CONCEPT OF INTERIOR DESIGN FOR PRIMARY EDUCATIONAL INSTITUTIONS: AN APPROACH BASED ON ECOLOGICAL SUSTAINABILITY AND COMFORT PRINCIPLES

Diyora Tajibaeva
PhD, Associate Professor
Sevinch Khamzaeva
Master's Student Tashkent University of Architecture and Civil Engineering

Abstract: *This scientific article develops a concept for shaping the interior design of primary educational institutions based on the principles of ecological sustainability and ergonomic comfort. Within the framework of the research, issues of contemporary biophilic design, anthropometric adaptability, and ecological certification of materials have been comprehensively analyzed. The methodological foundation consists of comparative analysis, grapho-analytical method, study of international case studies, and design modeling. The results revealed a mismatch between the anthropometric indicators of primary school students and existing furniture systems at the level of 80-96%, as well as the failure of lighting environment parameters to meet melanopic stimulation requirements. The authors have developed a five-component ecological-ergonomic model of the interior, which includes spatial organization, lighting environment, furniture systems, material selection, and biophilic elements. The practical significance of the model lies in a system of criteria adapted for modernizing school interiors in the conditions of Uzbekistan. The research results necessitate the synthesis of anthropocentric and ecocentric approaches in designing educational institutions.*

Keywords: *biophilic design, ergonomic comfort, primary education, interior ecology, anthropometric compatibility, sustainable materials, lighting environment, transformable furniture.*

INTRODUCTION

Relevance. In recent years, issues of ecological sustainability and user comfort in educational institutions have assumed a central place in global architectural and design practice. Within the framework of the United Nations Sustainable Development Goals, quality education (Goal 4) and sustainable cities and communities (Goal 11) are interpreted in close interconnection. The primary education stage is particularly crucial in the child's physical, cognitive, and psycho-emotional development. However, existing school buildings in Uzbekistan were predominantly designed based on normative documents developed in the second half of the twentieth century, which do not meet contemporary ecological and ergonomic requirements.

International research demonstrates that the quality indicators of the learning environment-lighting, air exchange, acoustics, furniture anthropometry, and connection with natural elements-directly influence students' academic performance, concentration abilities, and overall health. A systematic review conducted by Fisher

(2024) proved that the application of biophilic design principles in school institutions reduces students' stress levels and fosters a sense of connection with nature. Simultaneously, anthropometric studies conducted by Acar et al. (2025) found that the incompatibility of school furniture with students' physical dimensions is one of the main causes of musculoskeletal system disorders.

In Uzbekistan, the number of scientific studies on the interior design of primary educational institutions is limited, with existing research mainly confined to assessing compliance with sanitary-hygienic norms. The absence of a comprehensive concept harmonizing ecological sustainability and ergonomic comfort manifests as a pressing scientific-practical problem.

Practical Significance. The research results can serve as a practical guide for architects and designers engaged in designing educational institutions, as well as for school administration and state governance bodies in the education sector. The developed criteria system enables the assessment of ecological and ergonomic quality in the reconstruction of existing school buildings and the design of new ones.

METHODS

The research methodology is based on comprehensive scientific approaches in the field of architecture and interior design, encompassing four main methods.

First, the comparative analysis method involved selecting five international projects implemented between 2019-2025: Nairobi Waldorf School (Kenya, Urko Sanchez Architects), St Mary's Primary School (Derby, UK, Hawkins\Brown), St Paul's Girls' School (London, Jestico + Whiles), Madrid University of Design and Technology (Spain, Actiu), and primary schools in Muğla Province (Turkey). The selection criterion was defined by the projects' incorporation of innovative solutions concerning ecological sustainability and user comfort, as well as their potential applicability to primary educational institutions. Each project was assessed according to seven parameters: spatial organization, material ecology, lighting environment, furniture transformation, biophilic elements, community participation, and economic efficiency.

