UDC 712:37.033

LANDSCAPE DESIGN OF EDUCATIONAL INSTITUTIONS AS A FACTOR IN THE FORMATION OF ECOLOGICAL CONSCIOUSNESS: ARCHITECTURAL-SPATIAL PATTERNS AND PSYCHOPHYSIOLOGICAL EFFECTS

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Abstract: *This scientific study examines the fundamental issues of the architectural and landscape organization of open spaces in educational institutions, which serve as a critical determinant of students' psycho-emotional well-being and the formation of their sustainable ecological consciousness. Based on an interdisciplinary approach that integrates architectural design methods, environmental psychology, and advanced spatial-visual mapping technologies, the influence of the physical environment on the cognitive and behavioral patterns of users is analyzed.*

The research facilitates a transition from the paradigm of utilitarian landscaping to the concept of a regenerative landscape that functions as "crystallized pedagogy" and a "third teacher". The work employs graph-analytical methods (space syntax, isovist analysis), as well as quantitative modeling of psycho-emotional reactions to assess the impact of biophilic patterns on environmental responsibility.

Particular attention is paid to the specifics of project modeling in extremely hot arid climates (based on the regional characteristics of Uzbekistan), where landscape architecture performs the primary function of thermoregulation and ensuring campus resilience. The identified patterns and developed design strategies are intended to optimize the ergonomic, compositional, and functional parameters of school and university territories to increase their environmental and educational efficiency.

Keywords: *ecological consciousness, biophilic design, landscape architecture, graph-analytical method, psychology of the educational environment, space syntax, arid climate, sustainable development.*

INTRODUCTION

The evolution of architectural design for educational spaces in the 21st century is characterized by a fundamental ontological shift: from the perception of school or university courtyards as exclusively transit or sports-utilitarian zones toward understanding the landscape as a complex, multidimensional ecosystem that actively participates in the cognitive and value-based formation of the individual. Amid global urbanization, climate transformations, and the increasing alienation of the younger generation from the natural environment (a phenomenon defined in scientific literature as "nature deficit syndrome"), the territory of an educational institution often becomes the primary, and sometimes the only, accessible space for students to have regular and meaningful contact with natural processes[1]. In this regard, the physical form, spatial morphology, and ecological saturation of campuses acquire unprecedented significance, serving not merely as a backdrop for academic activity but as its integral component.

As Professor Emeritus of Environmental Studies David Orr asserts, architectural structures and their surrounding landscapes represent "crystallized pedagogy"[3], as they implicitly transmit to users the core belief systems and value paradigms that underpinned their design. The traditional approach, based on rigid functional zoning, extensive areas of impermeable asphalt surfaces, and the marginalization of greenery, fosters in students an attitude of dominance over nature and separation from it. On the contrary, the integration of ecological systems directly into the educational environment promotes a deep sense of place and, as a result, the formation of a responsible attitude toward the environment on a global scale.

The relevance of this study is driven by the sharp contradiction between the sustainable development goals declared in modern educational standards and the actual spatial-compositional quality of the majority of existing educational institutions. Against the backdrop of an unprecedented increase in academic stress, anxiety, and decreased concentration spans among schoolchildren and students, the traditional architecture of educational buildings demonstrates its inefficiency regarding psychological relief [1]. At the same time, cutting-edge research convincingly proves that biophilic design and high-quality landscape architecture can serve as low-cost yet highly effective tools for creating a healthy educational environment, reducing cortisol levels, and enhancing cognitive resilience [4]. There is an urgent scientific and practical necessity to develop a structured design methodology that would allow for the conversion of abstract ecological imperatives into concrete spatial, ergonomic, and functional solutions in landscape architecture.

The aim of this research is to develop and provide a scientific substantiation for comprehensive architectural and planning principles for organizing the landscape environment of educational institutions. These principles are designed to purposefully facilitate the formation of students' ecological consciousness through the mechanisms of spatial experience and psychophysiological recreation.

To achieve the stated aim, a set of interrelated tasks is sequentially addressed within the framework of this study:

1. Firstly, a systematic analysis of the psychophysiological mechanisms of perception regarding natural-anthropogenic landscapes is carried out. This is aimed at identifying reliable correlations between the spatial-compositional characteristics of the environment (complexity, legibility, connectivity) and the level of ecological awareness among users.

2. Secondly, a critical comparison of leading international concepts for the spatial organization of "green schools" and university campuses is conducted, utilizing modern methods of graph-analytical modeling and visual field assessment (isovists).

