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Lessons from Ecological Educational Buildings: Teaching Sustainability to Young Learners through Design

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Abstract

Ecological structures in education stand at the very juncture between environmental education and sustainable design, and function as transformative spaces for the fostering of eco-literacy among students. These schools represent an advance over traditional learning environments, incorporating immersive and experiential educational opportunities to nurture environmental awareness and sustainable living practices. While integrating natural elements, energy efficiency technologies, and eco-sensitive materials helps reduce the building's ecological footprint, they also become living laboratories that give students hands-on lessons in the principles of sustainability. This paper will analyze the environmental features, pedagogical opportunities, and impacts on society a of five outstanding ecological schools: the Benjamin Franklin Elementary School, Nueva School Science and Environmental Center, and Sidwell Friends Middle School in the United States; the Druk White Lotus School in India; and the Academy of St. Francis of Assisi in the United Kingdom. standing as examples of establishments that integrate sustainable architecture with environmental education, this set of schools reflects regional and cultural nuances while still following common guiding principles for ecological design. The paper goes on to conduct in-depth research into the guiding philosophy upon which the above-mentioned institutions were based, highlighting among other things the inclusions of biophilic design elements, renewable energy systems, water conservation, and adaptive use of material. It also probes how these architectural features enhance eco-literacy in a design that provokes wonder, inspires critical thinking, and evokes awareness for the natural world. Finally, it identifies how schools have the potential to function as community hubs by leveraging their mission to extend educational purposes within the school, but rather wider awareness to the environment outside of it. The findings highlight how ecological educational structures are facilitators of global environmental awareness. In this, the school settings reflect a physical environment that corresponds to the set educational goals and illustrate what architecture can do in the change of behavior toward sustainable development. Some recommendations are made on how the design of educational space could promote environmental responsibility and enhance learning experiences and contribute to sustainability in and outside of school.

Keywords: *Eco-Literacy, Ecological Schools, Environmental Education, Green Building Design, Eco-Friendly Educational Spaces.*

I. INTRODUCTION

The escalating threats of climate change and the depletion of natural resources require immediate and creative solutions. leading among them, is education for fostering environmental awareness and behaviors that are in concern with sustainability. Early education presents a singular opportunity to introduce eco-literacy-a knowledge of ecological systems and the competencies to act sustainably-at a crucial life stage. Since young learners spend a considerable amount of time in educational buildings each day, these facilities can dramatically shape the attitude toward sustainability and natural world interaction.

Today's educational buildings need to serve dual purposes. First, the buildings should be eco-friendly, with infrastructure that ensures minimal environmental impact through energy efficiency, renewable materials usage, and waste minimization. Secondly, they need to act actively as agents of learning in building up a direct interplay between the students and the ecological principles facilitated by design elements like natural light, greenery, and biophilic responses. These schools can become living laboratories in which children will not only learn about sustainability but experience it firsthand in daily activities.

This paper discusses how ecological design principles can be integrated with eco-literacy frameworks in order to provide relevant learning environments that will affect young students. Using three case studies from: the Benjamin Franklin Elementary School, Nueva School Science and Environmental Center, and Sidwell Friends Middle School in

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the United States; the Druk White Lotus School in India; and the Academy of St. Francis of Assisi in the United Kingdom. The paper outlines how these institutions represent the nexus of sustainable infrastructure and environmental education. Through the analysis of case studies in regard to design features, environmental impacts, and influences on the children, the article points out that recommendations can be given to architects, educators, and policymakers on how to create schools that protect and educate future stewards of the planet.

II. METHODOLOGY

This is a comparative case study that explores how ecological architecture can contribute to eco-literacy among young learners in educational settings. The findings are based on an integrated analysis of qualitative data from architectural design analysis, building performance analysis, and educational outcome analysis, all gathered from purposefully selected case studies; the Benjamin Franklin Elementary School, Nueva School Science and Environmental Center, and Sidwell Friends Middle School in the United States; the Druk White Lotus School in India; and the Academy of St. Francis of Assisi in the United Kingdom. Analyzing the effects on sustainability and eco-literacy. To then propose a roadmap for integrating ecological design into schools

➢ *Data Collection*

This study collects qualitative data related to natural lighting, ventilation, use of safe, natural, and sustainable materials, energy efficiency, and integration of environmental education through design features. Through design reports from architectural journals or from the architect or the institutional representative. Detailed project documents obtained from architectural firms and published case studies will form the main sources of obtaining an understanding of these design elements.

In addition, energy performance, use of sustainable materials, and energy-efficient systems will be evaluated to measure sustainability efforts. Data will be gathered from schools or architectural firms on the sustainability assessments and environmental impact reports, quantifying the overview of the results gotten through these measures.

More so, the curriculum documents and case studies from the selected schools will be considered in order to analyze exactly how ecological principles are connected with teaching. This includes studying sustainability-focused studies, environmental science curricula, and eco-literacy projects that involve hands-on student engagement in activities such as gardening, water conservation, and waste management. These insights will highlight how the physical and educational aspects of ecological schools work together to promote eco-literacy and sustainable practices.

➢ *Data Analysis*

Comparative Analysis: Information gathered will be compared as to the following aspects from the case studies regarding the following principals.

- Natural Lighting: capacity of each school to fully utilize daylight with the minimum expenditure of energy to attain ideal inside conditions, and at the same time, to have contact with nature for the pupils.
- Natural Ventilation: Describe the different ventilation systems of the buildings to control temperature and air quality based on natural currents of air.
- Sustainable Materials: Materials used, considering the environmental impact and source location.
- Energy Efficiency: How each building has minimized its energy use, including passive solar design, efficient systems, and renewable energy systems.
- Integration of Eco-Literacy: How the designs of schools help to deliver curricula that promote eco-literacy-for example, hands-on practices in sustainability, such as gardening, composting, or rainwater collection.
- Cultural and Regional Adaptation: The design reflects local climatic conditions, addressing high humidity and seasonal winds.
- Outcome Evaluation: Qualitative feedback from the interviews with teachers and students will help to identify what the actual impact these ecological design elements will have on the eco-literacy of students. A review of any performance or behavioral data, where available, concerning sustainability initiatives at schools.

III. CASE STUDIES

➢ *Ecological Educational Buildings*

This section reviews five representative schools, namely, the Benjamin Franklin Elementary School, Nueva School Science and Environmental Center, and Sidwell Friends Middle School in the United States; the Druk White Lotus School in India; and the Academy of St. Francis of Assisi in the United Kingdom, with an assessment of their ecological features and the influence these may have on eco-literacy.

➢ *Druk White Lotus School, Ladakh, India*

Druk White Lotus School, (figure 1) also referred to as the Druk Padma Karpo School, is a school located in Shey, Ladakh, India. The school was founded with a purpose of preserving the rich cultural heritage of Ladakh, born out of its Tibetan Buddhist traditions, through a modern approach to schooling. This building bestows sustainable and climate-responsive design. Arup Associates' architecture integrates local materials and traditional building methods with the latest environmental techniques to create a building adapted to some of the most extreme climatic conditions. (Figure 2) of the site plan and architectural layout of Druk White Lotus School, Ladakh, illustrates the integration of courtyards, sustainable features, and culturally inspired design elements. (eartharchitecture.org)

The passive solar heating, natural ventilation, and use of locally sourced materials minimize environmental impact and raise ecological awareness among students. (Sharma, 2016)

This combination of cultural preservation and sustainable design received international recognition for the 'Inspiring Design – International' award given by the British Council for School Environments in 2009. (www.e-architect.com) The Druk White Lotus School can be considered an example that integrates education, cultural heritage, and environmental sustainability.

