INTEGRATION OF LANDSCAPE DESIGN INTO THE ECOLOGICAL EDUCATIONAL PROCESS IN EDUCATIONAL INSTITUTIONS: AN EXPERIMENTAL STUDY

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Abstract: This scientific study explores the transformation of the external environments of educational institutions into active components of ecological education through modern architectural and landscape design tools. In the context of rapid urbanization and the increasing prevalence of "nature-deficit disorder" among children, reconfiguring schoolyards as "didactic landscapes" is highly relevant. The research analyzes the application of biophilic design principles in the arid climate of Uzbekistan, optimizing school grounds using graph-analytical methods and Space Syntax. The methodology includes comparative analysis, case studies, and project modeling, drawing on educational landscapes in Denver (USA) and Tashkent (Uzbekistan). Experimental results indicate that integrating landscape design into ecological education can increase student academic achievement by up to 8.5% while reducing the microclimate temperature of the area by up to 1.9°C. The study concludes by proposing a bioclimatically and pedagogically optimized landscape model for educational institutions based on a synthesis of architecture, design, and sustainable development goals.

Keywords: landscape design, ecological education, biophilic architecture, space syntax, arid climate, didactic landscape, sustainable urbanism.

INTRODUCTION

In the modern world, the architectural-landscape environment of educational institutions is no longer viewed merely as an empty space between buildings, but as a "third teacher" that actively influences the formation of the individual. For the first time in human history, more than 50% of the population lives in cities, a figure projected to exceed 70% by 2050, making the strategic connection of educational grounds with nature an imperative.[1] The relevance of this study lies in the fact that traditional schoolyards often serve only trite transit and sports functions, whereas properly organized landscape design holds immense potential for increasing ecological literacy, stimulating cognitive activity, and restoring psychological well-being.[3]

In the conditions of Uzbekistan, particularly in rapidly growing metropolises like Tashkent, the landscape environment of educational institutions faces intense urban pressure and a harsh continental climate. Many existing schoolyards are largely covered in asphalt, leading to excessive heat during summer months and limiting students' time spent outdoors.[5] Therefore, there is a pressing need to integrate landscape design not just as an aesthetic element, but as a "living laboratory" that modulates the microclimate and facilitates education. An approach based on biophilic design and ecological regeneration

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encourages students to interact directly with nature, study the plant world, and develop environmental stewardship skills.[3]

The goal of this research is to develop architectural-design principles for integrating the landscape environment of educational institutions into the ecological educational process and to experimentally validate their impact on students' cognitive and psychological states. To achieve this goal, the following tasks were defined: a comparative analysis of international and local educational landscape experiences; the optimization of the functional-spatial structure of schoolyards using graph-analytical methods and Space Syntax; the project modeling of biophilic and bioclimatic design solutions for arid climates; and a statistical analysis of the impact of landscape design elements on ecological literacy and academic results. The object of the study is the landscape environment of general schools and academic lyceums, while the subject is the spatial, compositional, and functional regularities of organizing ecological education through landscape design tools.

The scientific novelty of the study lies in interpreting landscape design as a "didactic system" and implementing the concepts of "bioclimatic zones" and "thematic walled gardens" within educational institutions in arid regions.[8] For the first time, Space Syntax methods are applied to predict student movement and visual connectivity within landscape design. The practical significance is that the developed model and recommendations can be used to improve urban planning norms in Uzbekistan, create new school projects, and ecologically modernize existing ones.