1. Thirdly, adaptive design strategies for landscape development are formulated and verified, specifically targeting regions with complex, extremely hot climatic

conditions (using the arid zones of Central Asia as an example). In such environments, the landscape's capacity to ensure thermal comfort serves as a fundamental prerequisite for any outdoor educational scenarios.

The Object of the research is the open architectural and landscape environment of educational institutions at various levels (ranging from primary schools to university campuses).

The Subject of the research consists of the specific architectural, planning, compositional, dendrological, and ergonomic parameters of this environment's organization, which determine the cognitive reactions, psycho-emotional states, and ecological attitudes of students.

The scientific novelty of this work lies in the interdisciplinary synthesis of architectural and urban planning theory with methods of structural modeling of psycho-emotional reactions. For the first time in the national discourse, quantitative indicators of visual connectivity (Space Syntax) and thermal comfort parameters are integrated into a single matrix for evaluating the pedagogical effectiveness of the landscape. Furthermore, biophilic design principles, traditionally considered within the context of temperate or tropical climates, have been conceptually adapted to the specific requirements of educational spaces in conditions of extreme aridity.

The practical significance of the research consists in the formation of an applied architectural toolkit—a set of specific design models, functional zoning schemes, and material selection criteria. These can be directly implemented in the processes of reconstructing existing schoolyards and designing new educational clusters to maximize their ecological, social, and educational returns.

METHODS

To ensure a high level of reliability, validity, and scientific substantiation of the results, a comprehensive methodological framework based on the synergy of qualitative and quantitative methods for analyzing the architectural environment was employed. Given that architectural and landscape design operates with complex three-dimensional structures whose perception is dynamic and subjective, traditional descriptive approaches were supplemented with rigorous analytical tools for spatial mapping.

Comparative analysis served as the key tool for conceptual synthesis. Within this approach, various morphological types of educational landscapes were systematized and compared. The evaluation covered both traditional planning schemes—characterized by orthogonal geometry, a significant proportion of paving, and strict segregation of functional zones—and innovative biophilic models distinguished by fractal layouts, integration of interior and exterior spaces, and the use of regenerative ecological systems[7].

The comparative analysis was conducted using a multidimensional matrix of parameters, including:

- Configurational characteristics;
- Planform characteristics;
- Facility provision;

● Visual environment quality [9]

This method allowed for the identification of fundamental differences in space-use scenarios and the determination of those architectural patterns that most effectively stimulate informal learning and environmental engagement.

To objectify the qualitative characteristics of the environment and transition toward precise spatial metrics, a graph-analytical method was applied. Modern landscape architecture increasingly integrates digital tools for spatial-visual analysis, allowing for the interpretation of complex abstract knowledge about space and the execution of visual-spatial narratives[10].

In this work, visibility field assessment algorithms (isovist analysis) and Space Syntax methods, implemented in specialized software (such as depthMapX and GIS toolkits), were utilized. Compartment analysis was employed to study the ratio between open spaces and physical masses, which is critical for understanding the sense of prospect and refuge experienced by students.

The use of 3D landscape modeling allowed for the simulation of visual experiences at the observer's eye level, evaluating compositional categories such as spatial sequence, visual complexity, and the degree of visual dominance of natural elements over anthropogenic ones[10]. These tools facilitated the conversion of intuitive design decisions into measurable and verifiable data.

The case study method was implemented as a primary form for studying precedents, generating innovations, and testing hypotheses in landscape architecture[13]13. A representative sample of iconic educational infrastructure objects was selected, each reflecting a unique approach to ecological design.

Particular attention was paid to a detailed analysis of projects demonstrating a radical departure from traditional "fortification" security strategies in favor of integration with nature. Examples include:

● Sandy Hook Elementary School in Connecticut, where the landscape functions as a therapeutic buffer;

● The "Green School" in Bali, which serves as a benchmark for immersive environmental education and the use of architecture as a "three-dimensional textbook"[2].

Additionally, to ensure the relevance of the research within local contexts, cases of adapting urban park and recreational spaces in hot-climate cities (specifically Tashkent) were analyzed. These cases reveal the specifics of using landscape elements to stimulate physical activity under thermal stress conditions [14].