Fig 1 Druk White Lotus School, Ladakh – Sustainable Architecture and Traditional Ladakhi Design. 3https://www.dwls.org/

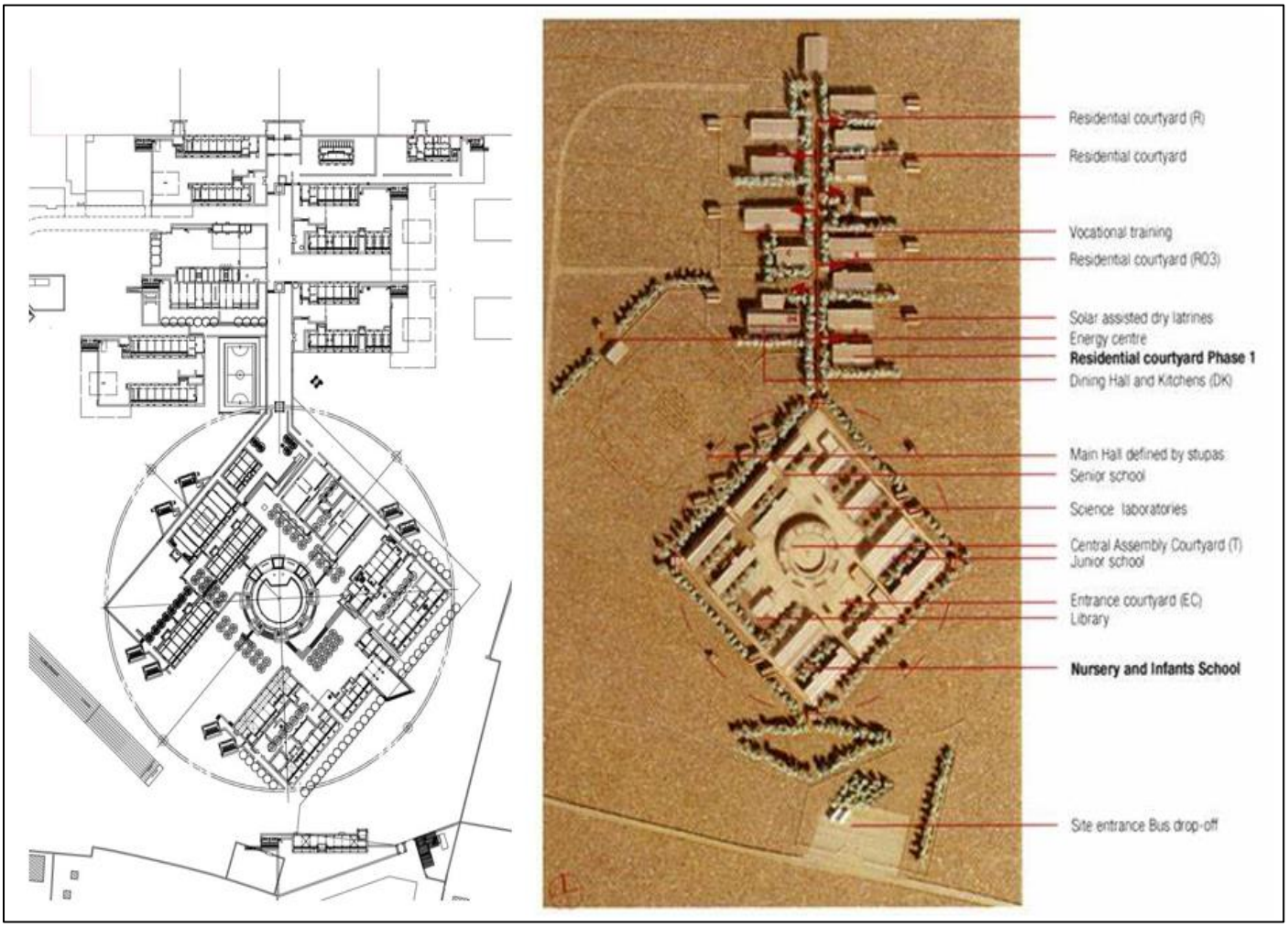

Fig 2 Site plan and architectural layout of Druk White Lotus School, Ladakh, illustrating the integration of courtyards, sustainable features, and culturally inspired design elements, Sharma, 2016 & eartharchitecture.org

- *Key Sustainable Features:*

The Druk White Lotus School incorporates a variety of sustainable elements, for Passive Solar Heating, the Buildings are oriented 30 degrees east of true south to optimize solar heat gain to warm the buildings during cold winters, and for materials, the Trombe Walls act as passive solar elements that absorb heat during the day and release it at night; the roof overhangs moderate this to prevent summer overheating, while the Timber-framed structures, cross-bracing, and independent walls ensure resistance in this seismically active zone. Along with using Local Materials such Mud bricks, local stones, and willows to a great extent to maintain the cultural authenticity and reduce environmental impact. (figure 3)

As for Water Management, Glacier water, surface water, and wells are together utilized to help in meeting the water requirements at the campus, and toilets are fitted with solar-assisted ventilated composting that makes odorless compost.

Photovoltaic panels meet the needs for electricity at the campus accomplishing Energy Efficiency while growing demand, while Clerestories and operable windows are designed to maximize daylight while providing cross-ventilation, reducing the reliance on artificial systems. (eartharchitecture.org)

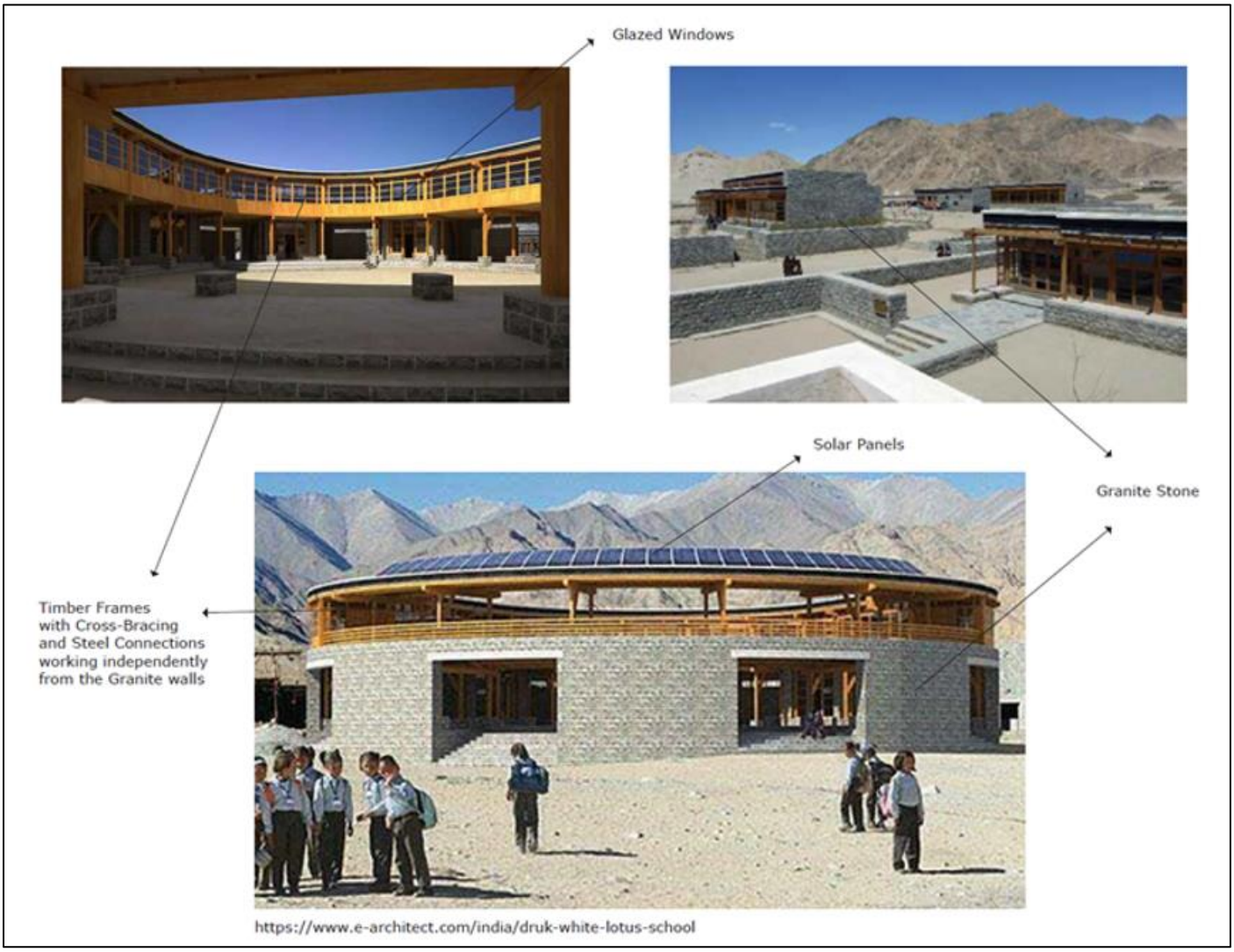

Fig 3 Architectural elements of Druk White Lotus School featuring sustainable design components, eartharchitecture.org

➢ *Awards and Recognition:*

The school has gained numerous international recognitions that include the 2002 World Architecture Award for the Best Green Building and the 2013 International Architecture in Stone Award for its creative and very environmentally conscious design. (Sharma, 2016).