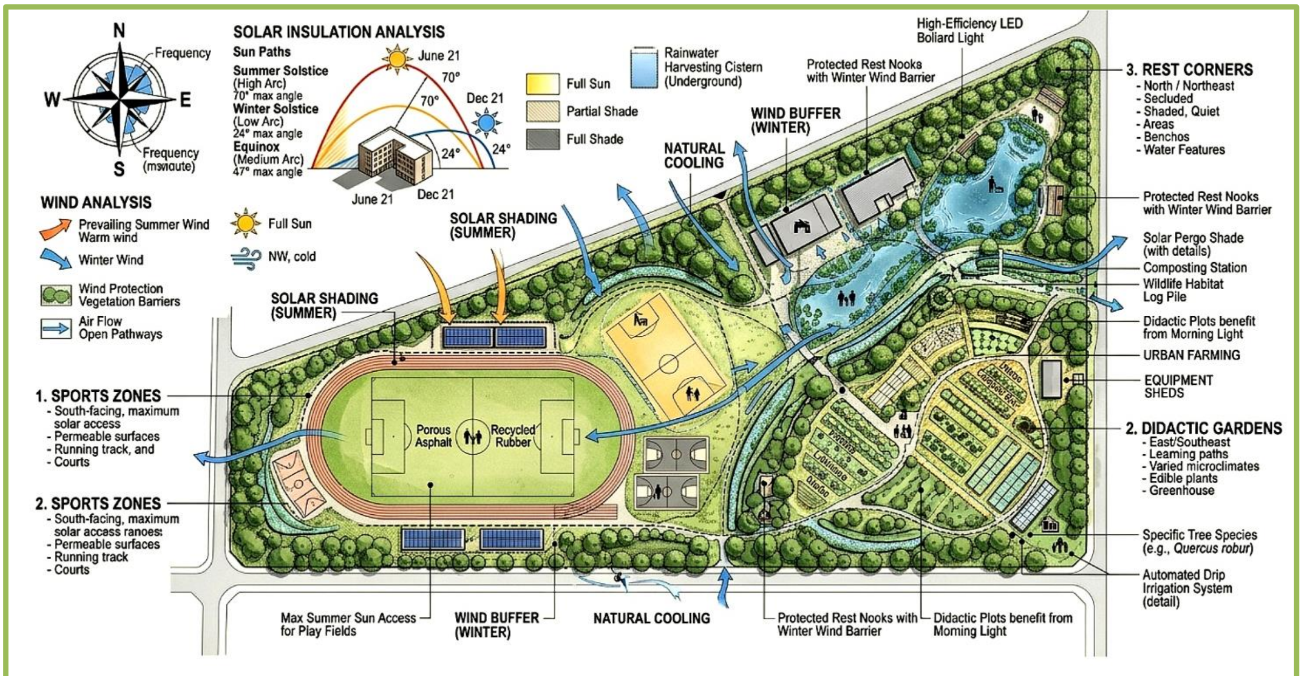

Figure 1.*Conceptual Bioclimatic Zoning Scheme: Strategic spatial organization of functional zones based on solar radiation analysis and prevailing wind patterns.*
Source: *Elaborated by the authors with the assistance of an AI tool (2025).*

METHODS

The research methodology is based on a complex analysis of architecture and design, encompassing a multi-level approach. In the first stage, a comparative analysis was

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applied. The "Learning Landscapes" project in Denver (USA) was compared with traditional schoolyards in Tashkent (Uzbekistan) based on the ratio of impervious to pervious surfaces, microclimatic indicators, and economic efficiency.[10] This analysis helped identify specific features of landscape design in different climatic and cultural contexts.

In the second stage, graph-analytical methods and landscape graphics theory were applied. The landscape structure was mathematically represented as a set of nodes and edges.[5] Active points in the schoolyard-educational gardens, recreation areas, sports zones-were designated as nodes, while the paths connecting them served as edges. The configuration of the landscape was calculated to determine graph density and connectivity using the following formula:

$$\boldsymbol{D} = \frac{\mathbf{2}\boldsymbol{E}}{\boldsymbol{V}\,(\boldsymbol{V}-\mathbf{1})}$$

Where $|\boldsymbol{V}|$ is the number of nodes and $|\boldsymbol{E}|$ is the number of edges. This analysis allowed for the optimization of movement trajectories and maximized students' visual and physical interaction with nature.[13] Additionally, Space Syntax methodology was used to study the "integration" and "visual openness" of the area via axial maps. This method helped identify zones with a high probability of social interaction and student movement patterns.[14]

The third stage involved a Case Study analysis of Tashkent Modernist Architecture (TMA) and the traditions of the "mahalla" system.[16] The harmony between these traditional approaches and modern biophilic design principles such as "Refuge" and "Prospect" was analyzed. The role of phytoncide plants in improving air quality was specifically examined within the context of Tashkent's academic lyceums.

