# Ranking Perceived Biophilic Dimensions is Method-Dependent: Evidence from Four Ugandan Primary Schools

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## ABSTRACT

Schools with limited resources need credible evidence about which environmental qualities to prioritise, yet rankings of biophilic dimensions may change with the analytical method used. This focused secondary analysis examined questionnaire records from 302 pupils in four government-sponsored primary schools in Mukono District, Uganda. Emotional and Social Environment was the outcome; perceived Nature in the Space, Sensory Nature Stimuli, Nature of the Space and Natural Analogues were the environmental domains. Spearman correlations, simultaneous ordinary least-squares regression and a school-fixed-effects sensitivity model were compared. All four domains were positively correlated with well-being (rho=.36-.43, all p<.001). Together, they explained 26.6% of variance (adjusted R2=.256; F(4,297)=26.85, p<.001). In the simultaneous model, Natural Analogues (beta=.23, p<.001) and Nature in the Space (beta=.19, p=.003) retained unique associations. After school adjustment, Nature in the Space, Natural Analogues and Nature of the Space remained associated with well-being, whereas Sensory Nature Stimuli did not. Natural Analogues ranked first by bivariate and simultaneous estimates, but Nature in the Space ranked first after school adjustment. The central finding is therefore not a winning dimension, but the instability of the ranking itself. For low-resource schools, design priorities should be based on converging evidence about direct nature, spatial experience and interior qualities rather than a single coefficient. Larger, longitudinal studies with validated measures are needed before resource-allocation rules 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, the attractive question is: which biophilic dimension should be prioritised first? Yet a single ranking can conceal how environmental dimensions co-occur and how school context shapes pupil responses. A strong bivariate association may weaken when overlapping domains are entered together, while a coefficient may change after differences between schools are considered. Ranking is therefore not merely a statistical exercise; it can influence which low-cost improvements receive attention and funding.

An earlier publication from the broader study established a general relationship between perceived biophilic environments and pupil well-being by integrating questionnaire and qualitative evidence (Marete, 2025). It did not examine whether the relative ordering of the four perceived environmental dimensions remained stable across bivariate, simultaneous and school-adjusted criteria. The present paper addresses that distinct decision and measurement problem through a focused secondary reanalysis of item-level questionnaire data.

The study asked: (1) how strongly is each perceived biophilic domain associated with Emotional and Social Environment scores; (2) which domains retain unique associations when considered simultaneously; and (3) does their relative ordering remain similar after adjustment for school? By comparing the answers rather than selecting one preferred model, the study tests whether a fixed hierarchy is defensible in this context.

## CONCEPTUAL AND ANALYTICAL RATIONALE

The five composites were specified a priori from the questionnaire structure rather than selected from the present results. 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. Emotional and Social Environment (ESE) represents pupils' reported comfort, calmness, safety and social experience and was treated as the outcome. 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); 148 were boys and 154 were girls. The observed age range extends beyond the intended 11–12-year target group. Accordingly, age composition and the inclusion of older pupils are treated as potential sources of sensitivity rather than assumed to be inconsequential.

Relationship to the broader study. The data originated from the doctoral research programme reported by Marete (2025). Whereas the earlier article addressed the overall mixed-methods relationship between biophilic school environments and well-being, the present analysis addresses the stability of comparative domain estimates. No new participants were introduced. Composite scores and all estimates reported here were recomputed directly from the item-level workbook using the scoring and sensitivity procedures specified below; differences from previously reported coefficients should therefore be interpreted in relation to this distinct analytical specification.

**Measures and data quality**

Pupils answered 50 statements on a five-point scale from 1 (strongly disagree) to 5 (strongly agree). Items were assigned to domains before analysis according to their intended conceptual content (Table 1). For each pupil, a composite was calculated as the arithmetic mean of all items assigned to that domain. No reverse-scored items were used. Mean scoring retained the original 1–5 metric and allowed direct comparison across domains containing different numbers of items; higher values indicate a more positive perceived environment or, for ESE, more positive emotional and social experience. All constituent items were required because the workbook contained no missing values. The domains comprised ESE (8 items), NIS (10), SNS (10), NOS (13) and NA (9). Internal consistency was ESE alpha=.568, NIS alpha=.715, SNS alpha=.726, NOS alpha=.704 and NA alpha=.718. The full 50-item alpha (.893) is not presented as evidence that each domain is reliable because combining heterogeneous constructs can inflate or obscure scale quality. The modest ESE reliability is a material limitation and likely attenuates associations.

