-effects sensitivity model added three indicator variables for Schools B, C and D, with School A as the reference, together with the four pupil-level domain scores. The domain coefficients therefore describe associations among pupils within the same school after absorbing observed school mean differences, under the restrictive assumption that each domain has the same slope in all four schools. They are not estimates of school-level or settlement effects. HC3 heteroskedasticity-consistent standard errors were used. With only four institutions, school fixed effects consume degrees of freedom, cannot control unmeasured pupil-level confounding, do not estimate a population distribution of schools, and cannot support reliable cluster-robust or multilevel inference. Age sensitivity analyses added age as a linear covariate to the simultaneous and school-fixed-effects models and repeated the school-adjusted model among pupils aged 11-13 years. Measurement sensitivity repeated the models with the seven-item ESE score. All analyses remain exploratory.

Ethics

Permission was obtained from the Maseno University School of Graduate Studies and the Uganda Christian University Research Ethics Committee (UG-REC-026), together with relevant education and school authorities. Parents or guardians provided informed consent, and pupils provided verbal and written assent after receiving age-appropriate information about voluntariness, confidentiality and withdrawal. School and pupil identifiers were anonymised.

RESULTS

Table 1. Descriptive statistics and internal consistency

Domain	Items	Mean	SD	α
Emotional and Social Environment	8	3.87	0.63	.568
Nature in the Space	10	3.62	0.74	.715
Sensory Nature Stimuli	10	3.59	0.77	.726
Nature of the Space	13	3.59	0.67	.704
Natural Analogues	9	3.47	0.83	.718

Note. N=302. Means and SDs are based on pupil-level composite scores, not item-level dispersions.

Table 2. ESE item diagnostics

Item	Abbreviated content	Mean	SD	Corrected item-total r	Alpha if deleted
Q1	Classroom welcoming and friendly	4.2	1.15	0.362	0.509
Q2	Safe to express ideas	4.01	1.17	0.197	0.558
Q3	Gets along with classmates	3.79	1.24	0.232	0.548
Q4	Little teasing in classroom	3.05	1.46	0.104	0.598
Q5	Comfortable in classroom	4.14	1.27	0.392	0.495
Q6	Classroom temperature comfortable	3.44	1.43	0.212	0.559

Q7	Classroom lighting sufficient	4.15	1.15	0.44	0.484
Q8	Feels safe in classroom	4.19	1.16	0.34	0.515

Note. N=302. Full item wording is retained in the study instrument. Overall eight-item ESE alpha=.568. Item-total correlations exclude the focal item.

All four domains were positively associated with ESE, establishing clear convergence in direction. The coefficients ranged from .362 to .425, indicating moderate and broadly comparable relationships rather than one isolated environmental influence. NA ranked first, followed by NOS, SNS and NIS; because the estimates were relatively close, the more important result was the shared positive pattern across all four dimensions.

Table 3. Spearman associations with Emotional and Social Environment

Domain	**ρ**	**p**
Natural Analogues	0.425	<.001
Nature of the Space	0.411	<.001
Sensory Nature Stimuli	0.377	<.001
Nature in the Space	0.362	<.001

Note. Two-sided tests; N=302.

The simultaneous model was significant, F(4,297)=26.85, p<.001, R2=.266, adjusted R2=.256, showing that the four perceived environmental domains jointly accounted for a meaningful proportion of variation in ESE. VIFs ranged from 1.45 to 2.15, indicating no severe multicollinearity. Once shared variance was considered, NA and NIS retained statistically reliable unique associations, while the contributions of NOS and SNS were largely shared with the other domains. This pattern supports a complementary-systems interpretation: pupils may experience direct nature, sensory qualities, spatial characteristics and interior analogues together, even though only some dimensions contribute unique variance in a simultaneous model.

Table 4. Simultaneous regression predicting Emotional and Social Environment

Predictor	**B**	**SE**	**β**	**p**	**VIF**
Nature in the Space	0.162	0.055	0.192	0.003	1.72
Sensory Nature Stimuli	0.072	0.057	0.089	0.211	2.04
Nature of the Space	0.122	0.069	0.129	0.077	2.15
Natural Analogues	0.175	0.045	0.231	<.001	1.45

Note. N=302. Unstandardized B, conventional SE and standardized β are shown.