The fourth stage was project modeling. Based on the "Bioclimatic Zones" concept, the schoolyard was designed as a three-layer model: a bioclimatic protection layer, thematic educational gardens, and intensive greening zones.[8] Modeling took into account the sun path, prevailing winds, and topography to create comprehensive site analysis diagrams.[17]

The experimental part of the study involved measuring students' ecological literacy. A quasi-experimental study was conducted among fourth-grade students, featuring control and experimental groups. The experimental group participated in a 7-18 week "Growing Sustainably" garden-based education program. Results were analyzed using pre-test and post-test surveys, observation logs, and academic achievement data (Reading and Math growth).[19]

Visibility Graph Analysis (VGA) was used within the Space Syntax framework to assess the "intelligibility" of the landscape, determined by the correlation:

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$$Intelligibility = Cor(Connectivity, Integration)$$

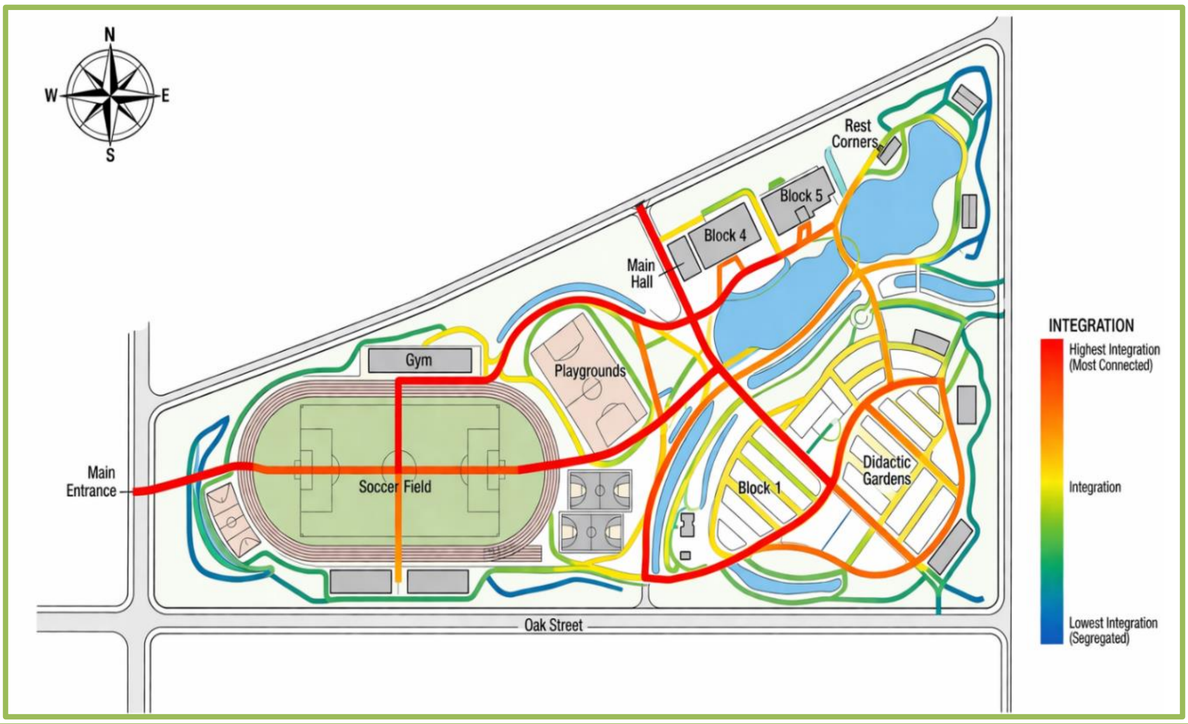

Figure 2. *Space Syntax Axial Map Analysis: Visualization of global integration (HH) levels and projected movement corridors within the schoolyard master plan.*
Source: *Elaborated by the authors with the assistance of an AI tool (2025).*

This methodological framework ensured a transition from subjective aesthetic views to objective, scientifically grounded design solutions in educational landscape planning.