➢ *Long-Term Viability:*

Longevity in the design incorporates materials such as granite and exposed concrete; detailed maintenance guidelines support this further. Feedback loops from operationally complete buildings contribute to continuous improvement, feeding into the school's model of sustainable growth.

Druk White Lotus School is exemplary in the potential of educational campuses to balance traditional aesthetics with leading-edge sustainability, therefore acting as a template for ecological design in extreme climates.

➢ *Druk White Lotus School principles of eco-literacy*

Druk White Lotus School demonstrates what can be achieved in regards to eco-literacy: It combines sustainable design features with educational opportunities that deeply learn from ecological principles. The building becomes a living classroom-and through such things as passive solar heating, Trombe walls, and waterless composting toilets, students are able to actually witness and participate in various

ways of putting ecological principles to use in the real world. The use of local materials and traditional Tibetan construction techniques in the building reinforce the pupils' connection with their cultural history and natural surroundings, and emphasize the importance of their preservation, and although no specific curriculum goals are found, but the school's focus on natural systems, water conservation, and renewable energy naturally fosters an eco-literacy agenda through the creation of opportunities for ecological awareness and experiential learning. Beyond that, by modeling environmental awareness, behavior, and decision-making, the school is able to act as a model for sustainability for the larger community. From this perspective, the Druk White Lotus School promotes an immersive learning environment in which students and stakeholders actively develop a deep understanding and commitment to ecological stewardship.

- *Sidwell Friends Middle School, Washington, D.C., USA*

The Sidwell Friends Middle School is the first LEED-NC Platinum K–12 school facility in the world, and it reflects its original Quaker mission to teach and mentor children in gaining social and environmental consciousness. With a green roof, outdoor classroom, biology pond, (figure 4) butterfly meadow, and Washington DC's first artificial wetland, the renovation and addition of the 50-year-old, 33,000-square-foot brick school structure aimed to expand the learning environment into the landscape.

With an underground cistern that collects and stores roof runoff and provides water to the biological pond during the dry summer months, as well as a closed-loop wastewater system, water conservation was a key component of the project design.

Because the campus uses native plants that draw birds and insects, it was recognized as a wildlife habitat by the National Wildlife Federation. (American Society of Landscape Architects (asla.org)

Fig 4 Constructed Wetlands and Outdoor Learning Spaces at Sidwell Friends Middle School, www.asla.org

- *Sustainable Design Features:*

Constructed Wetland and Wastewater Recycling: A constructed wetland in the school courtyard treats and recycles wastewater on-site. The system cleans roughly 3,000 gallons of water daily, which is then reused for flushing toilets and cooling; this has reduced potable water consumption by 93%. (figure 5) (American Society of Landscape Architects, asla.org)

Green Roofs and Stormwater Management: Green roofs absorb rainwater, reducing runoff and mitigating the urban heat island effect. All paved surfaces direct stormwater into vegetated swales and rain gardens, promoting groundwater recharge and preventing pollution of city storm drains. (figure 6)

Energy Efficiency: This building applies energy-efficient heating and cooling, including geothermal heat pumps; the careful orientation and window placement make full use of natural daylight, contributing to drastic reductions in energy consumption.

Use of Recycled and Local Materials: The renovation reused wood and stone, which kept over 100 tons of material from landfills. This too reduces environmental impact but can also tie the building to local history and resources. (www.asla.org)

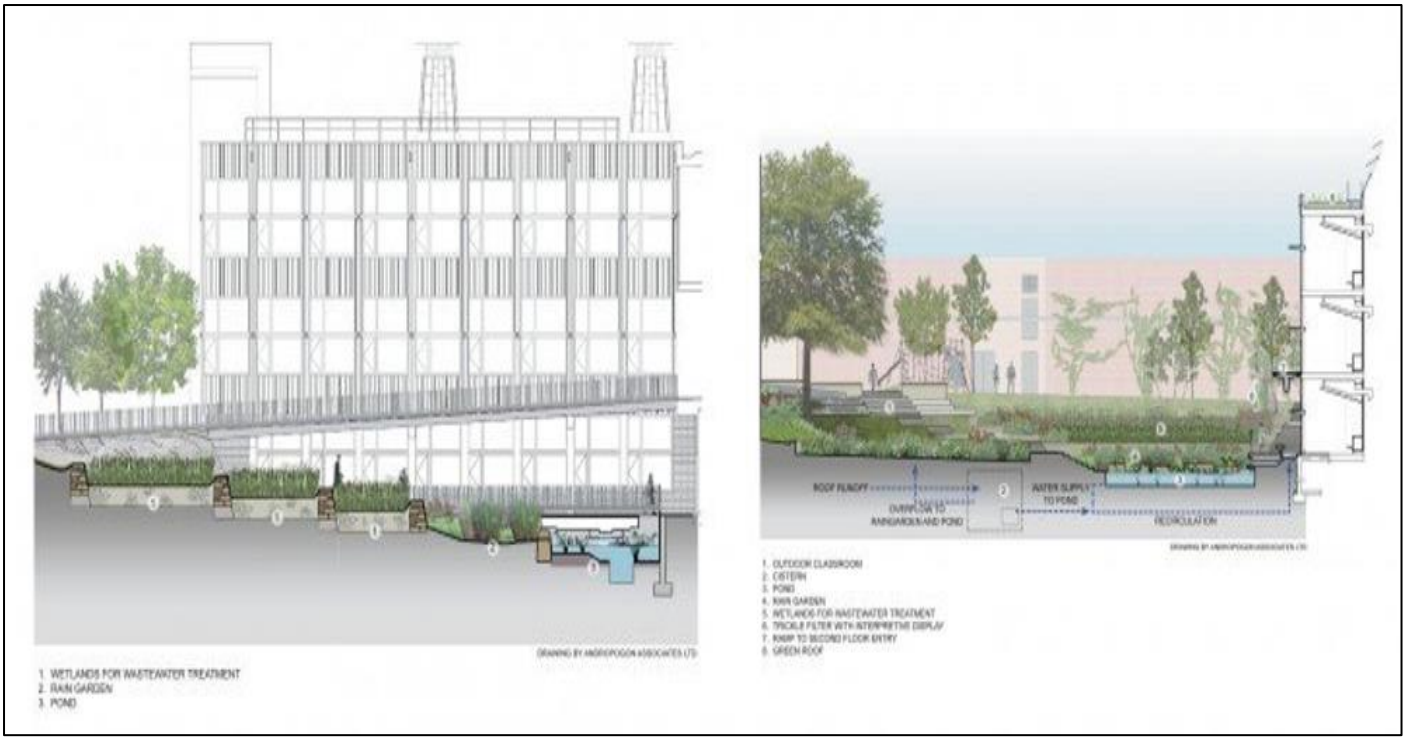

Fig 5, Sectional drawings of Sidwell Friends Middle School's sustainable systems, illustrating wetlands for wastewater treatment, rain gardens, green roofs, and outdoor learning spaces integrated into the campus design, www.asla.org

➢ *Sidwell Friends Middle School Principles of Eco-Literacy*

Sidwell Friends Middle School incorporates its sustainable infrastructure seamlessly into the educational experience of the students in effective ways to foster eco-literacy. This program infuses environmental education at many levels throughout the curriculum, offering real-life opportunities for students to experience the building's sustainable systems firsthand, such as monitoring the performance of the constructed wetlands and gleaning information regarding ecology, resource management, and the practices of sustainability. The school's outdoor spaces include a biology pond and butterfly meadow that function not only as living classrooms (figure4) but also as places where students study native plant species, water cycles, and local wildlife to further their learning about environmental stewardship. Sidwell Friends' commitment to sustainability draws many visitors each year, and students often give the tours, reinforcing their knowledge while placing them as spokespeople for environmental responsibility. This was through various unique programs and sensitive environmental design, making the school minimize its ecological footprint by providing values and knowledge to the students that will be necessary for them to become future leaders in the field of environmental sustainability.