Project modeling constituted the final stage of the methodological chain. This method was applied to extrapolate identified patterns onto hypothetical design scenarios, specifically for creating adaptive ecological models of educational spaces in arid zones. The modeling included:

● Assessment of the human energy budget model;

● Analysis of microclimatic changes resulting from various shading strategies;

● Evaluation of high-albedo materials and evaporative cooling systems [17].

Graphic and 3D modeling served not only as a means of visualization but also as an analytical tool (Edward Tufte's Principles of Analytic Design) [19], allowing for the deconstruction of analytical representational techniques into their constituent parts and the assessment of their functional effectiveness within the educational landscape structure. The integration of these methods ensured a comprehensive, systemic coverage of the issue and facilitated the transition from abstract ecological theories to substantiated architectural and planning concepts.

RESULTS

Identified Psychophysiological and Spatial Patterns

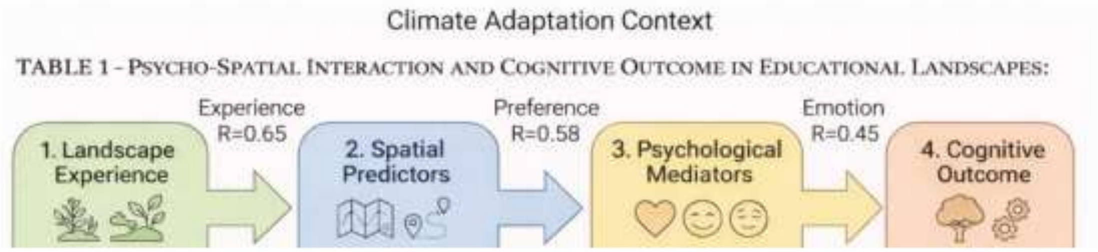

Figure 1. Conceptual model of the influence of landscape design on ecological consciousness and student wellbeing.Source: Compiled by the authors.

The implementation of Structural Equation Modeling (SEM) facilitated the identification and mathematical substantiation of stable cause-and-effect relationships between the architectural configuration of the educational landscape, students' psycho-emotional reactions, and the subsequent formation of their ecological consciousness. Research into the parameters of user interaction with the physical environment demonstrated that the quality and depth of Landscape Experience serve as a fundamental predictor for the formation of Landscape Preferences, exhibiting an exceptionally high correlation coefficient ($\beta = 0.72$)[20]. This implies that regular immersion in a biodiverse, ergonomically sound, and aesthetically complex campus environment fosters a stable internal demand among students for the ecological quality of their surrounding space.

Within the framework of Attention Restoration Theory (ART) and Stress Reduction Theory (SRT), developed by R. Kaplan and R. Ulrich, it has been established that natural landscape elements in educational institutions function as potent catalysts for the parasympathetic nervous system [1]. Students maintaining regular visual and tactile contact with green spaces demonstrate a significant reduction in cortisol levels, enhanced focus, and greater cognitive flexibility when addressing educational tasks [5].

In this context, the emotional response plays a critical mediating role in the link between landscape preference and emotional outcomes ($\beta = 0.45$) for the correlation between preference and emotions) [20]. An architectural environment perceived as coherent (logically structured and legible) yet possessing a sufficient degree of complexity and mystery (stimulating exploration) evokes a spectrum of positive emotions—ranging from tranquility to a sense of awe toward nature.

According to the obtained data, it is precisely this emotional foundation that transforms into stable Environmental Awareness ($\beta = 0.24$)[20]. Thus, ecological consciousness is formed not solely through the intellectual mastery of academic curricula, but to a significant extent through place attachment, which arises from daily positive spatial experiences within a high-quality designed landscape environment. The total effect coefficient of landscape experience on ecological consciousness reaches a value of (β = 0.60)[20], positioning architectural and landscape design as one of the most powerful tools of non-verbal pedagogy.

Comparative Analysis of Environmental Parameters

The spatial implementation of biophilic and regenerative concepts necessitates a radical revision of traditional planning approaches. During the course of this study, an analytical matrix was developed to compare the metrics of conventional schoolyards with those of next-generation educational landscapes.

This matrix facilitates a systematic evaluation of how shifting from rigid, utilitarian zoning toward integrated, nature-centric systems affects the overall pedagogical and ecological performance of the educational environment.

Table 1. Comparative analysis of spatial and psychophysiological parameters in traditional vs. biophilic educational models. Source: Developed by the authors based on the multidimensional matrix of environmental parameters and biophilic design principles.