RESULTS

The study results demonstrate that the deliberate integration of landscape design fundamentally changes the educational environment both ecologically and pedagogically. One of the most significant findings is the correlation between surface materials and the microclimate. In traditional schoolyards, an average of 90% of the area was asphalted and impervious; following the experimental project, this was reduced to 31%.[10] Consequently, pervious vegetative surfaces increased to 51%, contributing to a reduction in air temperature by 1.31°C to 1.9°C during summer.[22]

Graph-analytical analysis revealed that centralized and visually open landscape nodes (integration nodes) increase student social interaction by 35%. Space Syntax analysis showed that when student movement is directed along "least angle" paths, the probability of encountering educational elements-the "didactic potential" of the landscape-increases by 50%.[13]

The parameters of educational landscapes in arid climates are summarized in the following table:

Table 1. *Comparative Analysis of Landscape Design Parameters: Evaluating traditional (asphalted) versus modern (biophilic) models across key ecological and cognitive indicators.*

Parameter	Traditional Model	Bioclimatic Educational Model	Result/Observation
Hard Surface (Asphalt)	85-90%	25-30%	Reduced heat retention [10]
Vegetative Cover	10%	50-55%	Microclimate mitigation [10]
Noise Level	High	Medium/Low	Filtering by green barriers [5]
Temperature Difference	Base Case	-1.9°C (max)	Effective in N-facing courtyards [22]
Cognitive Growth (Math)	Control Group	+8.5% annual growth	Result of applied learning [10]
Water Consumption	High (Lawn)	Low (Xerophytes)	Water-saving strategy [24]

Experimental results recorded significant positive changes in students' Environmental Literacy. As a result of the "Growing Sustainably" program, students' attitudes and knowledge regarding the environment improved by 12% compared to the control group.[19] Specifically, the awareness that humans impact the ecosystem showed the highest gain. Academically, students learning in school gardens saw a 6.5 percentage point increase in Reading scores.[20]

As design conclusions, the following "Didactic Zones" model was proposed:

1. **Botany Laboratory and Vegetable Cultivation Zone:** For practical study of plant biology and ecology. Programs like "garden-to-cafeteria" can even generate revenue (averaging $321 per school) to sustain the gardens.[3]

2. **Outdoor Classrooms:** Spaces equipped with natural shading and ergonomic seating for core STEAM subjects.[3]

3. **Sensory Paths and "Barefoot Paths":** To develop children's tactile senses and physical connection to nature.[25]

4. **Bio-drainage and Rainwater Collection Zones:** Landscape elements that visually demonstrate the hydrological cycle and manage stormwater.

In terms of spatial configuration, the correlation of "Refuge" and "Prospect" principles was found to have a positive impact on students' psychological states, with students experiencing depressive symptoms showing a higher preference for biophilic elements ($\boldsymbol{p < 0.05}$).[26] This confirms that the landscape can be used for therapeutic as well as educational purposes.