Fig 6, Green Roofs and Stormwater Management, www.asla.org

IV. BENJAMIN FRANKLIN ELEMENTARY SCHOOL, USA

Ecological features make Benjamin Franklin Elementary School in Kirkland, Washington, an example of sustainable design. designed by Mahlum Architects. Opened in 2005, the school serves 450 students from kindergarten to 6th grade. (eryeldiz,2025) The architecture of the school employs natural ventilation systems by using "chimneys" to create a natural stack effect that will aid in the improvement of airflow within the classrooms. The windows are oriented for maximum daylight while shading devices control glare to minimize artificial lighting. (figure 6) It incorporates nontoxic, recycled, and low-impact materials throughout the school's construction in order to reduce environmental impact while providing a healthy indoor environment. These design features, part of the sustainability embedded in the school design, not only reduce ecological footprints but serve as physical teaching tools that make science and environmental stewardship integral to the student experience. (www.mahlum.com)

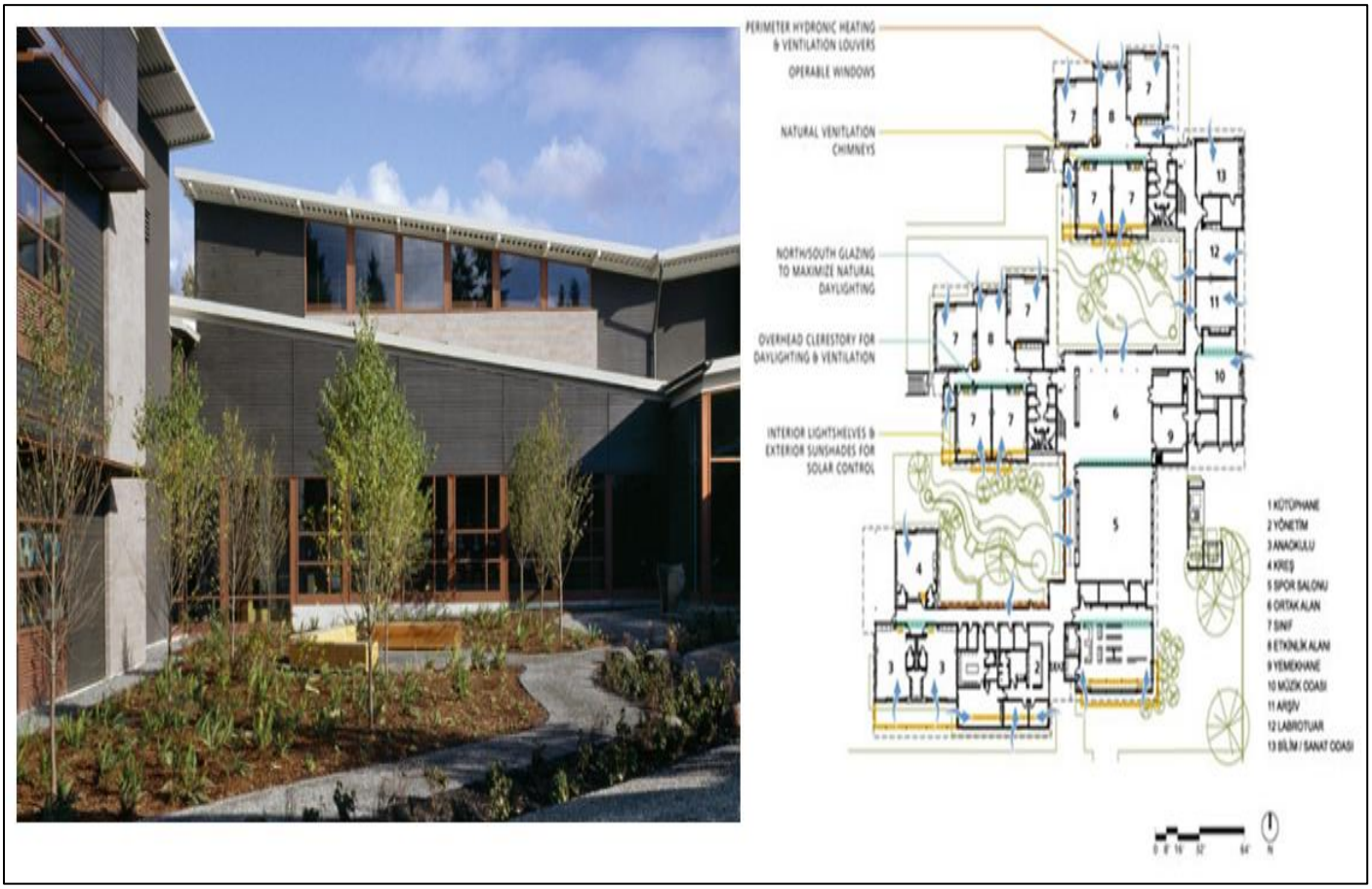

Fig 7 Architectural features make Benjamin Franklin school, www.mahlum.com

➢ *Sustainable Design Features:*

Natural Ventilation: Ventilation chimneys utilize the natural stack effect to distribute fresh air within the classrooms, lessening the need for mechanical systems.

Daylighting: Calculated window orientation allows optimal intake of natural light; glare is controlled and energy usage minimized with the help of shading devices, in order to create well-lit and comfortable interior spaces.

Energy Efficiency: Energy performance 35% better than required by building code; from energy-efficient systems to reused and recycled materials used everywhere in the facility.

Stormwater Management: Permeable surfaces and bioswales manage the stormwater runoff to decrease the impact on the environment while increasing the groundwater recharge. They also act as practical teaching tools for sustainability.

Sustainable Materials: The building includes non-toxic, recycled, and low-impact materials that have less impact on the footprints and consumption of resources.

Outdoor Learning Spaces: Courtyards with native plants allow for outdoor classrooms to facilitate hands-on learning while allowing students to understand a respect for nature.

Connection to Nature: Two-story classroom wings are oriented to a large wooded area beyond, providing visual and experiential links to the natural environment that inspire curiosity and environmental stewardship.