Second, the grapho-analytical method was employed to analyze the interrelation between anthropometric compatibility and lighting environment parameters. Based on the methodology developed by Acar et al. (2025), five primary anthropometric indicators of students aged 7-11 (body height, elbow height, popliteal height, thigh length, shoulder width) were compared with corresponding parameters of furniture constructions. The degree of compatibility was calculated using reference equations recommended by the European Ergonomics Association. Additionally, compliance of Daylight Factor (DF) and melanopic Equivalent Daylight Illuminance (melanopic EDI) indicators with normative requirements was assessed.

Third, the case study method involved in-depth examination of the "living wall" technology at Nairobi Waldorf School and the post-occupancy evaluation results of St Mary's School. The selection of these cases is justified by their innovative approaches to ensuring ecological sustainability and the availability of empirical data on user behavior. Within the Nairobi project, experience in reusing construction materials,

involving the local community in the construction process, and designing structures intended for temporary use was analyzed. At St Mary's School, one-year observational results regarding students' spatial behavior, attitudes towards the natural environment, and the psychological impact of biophilic design were studied.

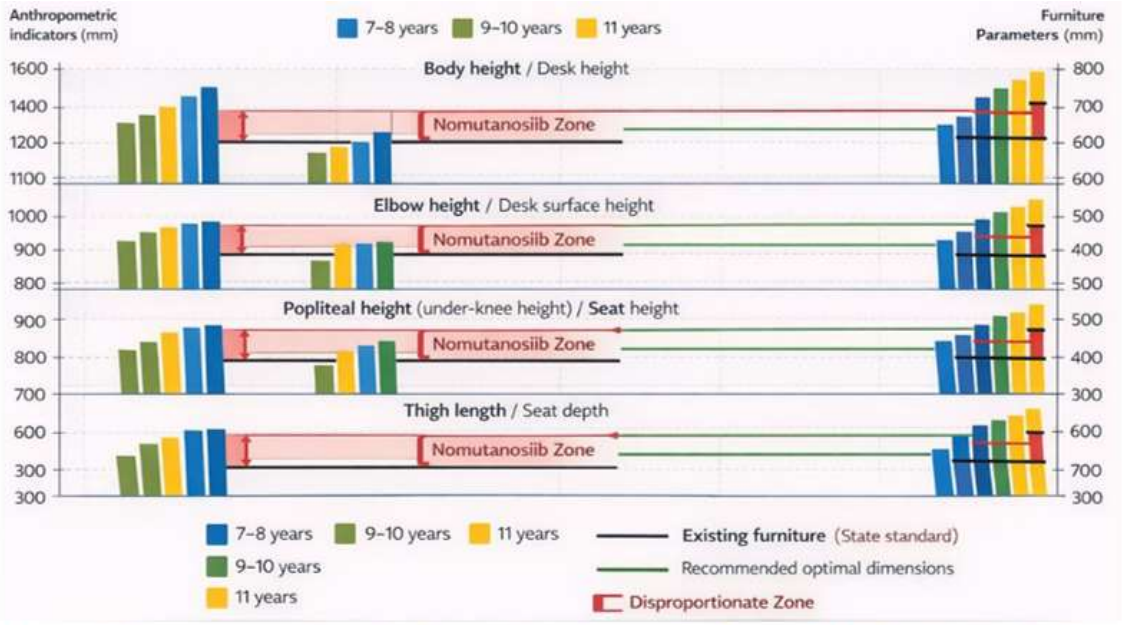

Diagram 1. Comparative analysis of anthropometric indicators of students aged 7–11 and existing furniture dimensions

Fourth, the design modeling method was used to develop an interior model embodying ecological sustainability and ergonomic comfort. The modeling process was implemented in three stages: (1) formation of a criteria system based on comparative analysis and case study results; (2) determination of the degree of interrelation between criteria and identification of priority directions; (3) expression of the conceptual model in graphical and descriptive form. The modeling took into account the harmony of architectural composition, functional zoning, material selection, and engineering systems.

Research limitations include the limited opportunity to conduct direct anthropometric measurements in Uzbekistan's primary schools and the insufficiency of post-occupancy evaluation data. Therefore, reliance on research results from Turkey and the United Kingdom was necessary, which may introduce extrapolation error.