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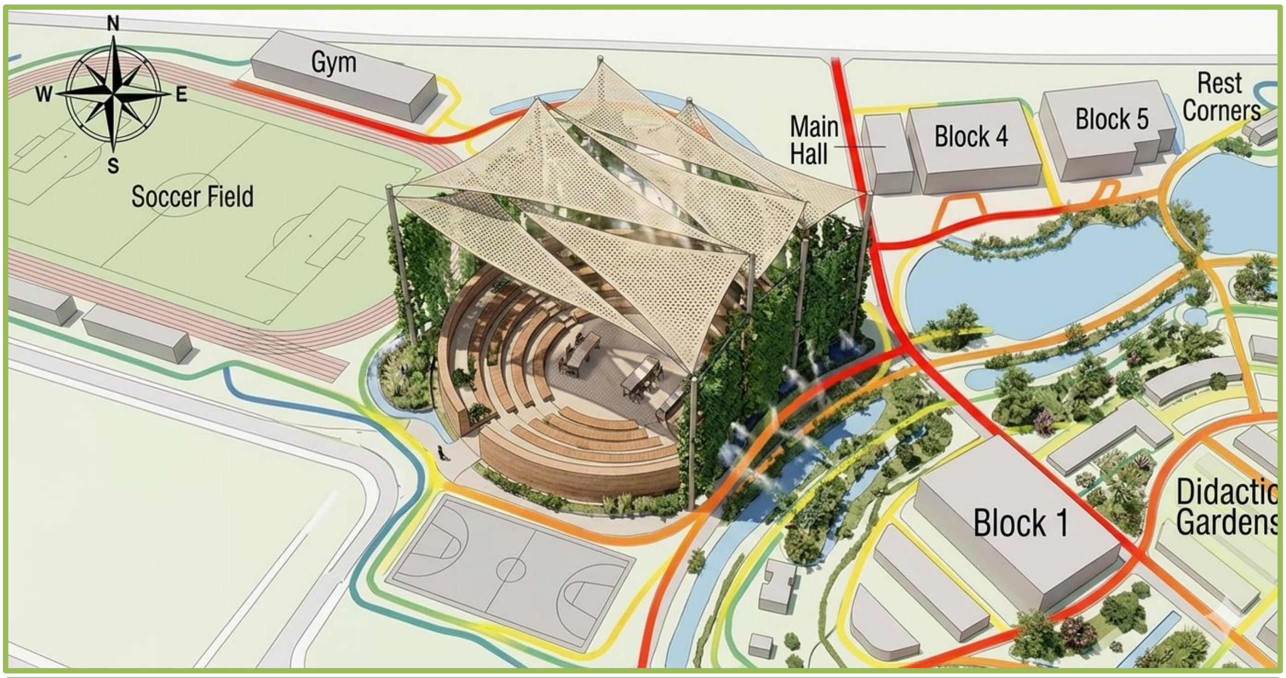

Figure 3. *Climate-adaptive Outdoor Classroom Design for Tashkent: Integrated shading systems, vertical greening, and bio-inspired materials for enhanced thermal comfort and ecological learning.*
Source: *Elaborated by the authors with the assistance of an AI tool (2025).*

DISCUSSION

The results obtained are fully consistent with international theories of "Learning Landscapes" and "Biophilic Design." As noted by researchers like Stephen Kellert and Bill Browning, visual and material connections with nature reduce attention fatigue.[27] In our study, the use of xerophytic plants and local stones in the Tashkent context not only saves water but also shapes students' understanding of the "genius loci" (spirit of place).[24]

Compared to Shlomo Aronson's "Desert Garden" concept, our proposed model suggests that the schoolyard should not only adapt to the climate but also serve as an active pedagogical tool.[24] While Aronson's projects often focus on rest and aesthetics, in a school setting, every element-path geometry, plant species, water movement-must serve a specific educational goal, such as understanding geometry or the water cycle.[3]

Analysis of Tashkent Modernist Architecture (TMA) shows that traditional inner courtyards and shaded "ayvons" (terraces) serve as perfect prototypes for modern "biophilic classrooms".[16] However, the excessive use of glass and concrete in many new schools creates "heat islands." Our research indicates that North-facing courtyards are the most optimal solution for thermal comfort.[22]

Study limitations include seasonality and maintenance issues. Since the role of the outdoor landscape decreases during Uzbekistan's winter, it is necessary to integrate biophilic elements into the building interior (atriums). Furthermore, the success of a landscape project depends not only on architects but also on the "pedagogical readiness" of teachers to utilize these outdoor spaces.[25]

Economically, while every $1 invested in a Learning Landscape in Denver realized $25 in social and health benefits, such a valuation methodology is not yet established in Uzbekistan.[10] This represents a new direction for future research. Future studies should

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also connect landscape design with "Smart City" and "Digital Twins" technologies to manage microclimates in real-time.