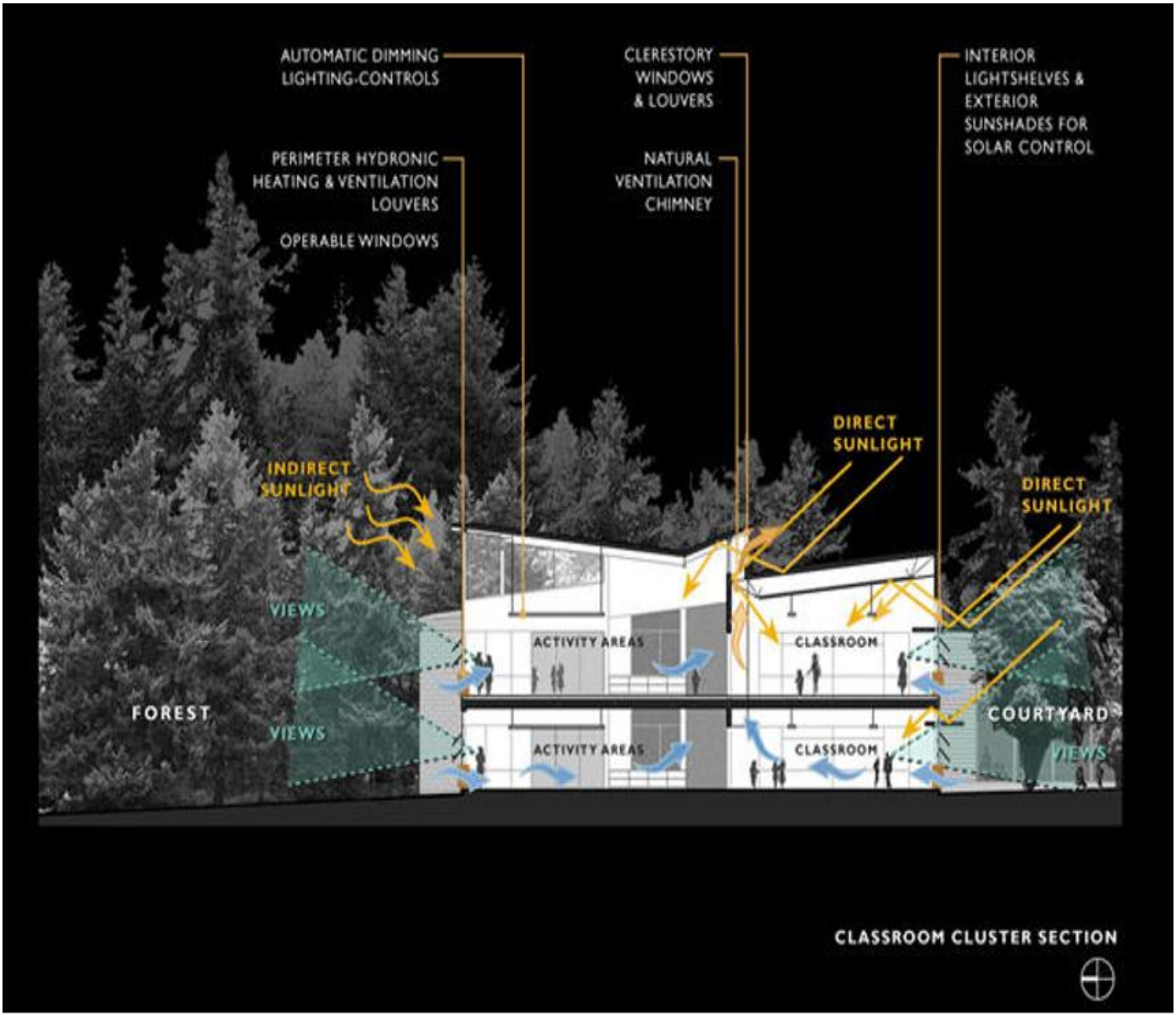

Fig 8 Classroom cluster section highlighting sustainable design features such as natural ventilation, daylighting, and solar control, integrated with views of the forest and courtyard. www.aiatopten.org

- *Benjamin Franklin Elementary School Principles of Eco-Literacy*

Benjamin Franklin Elementary School incorporates aspects of eco-literacy by smoothly integrating the sustainable features into the educational experience, which enables students to engage in ecological principles both inside and outside the classroom. Native plant landscaping of the outdoor courtyards at the school provides for living classrooms where students are able to explore environmental topics like biodiversity, life cycles of plants, and ecosystem health. Besides offering students hands-on opportunities with regard to the development of sustainable water practices through its permeable surfaces, bioswales, and other stormwater management systems, the energy-efficient mechanical systems and natural ventilation not only serve the functionality aspect but also function in an explicit way to bring about lessons in resource efficiency and a reduced use of energy in everyday living. With its connection to the surrounding natural environment and emphasis on experiential learning, Benjamin Franklin Elementary School empowers students to apply sustainability principles in their everyday lives.

V. NUEVA SCHOOL SCIENCE AND ENVIRONMENTAL CENTER

The Nueva School was founded in 1967 by Karen Stone McCown as an independent school in California for gifted students in pre-kindergarten through twelfth grade. With two campuses, one housing the lower and middle school in Hillsborough and the other housing the upper school in San Mateo, the school implements a project-based, progressive curriculum that incorporates design thinking and social-emotional learning. The Nueva School's Science and Environmental Center is located in Hillsborough, California, and represents perhaps the ultimate in the integration of sustainable design and environmental education. Opened in 2021, this facility typifies the school's commitment to fostering environmental stewardship and sustainability as foundational elements of 21st-century education. (archdaily.com)

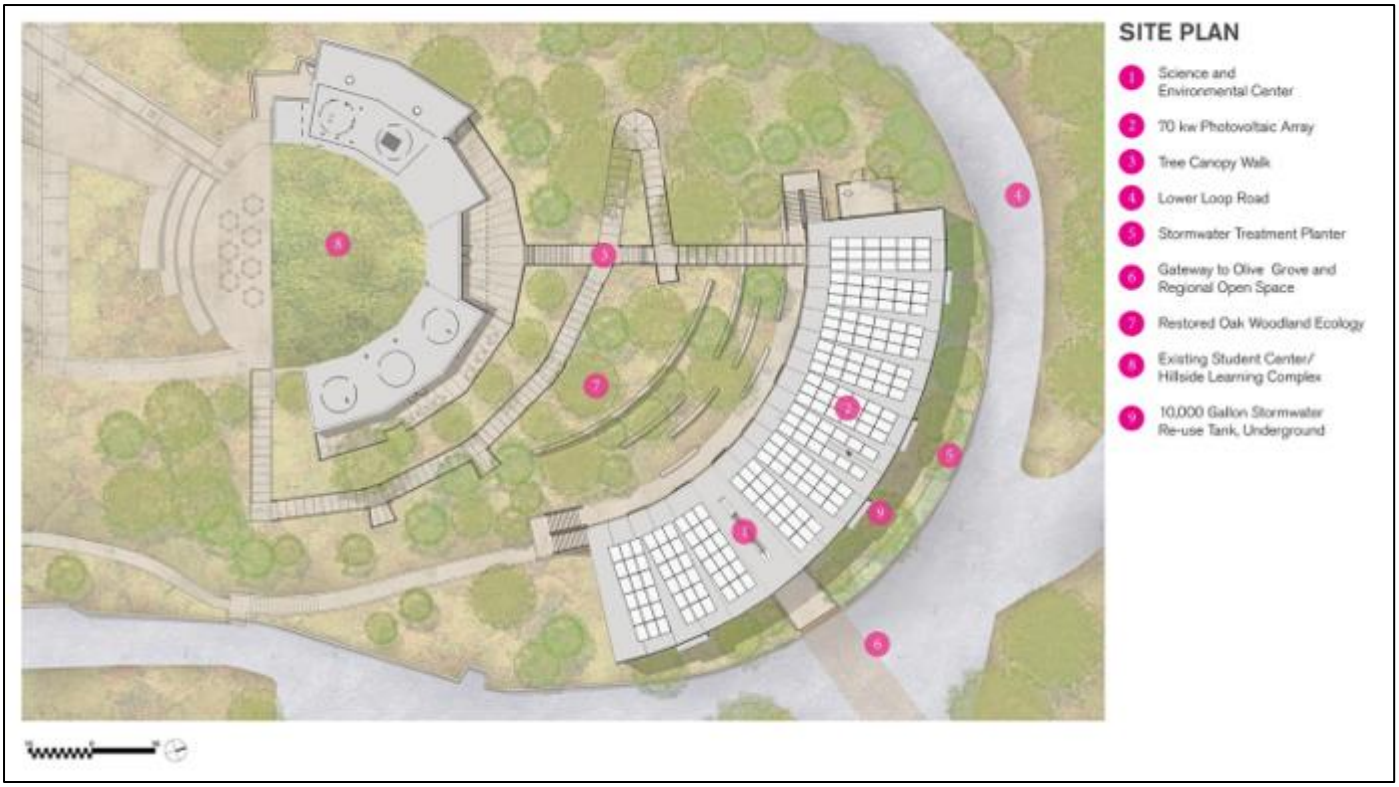

Fig 9 Site plan of the Nueva School's Science and Environmental Center, archdaily.com

➢ *Sustainable Design Features:*

Energy efficiency: A 100 KW photo-voltaic array offsetting the building's use during the year showcases renewable energy.