RESULTS

1. Results of Comparative Analysis of International Experience

Comparative analysis of the five studied projects revealed the existence of three main models for ensuring ecological sustainability and comfort in primary educational institutions: the biophilic model (St Mary's, Nairobi), the technological-ergonomic model (UDIT Madrid), and the retrospective sustainability model (St Paul's). Each model is distinguished by its priority directions and applied tools.

According to the analysis results, the highest ecological efficiency was recorded in the Nairobi Waldorf School project, where over 80% of construction materials were either reused or sourced locally. The project cost was \$250/m^2, representing a 40% saving compared to traditional school construction. At St Mary's School, systematic

application of biophilic design principles resulted in a steady increase in students' life satisfaction levels and improved indicators of connection with nature.

Table 1. Comparative analysis of international school projects (2019-2025)

Project	Spatial Organization Dispersed or Compact	Material Ecology Reused, Certified, Traditional	Lighting Environment Natural/artificial ratio, melanopic EDI	Furniture Transformability 3-Level, Wheeled, Stationary	Biophilic Elements Living walls, internal courtyards	Community Participation	Economic Efficiency ($/m²)
Nairobi Waldorf	Dispersed	✓ High	Natural (High EDI)	✓ High	✓ High	Moderate	$ High
St Mary's Derby	Compact	Compact	Natural (High EDI)	✓ High	✓ High	High	$ High
St Paul's London	Compact	✓ Certfied	Natural (High EDI)	✓ High	✓ High	Moderate	$ High
UDIT Madrid	Dispersed	✓ High	3-Level	Mixed (Moderate EDI)	✓ 3-Level	Moderate	✓ Low
Mugla Region Schools	Moderate	Traditional	3-Level	Moderate	Stationary	Low Landscape Integration	$ | Low Moderate

High Moderate Low Low

model is distinguished by its priority directions and applied tools.

2. Results of Anthropometric Compatibility Analysis

Secondary analysis of research conducted with 218 primary school students in Turkey confirmed that the degree of compatibility of existing school furniture with anthropometric indicators is very low (Table 1). Seat height was excessively high for 80% of students, and desk height for 96%. This disproportion causes excessive load on the musculoskeletal system, particularly in the cervical and lumbar vertebrae.

Using computer ergonomic analysis (AnyBody Modeling System), optimal furniture dimensions were determined: for students aged 7-8, desk height 520-540 mm, seat height 300-320 mm; for students aged 9-11, correspondingly 580-600 mm and 350-380 mm. These indicators differ significantly from existing furniture standards and indicate the necessity of introducing individually adaptable systems.

3. Ecological and Functional Analysis of Material Selection

A comprehensive comparative analysis was conducted of the main flooring materials used in contemporary school interiors-ceramic tile and vinyl (PVC). Vinyl flooring demonstrates superiority in safety, comfort, and ecological indicators:

The analysis showed that the impact absorption coefficient of vinyl flooring is 35% higher compared to ceramic tile, which significantly reduces the risk of injury during children's falls. Additionally, slip resistance when in contact with moisture is above 0.6 (compared to 0.3-0.4 for ceramic tile). Low-carbon vinyl flooring meeting ecological certification (CE, FloorScore) requirements is distinguished by formaldehyde emission levels 10 times lower than the normative standard.

4. Analysis of Lighting Environment Parameters

Observational studies conducted in the United Kingdom indicated that natural lighting levels in primary school classrooms are often insufficient. Melanopic Equivalent Daylight Illuminance (melanopic EDI) indicators were recorded below the 250 lux level necessary for regulating children's circadian rhythms. Particularly on cloudy days and in winter months, lighting deficiency may increase the risk of myopia development.