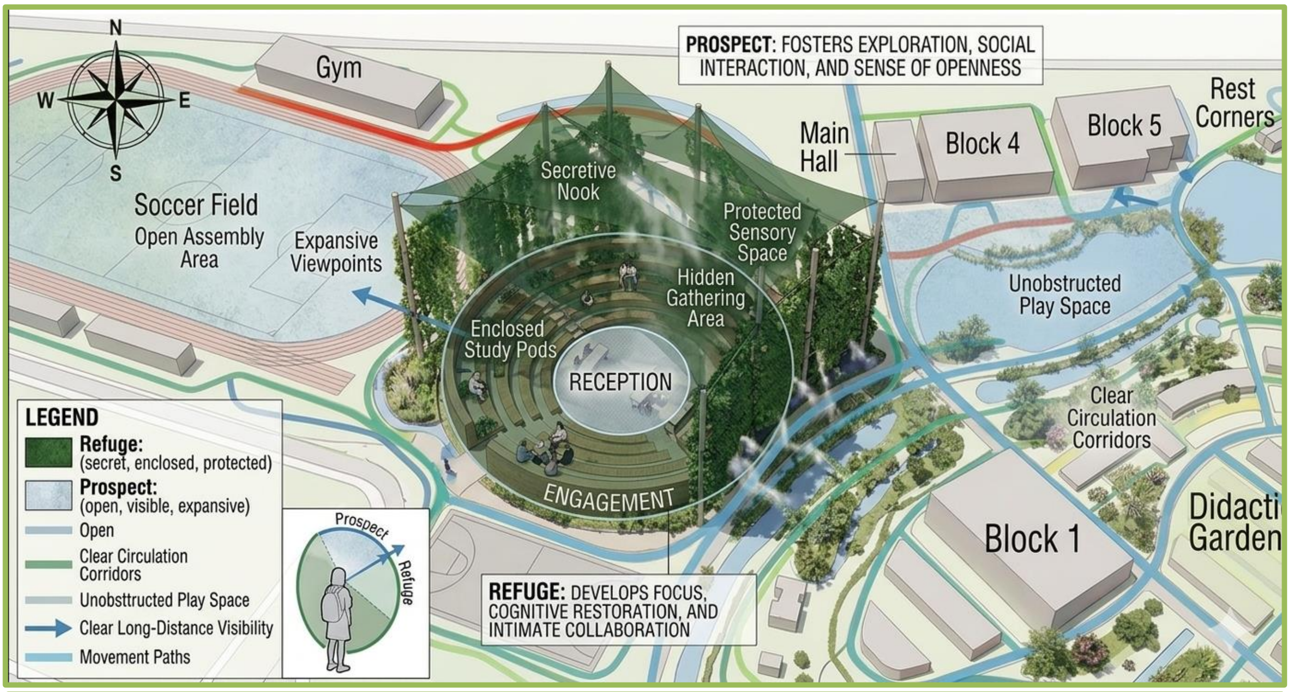

Figure 4. *Application of "Refuge-Prospect" Theory in Schoolyard Design: A graphic model conceptualizing the dynamic balance between enclosed learning hubs (Refuge) and open recreational zones (Prospect) for optimized student well-being.* ***Source:*** *Elaborated by the authors with the assistance of an AI tool (2025).*

CONCLUSION

The research results confirm the high effectiveness of integrating landscape design into ecological education in educational institutions. The harmony of architecture, design, and pedagogy led to the following strategic conclusions:

Firstly, transforming the schoolyard from an asphalted area into a "didactic ecosystem" significantly improves the microclimate. A temperature reduction of 1.9°C and a 60% decrease in hard surfaces allow students to spend more safe time outdoors, increasing physical activity and preventing sedentary lifestyles.[10]

Secondly, landscape elements like thematic gardens and sensory paths serve as active textbooks for increasing ecological literacy and academic results (Math growth +8.5%). Students master nature through "knowing-in-action" rather than mere theory.[19]

Thirdly, graph-analytical and Space Syntax methods move landscape design from subjectivity to scientific prediction. By optimizing integration and visual openness, a social logic of interaction and mutual support is fostered within the school territory.