Net Zero Carbon Design: The facility will achieve net zero carbon emissions as an all-electric building that acts as a model for resiliency and a low-carbon future.

Integration into the Natural Environment: Situating the building in a restored oak woodland ecosystem allows the establishment of harmony with nature-to enhance educational experience with ready access to outdoor learning environments. (figure 10)

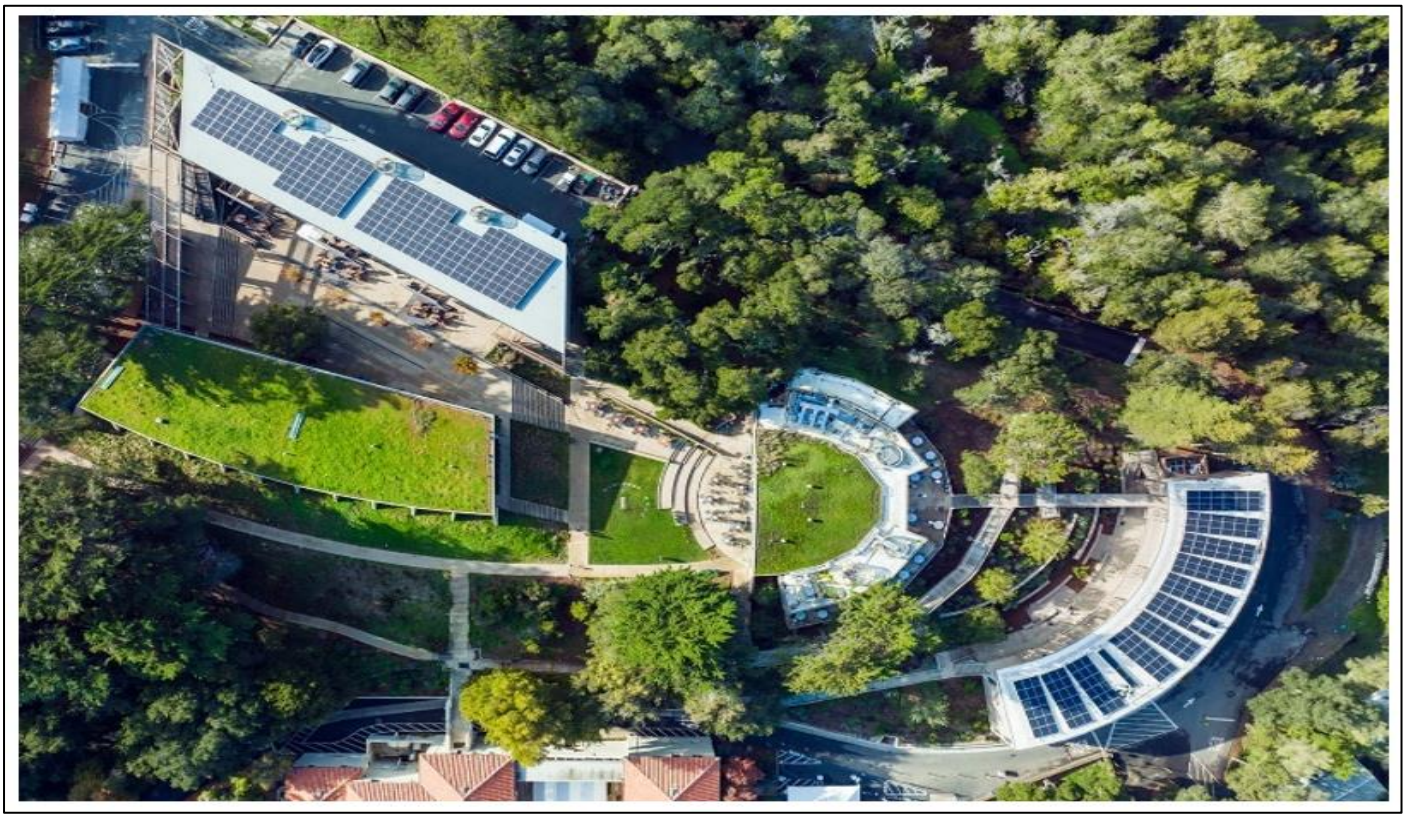

Fig 10 Campus Integration into the Natural Environment, architectmagazine.com

Fig 11 Exterior Learning Areas, archdaily.com

Flexible Learning Spaces: Housing an 11,600-square-foot, two-story building containing eight adaptable science classrooms with exterior learning areas that allow for interdisciplinary and experiential learning opportunities. (figure 11)

Sustainable materials: All lumber, both interior and exterior, are FSC-certified and sourced from ethically managed forests on the West Coast.

Among these are steel, concrete, cotton insulation, and aluminum that have 15% of their constituent materials as recycled ones. With more than 60% of the steel used in the above-mentioned main construction is recycled, and no-VOC paints, adhesives, formaldehyde-free materials, and linoleum flooring were made for the purpose of ensuring healthy indoor air quality.

During construction, 89% of the generated waste and debris from the site were recycled and did not reach landfills, hence reducing the amount of possible harm to the environment.

Safe Indoor Air Quality: The building's 100% fresh air mechanical ventilation system and health-promoting components provide safe indoor air conditions. The MERV13 filtering technology keeps the air pure during wildfire smoke events and may be adjusted for even greater filtration levels if necessary. (sustainablesanmateo.org)

Water Conservation and Storm Water Management: This project limits the use of potable water by more than 89 percent to reduce stormwater drainage burdens, making the practice better compatible with available supplies. (sustainablesanmateo.org)

Integration into Nature: Wrapped by the restored oak woodlands and providing direct access to their extensive outside learning spaces, this will help the children make life-long connections with nature.

- *The Nueva School Principles of Eco-Literacy*

The Nueva School Science and Environmental Center is a statement in sustainable design, (figure 12) combining resource conservation, renewable energy, and health-focused features into one safe and innovative learning environment that addresses the challenges of climate resilience while it actively promotes eco-literacy through the integration of sustainable features into the educational experience, building a connection between the students and nature. The center is supposed to be leading the Nueva environmental citizenship program by inviting students to explore the interdependencies between natural and human-constructed systems. Outdoor learning spaces amidst restored oak woodlands introduce students to hands-on experiences in ecology, earth sciences, and sustainable practices. The building itself serves as a teaching tool, showcasing such features as net-zero carbon design, photovoltaic energy systems, and innovative water conservation methods that inspire students to understand and adopt sustainable solutions. Through design thinking projects, outdoor exploration, and interdisciplinary curricula, students are empowered with practical skills and a great sense of responsibility toward environmental stewardship to address ecological challenges on a global scale.