**Table 1. Construction and scoring of the study composites**

| Composite | Role and conceptual content | Items | Scoring |
|---|---|---|---|
| ESE | Outcome: emotional comfort, calmness, safety and social experience | 8 | Mean of assigned items; 1–5 |
| NIS | Direct nature: vegetation, daylight, views and air movement | 10 | Mean of assigned items; 1–5 |
| SNS | Sensory contact: natural sound, scent, touch and thermal variation | 10 | Mean of assigned items; 1–5 |
| NOS | Spatial experience: prospect, refuge, mystery, movement and legibility | 13 | Mean of assigned items; 1–5 |
| NA | Indirect nature: materials, colour, imagery, furniture and arrangement | 9 | Mean of assigned items; 1–5 |

**Analysis**

Domain means and standard deviations were calculated from pupil-level composite scores. Spearman correlations estimated monotonic bivariate associations; 95% confidence intervals were calculated using Fisher's z transformation. An ordinary least-squares model then entered all four domains simultaneously; unstandardised coefficients, their 95% confidence intervals and standardised coefficients were used for interpretation, and variance-inflation factors assessed collinearity. A sensitivity model added school indicator variables and used HC3 heteroskedasticity-consistent standard errors. The three criteria answer different questions: overall association, unique association conditional on the other domains, and within-school association after accounting for mean school differences. Because only four schools were observed, the indicator model cannot establish school-independent effects or substitute for multilevel inference. It is reported solely as a sensitivity analysis showing whether the ordering of pupil-level coefficients changes after removal of observed mean differences among these four schools.

**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 2. Descriptive statistics and internal consistency

| Domain | Items | Mean | SD | α |
|---|---|---|---|---|
| Emotional and Social Environment | 8 | 3.87 | 0.63 | 0.568 |
| Nature in the Space | 10 | 3.62 | 0.74 | 0.715 |
| Sensory Nature Stimuli | 10 | 3.59 | 0.77 | 0.726 |
| Nature of the Space | 13 | 3.59 | 0.67 | 0.704 |
| Natural Analogues | 9 | 3.47 | 0.83 | 0.718 |

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

All four domains were positively associated with ESE, establishing convergence in direction. Their bivariate coefficients occupied a relatively narrow range, from .362 to .425. NA ranked first, followed by NOS, SNS and NIS; the closeness of the estimates indicates that this order is descriptive rather than evidence of sharply separated effects.

**Table 3. Spearman associations with Emotional and Social Environment**

| Domain | ρ | 95% CI | p |
|---|---|---|---|
| Natural Analogues | 0.425 | .328–.513 | <.001 |
| Nature of the Space | 0.411 | .313–.501 | <.001 |
| Sensory Nature Stimuli | 0.377 | .276–.470 | <.001 |
| Nature in the Space | 0.362 | .260–.456 | <.001 |

Note. Two-sided tests; N=302. Confidence intervals were calculated using Fisher's z transformation.

The simultaneous model was significant, $F(4,297)=26.85$, $p<.001$, R2=.266, adjusted R2=.256. 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 NOS and SNS did not. The ranking therefore changed in magnitude and evidential support even before school context was introduced.

**Table 4. Simultaneous regression predicting Emotional and Social Environment**

| Predictor | B | SE | β | p | VIF | 95% CI for B |
|---|---|---|---|---|---|---|
| Nature in the Space | 0.162 | 0.055 | 0.192 | 0.003 | 1.72 | .054–.270 |
| Sensory Nature Stimuli | 0.072 | 0.057 | 0.089 | 0.211 | 2.04 | −.040–.184 |
| Nature of the Space | 0.122 | 0.069 | 0.129 | 0.077 | 2.15 | −.014–.258 |
| Natural Analogues | 0.175 | 0.045 | 0.231 | <.001 | 1.45 | .086–.264 |

Note. N=302. Unstandardised B, conventional SE, standardised beta and two-sided 95% confidence intervals are shown.

In the school-indicator sensitivity model, NIS (B=.219, HC3 p<.001), NA (B=.166, p<.001) and NOS (B=.142, p=.032) were associated with ESE; SNS was not (B=.082, p=.169). Adjusted R2 increased to .293. NIS, which ranked fourth in the bivariate analysis, had the largest school-adjusted coefficient. This change is evidence that the ranking is sensitive to adjustment for mean differences among the four participating schools; it is not definitive evidence that these associations are independent of school context. Table 6 summarises this deliberately limited comparison.