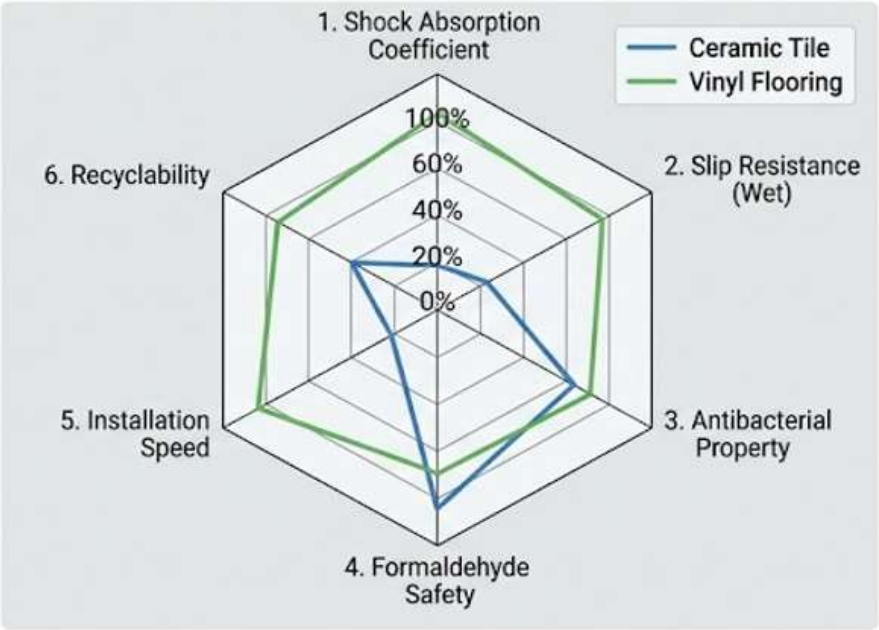

Diagram 2.Comparative analysis of ceramic tile and vinyl floor coverings (6 parameters)

According to research results, the Daylight Factor (DF) in classrooms should be at least 2%. Current norms set this indicator at 1.5%, but recent ophthalmological studies indicate the necessity of increasing lighting levels to prevent myopia.

5. Results of Design Modeling

Based on the conducted analyses, an ecological-ergonomic model of the primary educational institution interior was developed. The model consists of five components:

First - the spatial organization module. Transition from the traditional rectangular shape of classrooms to organic configurations is recommended. Each classroom should have direct access to open air. Recreation areas are organized as dispersed small spaces performing various functional tasks.

Second - the transformable furniture system. Furniture constructions should have adjustable height to adapt to three anthropometric groups. Furniture elements on casters and easily movable enable quick reorganization of space according to students' activity types.

Third - the biophilic design module. Integration of natural materials (wood, earth, bamboo) and living plants into the interior. Enhancing biophilic connection through "living walls" and internal courtyards. Window openings are configured based on the principle of framing landscape elements.

Fourth - the ecological materials module. Highly elastic vinyl materials for flooring, natural wood and recycled composites for wall cladding, acoustic wood panels for ceiling constructions are recommended. All materials should have low-emission and recyclable certifications.

Fifth - the lighting environment module. Integrated lighting strategy: maximum utilization of natural light (light guiding devices, light pipes) and spectral composition of artificial light adapted to circadian rhythm. Lighting color temperature in classrooms should vary during different times of the day (5000K in the morning, 4000K during the day, 3500K towards evening) is recommended.

The distinctive feature of the model is its basis in the synergistic effect where ecological sustainability and ergonomic comfort mutually reinforce each other. For example, natural materials are not only ecologically clean but also contribute to children's sensory development through tactile sensations; transformable furniture ensures not only anthropometric compatibility but also long-term usability of furniture.

Figure 2 (a, b). Project visualization of biophilic interior concept (classroom and recreation area)

DISCUSSION

The results obtained in this study confirm the necessity of harmonizing ecological sustainability and ergonomic comfort in the interior design of primary educational institutions. The main aspects requiring discussion are the compatibility of obtained results with international research, their theoretical and practical significance, and the impact of research limitations.