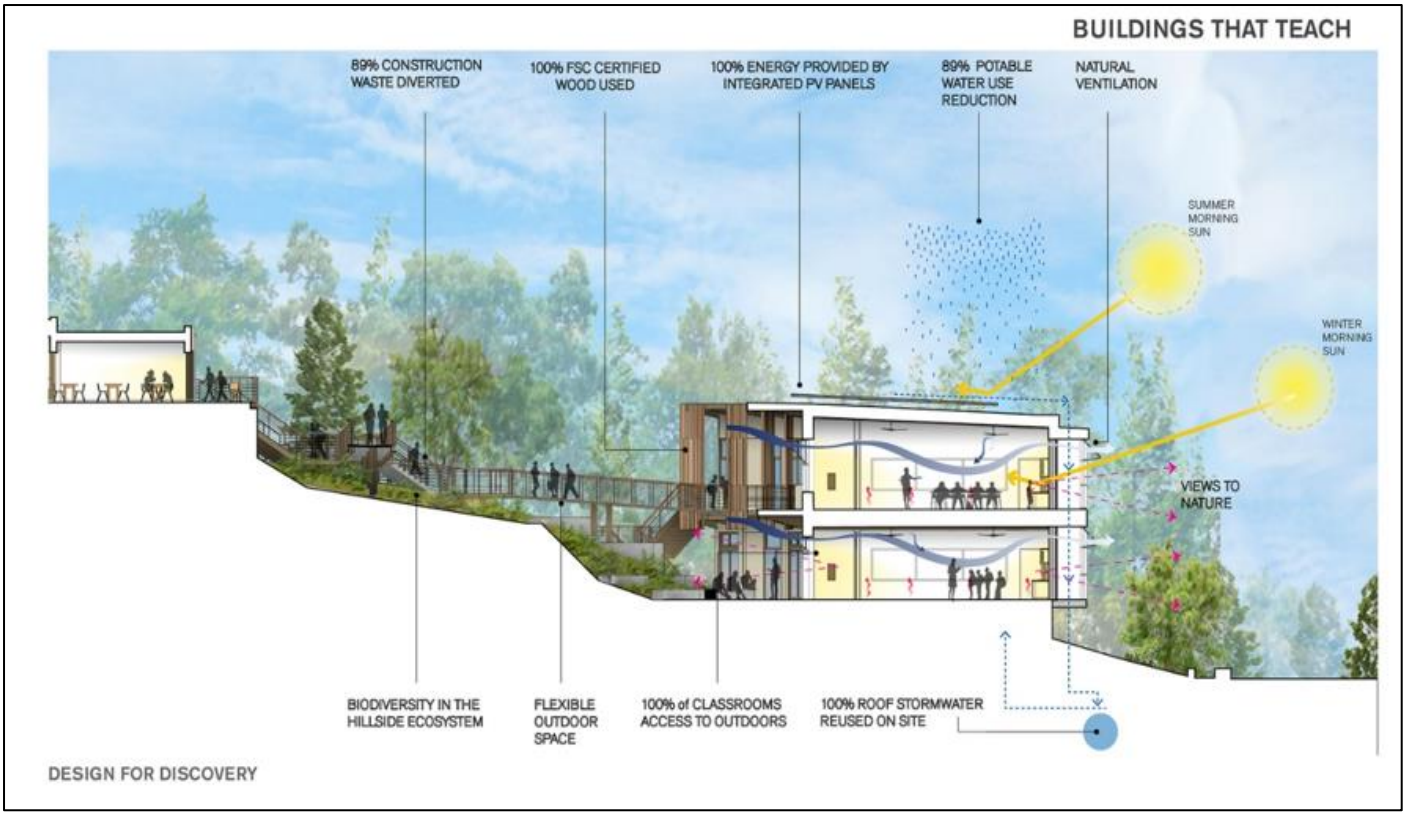

Fig 12 Cross-section of the Nueva School's Science and Environmental Center, showcasing sustainable features like natural ventilation, integrated solar panels, water reuse systems, and outdoor learning spaces that emphasize biodiversity and resource efficiency. archdaily.com

➢ *Assisi St. Francis Academy / Secondary School*

St. Francis Academy, close to Newsham Park in the United Kingdom, is a trendsetter in the integration of sustainable design principles within educational facilities. Funded by business sponsors and initiated by the British government, it promises free, high-quality education with an especially strong emphasis on environmental sustainability. Designed by Capita Percy Thomas (Capita Symonds), the school accommodates 900 students and combines modern facilities with cutting-edge sustainable practices, setting a benchmark for environmentally conscious school design. It is a co-educational secondary school and represents a unique joint-faith partnership between the Roman Catholic Archdiocese of Liverpool and the Anglican Diocese of Liverpool. As the Academy was established in 2005, it accommodates students from 11-16 years of age. The curriculum is exhaustive while uniquely focusing on sustainable development and environmental education. (eryeldiz,2025)

Fig 13 The Academy of St Francis of Assisi in Liverpool, UK , eryeldiz,2025 and urbanfabric.co.uk

➢ *Sustainable Design Features:*

Energy Efficiency: By running the facility on solar power, it lessens its reliance on fossil fuels and embraces renewable energy sources.

Rainwater Harvesting: By reusing the gathered rainwater for non-potable uses, water conservation is aided.

Low Maintenance and Thermal Mass: Over time, concrete walls require less maintenance and less energy because they are made to store heat.

Green Roofs: Sedum roofs and roof gardens will increase insulation, provide biodiversity, and reduce stormwater runoff at the school.

- *Innovative Roofing Materials:*

The roof of one branch is covered with crushed seashells from Morecambe Bay and local sandstone, integrating regional materials into the design.

The translucent roof of the atrium in ETFE-ethylene tetrafluoroethylene-allows more light penetration, is 70% cheaper to produce than glass, and is significantly lighter, reducing the structural demands. (eryeldiz,2025 & urbanfabric.co.uk)

Light Tunnels and Skylights: The underground gym receives natural light through strategically placed skylights, creating an energy-efficient, well-lit space.

Green Material: The exterior features both Douglas pine and brick cladding, while the north façade copper-covered windows bring in strength and aesthetic value.

➢ *Environmental and Educational Goals:*

St. Francis Academy is not only an architectural landmark but also has the status of a vital contact point in environmental education for the community. The school demands academic excellence and personal accountability while incorporating a unique educational curriculum with a special emphasis on environmental awareness. The academy will cultivate eco-literacy through use of its sustainable features within learning environments to encourage students into real-world ecological practices and solutions.

➢ *Spatial Design*

The L-shaped structure has two major blocks, classrooms in the long, north-oriented block, and specialized spaces in the other. The semi buried arrangement allows for efficient land use in the congested, house-bound neighborhood and also enhances thermal insulation.

➢ *Community and Citizenship Focus:*

St. Francis Academy also does much for its community, sharing facilities and other resources with other schools and organizations. It fosters an active role in citizenship and care for the environment by engaging not only its students but the community as well in sustainable habits. (urbanfabric.co.uk)