**Table 5. School-specific setting and analytical sample**

The analytical sample was unevenly distributed across schools, with Schools B and C contributing more than two-thirds of observations. Setting and sample-size differences therefore provide a plausible route through which between-school context could influence pooled estimates. These school-specific contextual descriptives reinforce the need to interpret pooled estimates cautiously.

| School | Setting | n | % of sample |
|---|---|---|---|
| A | Peri-urban | 23 | 7.6 |
| B | Peri-urban | 101 | 33.4 |
| C | Urban | 106 | 35.1 |
| D | Rural | 72 | 23.8 |

**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

### The absence of a universal hierarchy

The study produced a consistent substantive signal and an inconsistent hierarchy. Pupils who perceived stronger biophilic environmental qualities also reported more positive emotional and social experiences, but the identity of the leading dimension depended on what the model was designed to estimate. This pattern indicates that a single coefficient cannot adequately represent an interconnected school environment.

The shift from NA in the bivariate and simultaneous analyses to NIS after school adjustment suggests that between-school composition matters. Direct nature may become more visible when broad institutional differences are held constant, whereas analogue and interior qualities may partly travel with those differences. The analysis cannot identify the causal source of the shift, but it demonstrates why rankings derived from one model should not be converted directly into universal design priorities.

### What the Natural Analogues result means

NA included colour, imagery, material preference, furniture comfort and classroom arrangement. Its strong association is important because it draws attention to indirect and interior expressions of nature that may be attainable where extensive planting or reconstruction is difficult. At the same time, the breadth of the composite means that its coefficient may capture general interior comfort as well as symbolic connections to nature. The result therefore supports treating interior analogues as a serious design domain while also requiring sharper future measurement.

NOS presents a related measurement lesson. It combined spatial experiences such as prospect, refuge and legibility with potentially ambiguous conditions such as crowding or hidden spaces. Its return to statistical support after school adjustment shows that spatial experience should not be dismissed merely because it was non-significant in the simultaneous model. Instead, the domain should be refined so that restorative spatial qualities are distinguished from congestion, concealment and safety concerns.

**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). For Ugandan schools, protecting daylight and views, retaining mature trees, supporting natural ventilation and considering comfortable natural materials remain plausible low-cost strategies. However, the coefficients are associations between pupil-reported composites, not cost-benefit estimates for individual physical interventions. The practical implication is to develop bundles of context-appropriate improvements and evaluate them with both objective environmental measures and pupil experience rather than funding one supposedly dominant domain.

The findings also refine the broader mixed-methods conclusion reported by Marete (2025). The earlier study established that biophilic school experience was related to well-being. The present analysis adds that the relative importance assigned to component domains is conditional on the analytical criterion. That distinction matters for theory, because biophilic qualities may operate as an environmental system; for measurement, because broad composites can overlap; and for practice, because design prioritisation requires triangulation rather than a league table.

**Strengths and limitations**

The study benefits from complete pupil-level data, transparent reconstruction of composite scores, explicit comparison of three analytical criteria and a school-adjusted sensitivity analysis. Its boundaries are equally important. The four schools were purposively selected; data were cross-sectional and self-reported; the age range was heterogeneous; ESE reliability was modest; and the domain structure was not independently validated. The supplied analysis did not estimate sex-stratified models or re-estimate associations after restricting the sample to the intended 11–12-year age group. Consequently, robustness to sex, age and the inclusion of older pupils remains unresolved and should be tested from the source workbook before strong subgroup claims are made. Common-method variance may have strengthened associations, while the small number of schools prevented reliable multilevel estimation. Objective exposure, teaching quality and household or school-resource variables were unavailable. The findings establish a contextually important analytical pattern, not causal effects, school-independent effects or national prevalence.

## CONCLUSION

Across four Ugandan primary schools, perceived biophilic dimensions converged in their positive association with pupil well-being but diverged in their relative ranking. Natural Analogues led the bivariate and simultaneous estimates, while Nature in the Space led after school adjustment. The contribution is therefore a decision principle: biophilic priorities in resource-constrained schools should not be based on a universal hierarchy derived from one model. Direct nature, spatial experience and interior analogues should be treated as interacting dimensions and assessed through converging analytical, environmental and pupil-centred evidence. Future research should validate the measures across more schools and test context-appropriate intervention bundles longitudinally.

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