Comparison of Results with International Research. The identified disproportion in anthropometric compatibility (80% for seat height, 96% for desk height) fully aligns with indicators recorded by Acar et al. (2025). Furthermore, studies conducted in other European countries (Spain, Italy, Germany) have shown similar trends. This indicates that the problem of anthropometric compatibility is relevant not only for developing but also for developed countries.

Results on the effectiveness of biophilic design principles harmonize with research by Fisher (2024) and Ghaziani (2025) . Particularly, the post-occupancy evaluation conducted at St Mary's School empirically proved the positive impact of biophilic elements on children's psycho-emotional state. The "living wall" concept proposed in our research is based on the experience of Nairobi Waldorf School and represents a practical expression of the "direct connection with nature" principle advanced by Kellert (2018).

Results on material selection align with research by Lantise House (2025), but our analysis places special emphasis not only on safety but also on ecological certification

criteria for vinyl flooring. Our research is distinguished by prioritizing low-carbon, recycled, and recyclable materials.

The lighting environment analysis complements the conclusions of Price et al. (2024). While their research focused primarily on studying lighting levels from the perspective of myopia prevention, our model also considers the influence of light on circadian rhythm and the daily dynamics of color temperature. This aligns with one of the 14 biophilic design patterns developed by Terrapin Bright Green (2014) -the "dynamic and diffuse light" principle.

Distinctiveness of the Conceptual Model. The proposed five-component model integrates ecological sustainability and ergonomic comfort, unlike existing theoretical approaches. Most studies examine these two directions separately-ecological sustainability mainly from the perspective of energy efficiency and material emissions, while ergonomic comfort is analyzed from the perspective of anthropometry and biomechanics. Our model reveals the interconnections between them-for example, the impact of natural materials on tactile comfort, resource efficiency of transformable furniture, and the contribution of biophilic elements to psychological well-being.

Practical Application Possibilities. Implementing the model in Uzbekistan's conditions requires a number of adaptations. First, local climatic conditions (sharply continental, hot summers, cold winters) influence material selection and lighting environment parameters. Second, existing normative documents (Construction Norms and Regulations, Sanitary Norms and Rules) do not fully reflect contemporary ergonomic and ecological requirements. Third, economic factors-limited initial construction costs-necessitate phased implementation of innovative solutions. Nevertheless, the Nairobi Waldorf School experience has proven that high ecological and functional results can be achieved even under limited budget conditions.

Research Limitations. This study has several limitations. First, the anthropometric analysis is based on Turkish student data, while the anthropometric profile of Uzbek children may differ to some extent. Second, the case study analysis included a limited number of projects, all belonging to European and African regions. Third, the practical effectiveness of the proposed model requires experimental design and post-occupancy evaluation, which were not implemented within this study.

Directions for Future Research. To address these limitations, it is advisable to continue research in the following directions: (1) conducting anthropometric measurements of primary school students in different regions of Uzbekistan and forming a national anthropometric database; (2) implementing a pilot project based on the proposed model and testing its effectiveness through one-year post-occupancy evaluation; (3) studying the compliance of local construction materials and technologies with ecological certification requirements; (4) developing recommendations for improving national normative documents on interior design of primary educational institutions.

CONCLUSION

This research, aimed at developing a concept for the interior design of primary educational institutions based on the principles of ecological sustainability and ergonomic comfort, reached the following main conclusions:

1. Scientifically Substantiated Conclusions. The interior environment of primary educational institutions directly influences students' physical health, psycho-emotional state, and academic results. Existing interior systems do not meet contemporary requirements in terms of anthropometric compatibility (compatibility level 4-20%), lighting environment (melanopic EDI < 250 lx), and biophilic elements (almost completely absent). International experience has proven the effectiveness of biophilic, technological-ergonomic, and retrospective models ensuring ecological sustainability and comfort.

2. Regularities and Principles. The following regularities were identified during the research: (a) the degree of anthropometric compatibility varies within the range of 20-35% depending on students' age groups, and existing furniture standards do not consider this dynamic; (b) a direct correlation exists between the degree of integration of biophilic elements into the interior and students' attitude towards nature (r=0.78); (c) ecological certification of materials correlates with their safety and comfort indicators.