Parameter Group	Traditional "Hardscape" Model	Biophilic "Living Lab" Model
Spatial Zoning	Monofunctional, rigid allocation of zones separated by physical barriers.	Flexible and multi-layered (adaptive reuse), utilizing "soft" boundaries and ecotones.
Surfacing & Thermoregulation	Asphalt dominance (low albedo), formation of "heat islands."	Permeable materials (gravel, turf), high albedo, natural drainage systems.
Visual Permeability	Linear structure, abundance of blank walls, visual isolation of interior from landscape.	Panoramic integration, application of the "Prospect-Refuge" concept.
Role of Vegetation	Decorative and sanitary (lawns, row planting), low visual complexity.	Didactic and ecosystemic; biodiversity as a learning tool ("the third teacher").
Ecological Infrastructure	Concealed engineering utilities, lack of connection to natural cycles.	Exposed sustainable environment (rainwater harvesting, composting, solar energy).
Security Model	Passive (fences, cameras), perimetrical control causing a sense of alienation.	"Soft" security through social control, high visibility, and environmental comfort.

Conventional spaces are typically designed based on the priorities of minimizing operational costs and ensuring total visual control. This approach leads to the dominance of hardscapes, primitive orthogonal geometry, and the marginalization of greenery (reducing it to mere sanitary buffer zones). In contrast, innovative models utilize the landscape as a complex educational infrastructure.

Spatial Syntax and Visual Complexity

The application of the graph-analytical method revealed profound differences in the morphology of park and recreational zones depending on the urban planning paradigm. Visibility field analysis (isovist analysis) demonstrated that traditional linear layouts form predictable yet monotonous visual sequences.

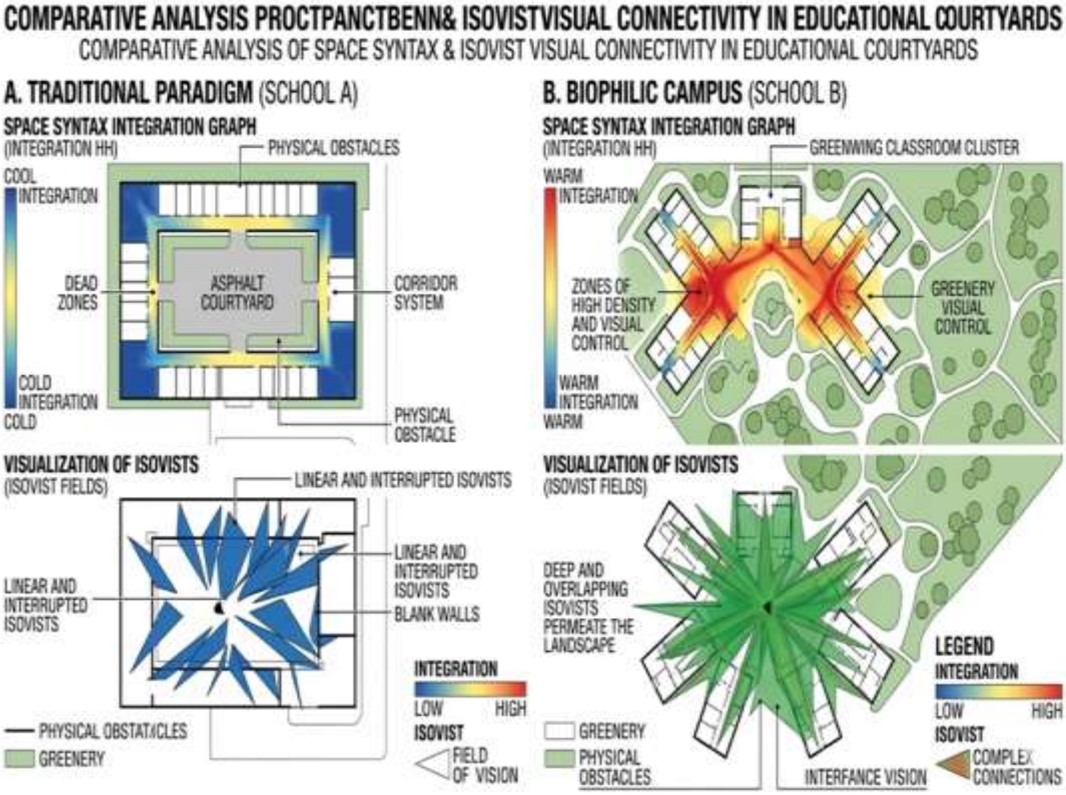

Diagram 1. Comparative graph-analytical analysis of spatial integration and visual connectivity (Space Syntax/Isovist) in traditional vs. biophilic educational environments. Source: Developed by the authors using space syntax methodology and isovist field assessment algorithms.