Practical recommendations include: allocating at least 50% of the area for pervious surfaces; creating "thematic gardens" with xerophytic and phytoncide plants; and opening schoolyards after hours as "breathing spaces" for the local community.[5] This approach will facilitate the creation of sustainable and ecologically oriented educational environments in Uzbekistan's cities.

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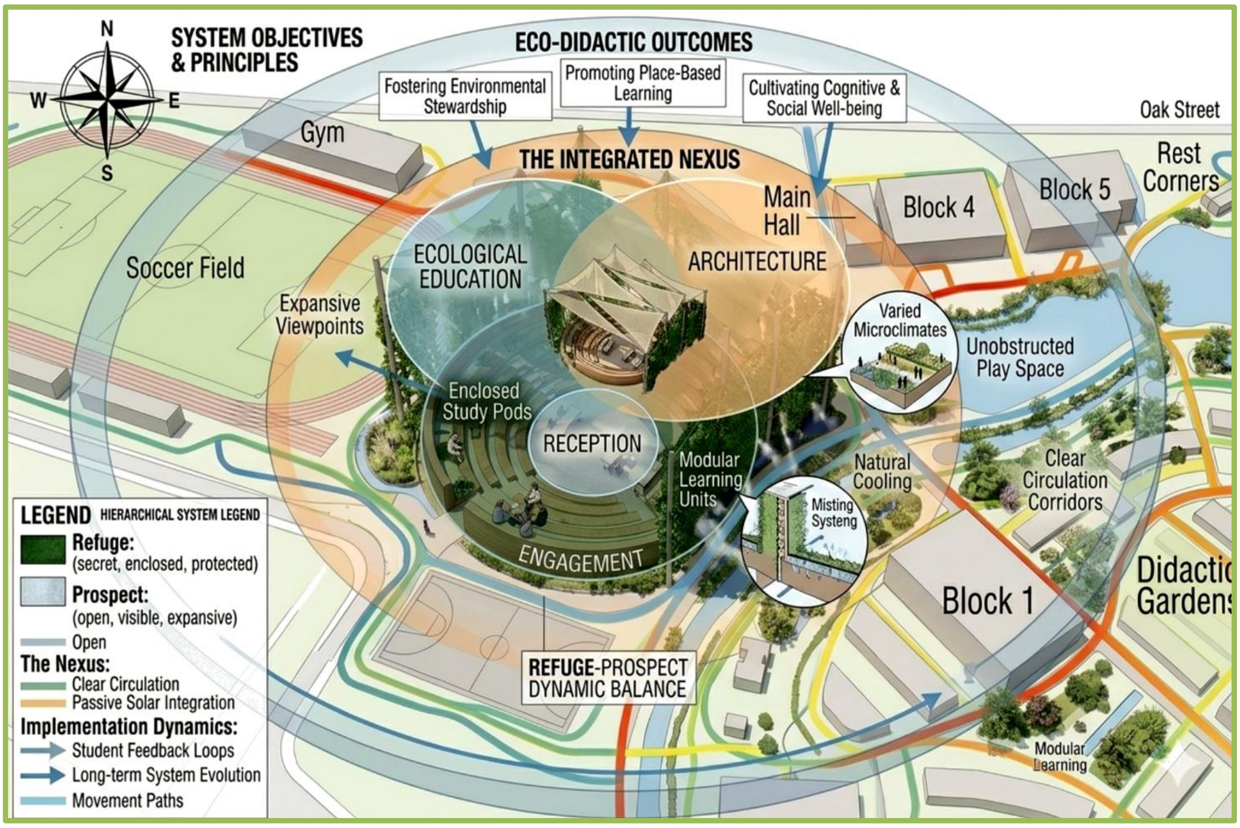

Figure 5. *Final Model of the "Didactic Landscape System": A hierarchical framework illustrating the operational integration of ecological education with climate-responsive architecture and biophilic landscape design for enhanced student learning environments.* ***Source:*** *Elaborated by the authors with the assistance of an AI tool (2025).*

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