In the school-fixed-effects model, School A was the reference and indicators represented Schools B-D. NIS (B=.219, HC3 p<.001), NA (B=.166, p<.001) and NOS (B=.142, p=.032) were positively associated with ESE; SNS was not independently supported (B=.082, p=.169). Adjusted R2 increased to .293. Thus, positive associations for three domains were evident even after mean differences among the four named schools were absorbed. NIS, which ranked fourth bivariately, had the largest school-adjusted coefficient, while NA remained consistently supported. These coefficients are conditional pupil-level associations within the participating schools; they neither estimate effects of school type nor generalise beyond the four institutions.

Age was weakly and negatively correlated with ESE (Spearman rho=-.130, p=.023) but was not significantly correlated with any environmental domain (absolute rho<=.089, all p>=.122). Adding age to the simultaneous model retained NA and NIS and produced adjusted R2=.268; age was negatively associated with ESE (B=-.066, HC3 p=.024). Adding age to the school-fixed-effects model again supported NIS (B=.210, p<.001), NA (B=.162, p<.001) and NOS (B=.145, p=.030), while SNS remained unsupported (B=.083, p=.160); age remained negative (B=-.075, p=.012) and adjusted R2=.307. Among the 238 pupils aged 11-13 years, NA remained supported, NIS was smaller, SNS was borderline and NOS was not supported. The persistence of NA and NIS across the principal age-adjusted models strengthens confidence in these two associations, while the restricted-age results appropriately temper claims about the precise ordering of the remaining domains.

When ESE was recomputed without Q4, NIS and NA remained supported in both simultaneous and school-adjusted models. This is an important robustness result because the two most consistent domains were not dependent on retaining the weakest ESE item. SNS remained unsupported, while NOS weakened from p=.032 to p=.069 in the school-adjusted model. The sensitivity analysis therefore strengthens the central NIS and NA findings while showing that conclusions about secondary domains remain responsive to outcome measurement when reliability is modest.

Table 5. Sensitivity of domain coefficients to school, age and ESE item composition

Analysis	**N**	**NIS B (p)**	**SNS B (p)**	**NOS B (p)**	**NA B (p)**	**Adjusted R2**
Primary simultaneous	302	.162 (.003)	.072 (.211)	.122 (.077)	.175 (<.001)	0.256
School fixed effects	302	.219 (<.001)	.082 (.169)	.142 (.032)	.166 (<.001)	0.293
School fixed effects + age	302	.210 (<.001)	.083 (.160)	.145 (.030)	.162 (<.001)	0.307
Ages 11-13, school fixed effects	238	.134 (.038)	.131 (.050)	.090 (.232)	.181 (<.001)	0.263
Seven-item ESE, school fixed effects	302	.253 (<.001)	.052 (.415)	.129 (.069)	.181 (<.001)	0.264

Note. HC3 p-values are shown in parentheses. School A was the fixed-effects reference. The age coefficient in the school-plus-age model was B=-.075 (p=.012). The seven-item ESE analysis omitted Q4 only as a diagnostic sensitivity check.

Table 6. How the leading biophilic dimension changed across analytical criteria

Criterion	First-ranked domain	Other supported domains	Interpretation
Bivariate association	Natural Analogues	NOS, SNS, NIS	All four positive; estimates close
Simultaneous unique association	Natural Analogues	NIS	NOS and SNS did not retain unique support
School-adjusted association	Nature in the Space	NA, NOS	Ranking changed after accounting for school

DISCUSSION

Consistent associations within a multidimensional system

The most consistent finding was positive: across the four participating schools, pupils who perceived stronger biophilic environmental qualities also tended to report more positive emotional and social experiences. All four domains were positively related to ESE bivariately, the combined model explained 26.6% of its variance, and NIS and NA remained supported through the principal simultaneous, school-adjusted, age-adjusted and measurement-sensitivity analyses. These converging results indicate that pupils' experiences of direct nature and nature-referencing interior qualities merit further attention in low-resource school research. At the same time, the identity and magnitude of the leading domain changed across analytical criteria. The contribution is therefore not a universal hierarchy, but evidence that positive relationships coexist with method-dependent ordering within a multidimensional environmental system.

The shift from NA in the bivariate and simultaneous analyses to NIS after school adjustment adds useful contextual insight. It suggests that part of the unadjusted ordering reflected mean differences among the four institutions, whereas direct natural qualities became more prominent when pupils were compared within the same school. Fixed effects strengthen this within-sample interpretation by conditioning on school membership, but they do not solve the limited institutional base. With only four schools, the model cannot separate school context from every unmeasured institutional characteristic, test random school variation or justify inference to other schools. The common-slope assumption may also be unrealistic if environmental domains operate differently across institutions.