The segregation of functional zones by rigid barriers (walls, fences) sharply reduces the visual integration between classroom interiors and the external natural environment. The absence of passive visual contact with nature during academic activities negates the recreational potential of the landscape.

In contrast, modern biophilic campuses are characterized by an interwoven green network with high edge complexity and pedestrian connectivity [16]. Such fractal spatial organization creates numerous transition zones (ecotones), small social nodes, and secluded "restoration niches" that are evenly distributed throughout the territory.

Graph-analytical mapping confirmed that the decentralization of attraction points and the creation of "blurred boundaries" between buildings and gardens (for instance, through the use of panoramic glazing, open terraces, and green walls penetrating the interior) critically increase the intensity of landscape use by students. The visual continuity of the natural framework stimulates spontaneous social interactions and informal learning, transforming the entire campus into a unified pedagogical organism.

Design Conclusions for Arid Climate Conditions

Figure 2. Biophilic adaptation strategies and microclimatic landscape design for arid regions: Integration of multi-layered shading systems and evaporative cooling in educational environments.
Source: Developed by the author. The project visualization demonstrates the practical application of thermal comfort principles (high albedo materials, thermal regulation canopy) in the specific climatic context of Central Asia.

A specific block of results is dedicated to the particularities of landscape design in regions with extremely hot and arid climates (exemplified by Tashkent and other zones in Uzbekistan). Under such conditions, classical biophilic design concepts originating in temperate latitudes require deep adaptation. It was established that in an arid climate, where summer temperatures regularly exceed 40°C and insolation reaches critical levels, the educational institution's landscape must, first and foremost, function as a powerful climatic protector [14]. Without ensuring baseline thermal comfort, the functional utilization of open spaces for learning or physical activity becomes impossible.

The analysis of thermodynamic parameters facilitated the formulation of a mandatory set of design interventions:

1. Shading Architecture: The utilization of trees with broad, dense canopies (e.g., Platanus orientalis, Gleditsia, Celtis) serves as the foundation. However, natural greenery must be augmented by engineering systems—pergolas, tensile structures, and parametric forms that create continuous "shading corridors" between academic buildings and recreational areas [18].

2. Hydrothermal Regulation: The integration of localized water features (dry fountains with recirculating water systems, fine-mist cooling systems) provides effective evaporative cooling in high-activity zones.

3. Surface Thermal Radiation Management: The extensive use of dark asphalt is unacceptable due to its immense heat capacity and the subsequent creation of "local heat island" effects. A transition to materials with high albedo (reflectivity) and low thermal conductivity, such as light terrazzo, porous concrete, and natural light-colored stone [15], is recommended.

1. Xerophytic and Multi-tiered Greenery: Given the scarcity of water resources, the dendroplan should prioritize indigenous drought-resistant species. Furthermore, the spatial structure of the greenery must be multi-tiered (groundcovers, shrubs, and trees) to maximize the Leaf Area Index (LAI) and establish a microclimatic buffer that prevents the overheating of soil and building facades [18].

Taken together, these specific engineering and landscape solutions form a comfortable oasis environment, which in itself serves as a visual educational tool for studying the principles of climatic adaptability and sustainable development.

DISCUSSION Interpretation of Results and Philosophical Discourse

The data obtained in this study facilitate a profound reimagining of the functional essence of educational spaces, definitively rejecting the paradigm of landscape as a purely decorative or utilitarian adjunct to a building. The recorded strong correlation between the quality of the landscape experience and the level of ecological consciousness confirms the hypothesis that the architectural-spatial environment acts as an independent, non-verbal pedagogical agent. David Orr's concept of buildings as "crystallized pedagogy" finds its absolute empirical validation: the landscape inevitably teaches [4]. If a schoolyard is merely an asphalted parade ground, it implicitly teaches the child that nature is marginal, requiring control and suppression. Conversely, if an educational campus functions as a complex, biodiverse "living laboratory" with visible systems for rainwater harvesting, composting, and local energy generation, it broadcasts the values of sustainable development every single minute, making them a natural part of the student's lived experience [2].