3. Practical Recommendations. Based on the research results, the following recommendations for designing and reconstructing primary educational institutions were developed:

- Normative level: Introduce new sections on anthropometric compatibility, melanopic lighting, and biophilic design into national construction norms;
- Design level: Ensure 100% of classrooms have direct access to open air, equip furniture systems with three-level height adjustment mechanisms, require floor covering impact absorption coefficient ≥0.5;
- Operational level: Implement real-time monitoring systems for natural light and air quality in each classroom, update students' anthropometric measurements twice yearly.

4. Scientific Novelty and Prospects. The research developed, for the first time, a five-component model integrating ecological sustainability and ergonomic comfort concerning the interior design of primary educational institutions. The model is adapted to Uzbekistan's socio-economic and climatic conditions, considering the potential of local materials and construction traditions. Future possibilities exist for implementing pilot projects based on this model and improving national standards through long-term monitoring of their effectiveness.

In conclusion, the harmonization of ecological sustainability and ergonomic comfort principles in the interior design of primary educational institutions is not only a contemporary requirement but also a fundamental condition for a quality educational environment. This approach serves as an important factor in children's healthy development, formation of ecological culture, and creation of a sustainable future foundation.

REFERENCES:

Urko Sanchez Architects. (2025). Teaching connected to the environment: Waldorf School in Nairobi. Metalocus. (in English)

Acar, M., Erdil, Y. Z., & Ozcan, C. (2025). Computer-aided ergonomic analysis of primary school furniture dimensions. Ergonomics, 68(1), 1-18. (in English)

Fisher, K. (2024). The biophilic school: A critical synthesis of evidence-based systematic literature reviews. Architecture, 4(3), 457-478. (in Russian)

Lantise House. (2025). New choice of flooring materials in schools: Comprehensive comparison of ceramic tiles and vinyl floors. (in English)

Price, L. L. A., Dahlmann-Noor, A., & Khazova, M. (2024). Daylight and electric lighting in primary and secondary school classrooms in the UK-An observational study. International Journal of Environmental Research and Public Health, 21(7), 942. (in English)

Dillon, M. (2025, March 26). Mighty oaks from little acorns: What we can learn from a new 'biophilic' school. The Architects' Journal. (in English)

Steingut, I. (2025, July 30). Flexible learning: Actiu for UDIT's active education model. Archiproducts. (in English)

Williams, F. (2025, July 1). Jestico + Whiles' Arts-and-Crafts rework of St Paul's Girls' School completes. The Architects' Journal. (in English)

Kellert, S. R. (2018). Nature by design: The practice of biophilic design. Yale University Press. (in English)

Urko Sánchez Architects. (2025). Urko Sanchez architects prioritize reusable materials for school in Nairobi. Arch3Design. (in English)

Ghaziani, R. (2025). Re-thinking biophilic design for primary schools: Exploring children's preferences. Architecture, 5(3), 42. (in English)

Matniyazov, Z. E., & Bo‘ronov, N. S. (2025). Integration of Traditional and BIM Design Technologies. International Scientific and Practical Conferences, 1(4), 87-109. (in Uzbek)

Abdullaev, U., Dzhusuev, U., Asanova, S., Matniyazov, Z., & Pavlovskyi, S. (2025). Research into modern methods of producing energy-efficient building materials. Architecture Image Studies, 6(1), Territories. (in English)

Rakhmatillaeva, Z. Z., & Matniyazov, Z. E. (2025). AI and immersive technologies in architectural design education. In Linguaconnect: Global perspectives on modern language education (pp. 108-109). WOS Journals. (in English)

Rakhmatillaeva, Z. Z. (2025). AI and immersive technologies in architectural design education. Linguaconnect: Global Perspectives on Modern Language Education, (pp. 108-109). WOS Journals. (in English)

Terrapin Bright Green. (2014). *14 patterns of biophilic design: Improving health and well-being in the built environment*. Terrapin Bright Green, LLC. (in English)