What the Natural Analogues result means

NA included colour, imagery, material preference, furniture comfort and classroom arrangement. Its consistently strong association suggests that pupils may respond not only to living natural features but also to how nature is evoked through the material and visual character of interiors. This is practically relevant for resource-constrained schools because finishes, imagery, furniture and arrangement may offer feasible routes for locally developed interventions. Nevertheless, the composite may also capture wider interior comfort rather than symbolic nature alone. NOS similarly combined prospect, refuge and legibility with potentially ambiguous conditions such as crowding and hidden spaces. These content boundaries invite refinement of the constructs before coefficients are used for capital-allocation decisions.

ESE measurement also requires caution. Its alpha of .568 indicates substantial random measurement error and possible multidimensionality. Such error can attenuate coefficients, reduce statistical power and make rankings unstable. Q4 showed the weakest item-total relationship, but deleting it produced only a modest reliability gain and weakened the NOS sensitivity result. The study therefore retained all eight items to avoid a post hoc redefinition of well-being and interprets the observed coefficients as uncertain associations with a study-specific composite.

Implications for design and research

The prominence of NIS after school adjustment is consistent with evidence concerning daylight, views, greenery and direct contact with nature (Arola et al., 2023; Barrett et al., 2015; Chawla, 2015). Together with the consistent NA finding and the school-adjusted NOS association, this points towards a practical portfolio of design hypotheses rather than a single prescribed feature. Within resource-constrained schools, protecting daylight and views, maintaining vegetation and ventilation, and exploring comfortable natural or nature-referencing materials are credible candidates for locally evaluated interventions. These actions are not proven priorities for other schools because exposure was perceived rather than objectively manipulated, the measures were not fully validated and the school sample was small. Their value lies in providing specific, testable directions for intervention research.

The findings extend the interpretation of Marete (2025) without constituting an independent replication. Both papers share the same respondents, ESE items and environmental item sets, and both report positive relationships between perceived environment and well-being. The earlier paper established the overall convergent mixed-methods pattern. The present contribution demonstrates which associations remain visible under different analytical conditions, shows that NIS and NA are comparatively robust within this dataset, and reveals why a fixed domain hierarchy would be misleading. Its transparent reconstruction, item diagnostics and age sensitivity analyses provide a more differentiated basis for designing future studies. The two papers should therefore be read as complementary analyses from one study, not as separate bodies of evidence.

STRENGTHS AND LIMITATIONS

The study contributes complete pupil-level data, transparent composite reconstruction, item-level ESE diagnostics, an explicitly specified fixed-effects model and sensitivity analyses for both age and outcome composition. These features make it possible to distinguish the recurring positive pattern from rankings that are less stable. The study nevertheless has clear boundaries. The four schools were purposively selected, leaving no basis for national or regional generalisation. The cross-sectional self-report design is vulnerable to common-method variance and cannot establish temporal or causal mechanisms. ESE reliability was modest, the domain structure was not validated through factor analysis, and all composites may contain measurement error. The age range was wider than intended; linear adjustment cannot capture all developmental or grade-related differences, and the restricted-age analysis changed the relative pattern. Pupils were nested within only four institutions, which was insufficient for stable multilevel or cluster-robust inference. Fixed effects absorb mean differences among the named schools but do not make the institutions representative or remove unmeasured pupil-level confounding. The results are therefore best treated as promising, hypothesis-generating evidence from these four schools.

CONCLUSION

Across the four participating Ugandan primary schools, stronger perceptions of biophilic environmental qualities were consistently associated with more positive emotional and social experiences. All four domains showed positive bivariate relationships, the domains jointly explained 26.6% of ESE variance, and NIS and NA retained the most consistent independent associations across the principal models and sensitivity checks. NOS also remained relevant after school adjustment. These findings support a multidimensional interpretation in which direct natural features, spatial qualities and nature-referencing interiors may make complementary contributions to pupils' experiences. For resource-constrained schools, daylight, views, vegetation, ventilation and comfortable natural or nature-referencing materials provide specific design hypotheses for locally evaluated improvements. The changing order across models cautions against selecting one universally dominant domain, but it does not negate the recurring positive pattern. Future research should validate the item structure with children, improve ESE reliability, include substantially more schools, model age and grade explicitly, combine perceived and objective exposure measures, and test these promising interventions longitudinally before wider priorities are recommended.

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