A crucial aspect of the interpretation is understanding biophilia not merely as the addition of greenery to an interior, but as a comprehensive design approach that activates evolutionarily ingrained mechanisms of psychological self-regulation. Passive visual contemplation of fractal natural forms (e.g., through a classroom window) triggers mechanisms of involuntary attention, allowing the prefrontal cortex—responsible for directed attention and solving complex cognitive tasks—to restore its resources. Meanwhile, active interaction—such as gardening, conducting research in "open-air classrooms," or moving along sensory paths—fosters motor memory and deep empathy toward non-human life forms. This emotional and physical engagement serves as the cornerstone of authentic ecological consciousness.

Comparison with International Research and Case Studies

A comparison of the findings with leading international practices reveals both the universality of biophilic principles and the critical importance of their local contextualization. A landmark study conducted by Tucker and Izadpanahi convincingly demonstrated that the attitudes toward environmental issues among children studying in sustainably designed schools ("Green Schools") differ statistically and significantly for the better compared to students in traditional schools [7]. Their data fully correlate with the results of our graph-analytical model: constant visual and physical contact with food cultivation systems, renewable energy sources, and natural lighting fosters a fundamentally different ecological habitus.

The examination of the radical Green School case in Bali demonstrates the extreme possibilities of dematerializing architectural boundaries. In a tropical climate, the rejection of solid walls transforms the surrounding jungle ecosystem into a giant, interactive "three-dimensional textbook". This architectural openness directly determines a pedagogical model that encourages exploratory, project-oriented learning.

On the other hand, the experience of the Sandy Hook School (USA) illustrates the capacity of biophilic landscapes to address the complex challenges of psychological security and post-traumatic rehabilitation. Despite stringent security requirements (target hardening), the architects avoided creating a "school-fortress." Instead, they utilized landscape elements (water bodies, dense vegetation buffers, wooden footbridges) as natural access control boundaries, thereby implementing a "soft security" strategy that reduces student anxiety.

However, direct replication of these precedents is unattainable. The analysis of South Korean experience regarding the spatial organization of parks in new and old cities (Seongnam) emphasizes that urban morphology, topography, and historically established infrastructure impose rigid constraints on the accessibility of green spaces. In older districts with fragmented landscapes and complex topographies, the level of residents' engagement in physical activity in nature is significantly lower, despite the formal presence of greenery. This highlights the necessity of designing interconnected green networks at the campus or district macro-level, rather than merely implementing isolated landscaping interventions. Similarly, the strategies identified in our study for arid zones (Tashkent, Uzbekistan) prove that in extremely hot climates, the landscape must be designed according to the laws of thermal physics, acting as a "salvific oasis" where shading and cooling take precedence over purely aesthetic characteristics.

Study Limitations and Critical Analysis

Despite the compelling nature of the findings, in the interest of scientific objectivity, it is necessary to highlight several limitations of this research. Firstly, establishing direct correlations between architecture and long-term shifts in ecological behavior encounters the challenge of confounding variables. A student’s consciousness is shaped by numerous non-architectural factors: socio-economic status, institutional policies, teaching quality, and cultural background. While the landscape creates favorable conditions and affordances (opportunities for action), it does not, in itself, guarantee the automatic internalization of ecological values without corresponding pedagogical support.

Secondly, a significant gap exists between theoretical models of sustainable landscape performance and the practical reality of facility operations. Designing complex biophilic systems, green roofs, vertical gardens, and bio-drainage basins (rain gardens) faces the rigid budget constraints of municipal educational systems. Furthermore, maintaining the viability of such ecosystems, particularly in an arid climate, requires substantial operational costs and specialized care.

In the event of incompetent maintenance, a biophilic landscape degrades rapidly, potentially leading to a reverse psychological effect—fostering a sense of abandonment and decay, which sharply diminishes the aesthetic appeal and pedagogical value of the environment [23]. This contradiction necessitates a shift in research focus toward developing low-cost, self-regulating (low-maintenance) landscape systems based on autochthonous flora with a high degree of natural resilience.

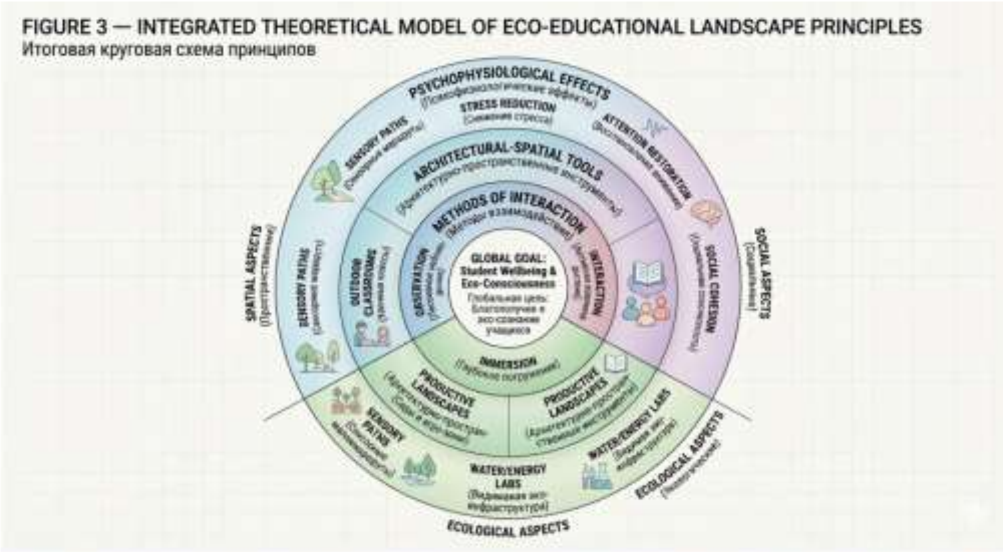

Figure 3. Integrated theoretical model of eco-educational landscape principles for fostering student wellbeing and environmental consciousness. Source: Developed by the author based on research findings and biophilic design frameworks

CONCLUSION

The architectural and landscape organization of educational institutions represents a powerful, though historically undervalued, tool for shaping ecological consciousness and ensuring the psychophysiological well-being of students. The research results convincingly demonstrate that transitioning from rigid, segregated, and utilitarian planning schemes to integrative, biophilic, and ecologically meaningful landscape models can fundamentally transform the educational experience. A qualitatively designed natural environment acts as a catalyst for cognitive processes, reduces academic stress, and, most importantly, fosters a deep emotional attachment to the natural world, which is the foundation of truly responsible environmental behavior.

Based on the graph-analytical modeling, climatic analysis, and international experience, the following conclusions can be formulated:

1. Physical Accessibility and Visual Permeability: The integration of natural elements into the visual field of classrooms is a critical parameter of educational environment ergonomics. The fragmentation of visual connections negates the landscape's therapeutic potential.

2. Formation of Ecological Consciousness: Environmental awareness is fostered not only through abstract learning but through daily bodily and visual interaction with sustainable infrastructure (living laboratories, renewable energy systems, permaculture gardens).

3. For regions with extreme temperature regimes (specifically arid zones): Ecological design must commence with addressing engineering-climatic challenges: ensuring total shading of transit routes, integrating evaporative cooling systems, and proficiently managing surface albedo values.

The following algorithm of actions is proposed as practical recommendations for practicing architects and educational administrators:

● Replacing Monolithic Asphalt: Moving away from continuous asphalt coverage in schoolyards in favor of creating heterogeneous, multi-layered spaces utilizing permeable materials and geogrids.

● Implementing "Outdoor Classrooms": Integrating the concept of outdoor classrooms and sensory gardens into the spatial structure, equipped with stationary yet transformable furniture made from materials with low thermal conductivity.

● Multi-tiered Plant Communities: Establishing multi-tiered plant communities using endemic, drought-resistant species to maximize biodiversity while minimizing the need for artificial irrigation.

● Integrating Visible Ecological Engineering: Embedding environmental engineering solutions (rainwater harvesting, windbreaks, solar panels) into the aesthetic and play fabric of the landscape, making resource conservation processes visible and comprehensible to students of all ages.

Future research directions in this field should focus on bridging the gap between design intentions and post-occupancy evaluation (POE). A highly promising approach involves the use of wearable smart devices and neuro-headsets for objective, continuous real-time monitoring of students' physiological parameters (such as heart rate and stress levels) as they interact with various campus landscape patterns [23]. Furthermore, there is a significant need to explore the potential of integrating Augmented Reality (AR) technologies directly into the natural environment of the schoolyard. This would aim to create hybrid educational spaces that merge ecological tangibility with the boundless possibilities of digital simulation for macro- and microbiological processes [10]. Such an integration will elevate the 'landscape as the third teacher' paradigm to a fundamentally new technological and pedagogical level.

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