Fig 14 The Translucent Roof of the Atrium at the Academy of St Francis

https://urbanfabric.co.uk

➢ *Analysis of Ecological Educational Buildings*

Table 1 Analysis of Ecological Educational Buildings

School Name	Basic Information	Passive Design. Natural ventilation/lighting	Sustainable Materials	Energy Efficiency	Water Management	Waste Management	Cultural Adaptation	Integration of Eco-Literacy
Nueva School Science and Environmental Center (USA)	**Ages**: Pre-kindergarten through Grade 12 **Size**: 11,600 sq. ft. **Climate Zone**: Temperate	Extensive glazing provides abundant daylight; natural ventilation complements electric systems for a well-lit, energy-efficient environment.	FSC-certified wood, recycled steel and concrete, and no-VOC finishes ensure air quality and reduce environmental impact.	A 100 KW photovoltaic array offsets annual energy consumption; net-zero carbon building.	Rainwater harvesting reduces potable water use by over 89%.	Recycling 89% of construction debris during development; waste reduction integrated into student projects.	Green roofs recreate California grassland ecosystems, blending with local biodiversity.	Environmental citizenship curriculum emphasizes sustainability with real-world projects and outdoor learning spaces.
Druk White Lotus School (India)	**Ages**: Nursery through Secondary School **Size**: 13 hectares **Climate Zone**: Cold and dry	South-facing facades and large windows maximize daylight, while passive ventilation systems are adapted to the high-altitude climate.	Locally sourced materials such as granite and mud bricks reflect traditional Tibetan designs.	Passive solar heating with Trombe walls optimizes thermal performance; solar electricity generation meets campus needs.	Rainwater harvesting systems and solar-assisted composting toilets manage water sustainably.	Biodegradable materials and composting promote waste management.	Incorporates Buddhist mandalas and Ladakhi cultural elements into design.	Solar electricity, water conservation, and traditional materials are incorporated into hands-on learning activities.
Sidwell Friends Middle School (USA)	**Ages**: Grades 5 through 8 **Size**: 33,000 sq. ft. **Climate Zone**: Humid subtropical	Large windows and skylights provide ample daylight; operable windows and passive ventilation enhance air quality and natural airflow.	Recycled and local materials, including green roofs, improve sustainability.	Solar panels and geothermal systems provide energy; wastewater is recycled through constructed wetlands.	Constructed wetlands recycle 3,000 gallons of wastewater daily, reducing potable water usage by 93%.	Composting and recycling initiatives educate students on waste reduction.	Outdoor classrooms blend with preserved local forests and biodiversity.	Outdoor biology ponds, butterfly meadows, and wetlands serve as hands-on ecological learning spaces.
Benjamin Franklin Elementary School (USA)	**Ages**: Kindergarten through Grade 5 **Size**: Not specified **Climate Zone**: Temperate	Optimized window placement ensures maximum daylight and glare control; stack-effect ventilation chimneys enhance natural airflow.	Non-toxic, recycled materials ensure safety and sustainability.	Energy-efficient systems outperform building codes by 35%; utilizes solar energy.	Rainwater harvesting systems reduce environmental impact and promote water reuse.	Waste separation and recycling programs engage students directly.	Design addresses local environmental needs while integrating natural elements.	Environmental projects like energy monitoring and water conservation educate students on sustainability practices.
Academy of St.	**Ages**: Ages 11	East-west orientation	Sedum roofs, local	Photovoltaic	Rainwater harvesting	Recycled constructio	Design reflects	The curriculum

School Name	Basic Information	Passive Design. Natural ventilation/lighting	Sustainable Materials	Energy Efficiency	Water Management	Waste Management	Cultural Adaptation	Integration of Eco-Literacy
Francis of Assisi (UK)	to 16 **Size**: 7,704 sq. ft. **Climate Zone**: Temperate	maximizes daylight and minimizes artificial lighting needs; natural ventilation enhances air circulation.	sandstone, and crushed cockleshells minimize material impact and highlight regional resources.	systems offset energy use; underground halls benefit from earth insulation.	reduces potable water consumption significantly.	n materials; student desks made from recycled yogurt pots.	diverse community values through Anglican and Catholic sponsorships.	integrates eco-literacy with hands-on experiences in environmental conservation and sustainability.

VI. FINDINGS

A. Analysis Findings

The case study analysis illustrates a wide range of ways through which ecological educational buildings have been able to make their various contributions to sustainable design and eco-literacy.

The Nueva School Science and Environmental Center (USA) demonstrates the integration of net-zero carbon design, photovoltaic energy systems, and rainwater harvesting. The curriculum includes environmental citizenship to empower students in implementing the principles of sustainability through practical projects.

Druk White Lotus School, India, is the exemplary model of adaptation of local material such as granite, mud bricks, and passive solar heating systems. The cultural and ecological design reinforces the bonding of the students with their natural and cultural heritage.

Sidwell Friends Middle School, USA, developed excellence in constructed wetlands for wastewater recycling, green roofs, and outdoor biology spaces serving as living laboratories of environmental education.

Benjamin Franklin Elementary School USA Passive ventilation, storm water management, and energy-efficient systems align environmental design with educational projects such as rainwater harvesting and energy monitoring.

Academy of St. Francis of Assisi UK Sedum roofs, photovoltaic systems, and regionally sourced materials are combined with an embedded eco-literacy within the curriculum that fosters environmental responsibility and cultural inclusivity. Emergent Patterns

Passive Design and Energy Efficiency: Natural lighting, passive ventilation, and renewable systems have been given much focus by all schools in a quest to reduce ecological footprints.

Cultural and Regional Adaptation: Schools like Druk White Lotus and St. Francis Academy are designed to ensure adaptability to the regional and local climate and culture.

Hands-on eco-literacy programs integrate sustainable features at schools with opportunities for active learning-such as gardening, energy monitoring, and wastewater management-through which students enhance ecological understanding in practice across the case studies.

B. Compareson Findings

A comparison among the five schools reveals that each of them excels in incorporating sustainable architectural features and fostering eco-literacy; however, some are exemplary models in certain areas. The Nueva School Science and Environmental Center really shows the leading edge of integrating technology with sustainability and features net-zero carbon emissions thanks to its photovoltaic systems and all-electric design; it serves as a benchmark for future-oriented educational facilities that are resilient. Similarly, the Sidwell Friends Middle School has set a global standard with its constructed wetlands and closed-loop wastewater systems that greatly reduce water consumption while serving as hands-on learning tools for students. Both schools thus evidence how seamlessly sustainable infrastructure can be integrated into the service of educational goals.

On the other hand, it is the Druk White Lotus School that stands out as a bright example of ecological design capable of successfully integrating into the local culture and environmental conditions. This is contextual regionalism through regional materials, passive solar heating, Trombe walls. By contrast, the Academy of St. Francis of Assisi and the Benjamin Franklin Elementary School were designed by the students to participate in a sustainable practice and included accessibility for the community to utilize such features of the design. Although all these schools have different contributions to eco-literacy and sustainability, the Nueva School and Druk White Lotus are the most striking of all-the former in relation to technological advance and innovation, and the latter regarding cultural integration and resilience in extreme climates. Such findings might hint at effective ecological educational buildings that balance their technological sophistication with cultural and environmental adaptability.

VII. DISCUSSION

The findings of this research confirm the critical role ecological educational buildings can play regarding eco-literacy and furthering sustainable development and the effectiveness of eco-literacy as a behavioral catalyst, enabling them to adopt sustainable behavior (Goleman, Barlow, & Bennett, 2013). Other studies also showed the impact of integrating sustainability features in school infrastructure on students' environmental awareness and behavior to a great extent.

Other examples include schools that have been developed, such as Nueva School and Sidwell Friends School, incorporating infrastructures directly into their design, like rainwater harvesting and the generation of renewable energy, thereby bringing notions of sustainability from abstraction into a much more hands-on-even tangible and experienced-approach.

Besides, it was underlined that knowledge, emotion, and action must be integrated in a holistic way in the education of eco-literacy. Among recent research on using ecoliteracy as a learning resource, one showed that this integration enhances environmental awareness and pro-environmental behavior of students. (Misbahudholam AR, Sama', & Aini, 2023).

This is further supported by the finding that studies are showing that education integrated with sustainability develops a generation understanding of ecological principles and how to apply responsible behavior towards the environment. Ecological educational facilities are using experiential learning opportunities for the development of students along the triad components of eco-literacy while serving as a living laboratory.

Inculcation of eco-literacy within the educational setting is vital for the development of sustainable behavior. The architecture of educational facilities combined with the holistic approach in eco-literacy education can trigger and develop citizens that are conscious of the environment and committed to taking the right path toward sustainability.

VIII. RECOMMENDATIONS

Integrate Integrated Eco-Literacy Frameworks: Architects and educators should jointly design buildings integrating features of sustainability as learning tools. For example, the system for water management, installations for renewable energy, and green roofs should be designed to provide educational benefits.

Prioritize Local Adaptation: School designs must reflect local climates, cultures, and resources; this ensures relevance and can be sustained. Examples include Druk White Lotus School.

Nurture Experiential Learning: Eco-literacy programs should be oriented toward hands-on experiences, such as gardening, energy monitoring, and water conservation, that root theoretical knowledge in practical application.

Engage Communities: Schools should extend their impact by engaging local communities in efforts of sustainability, including workshops on renewable energy or waste reduction, to effect a more pervasive cultural turn toward environmental responsibility.

Scale-Up Sustainable School Models: Policymakers should take these successful examples of ecological schools to the forefront of informing national and global educational infrastructure strategies with scalability and accessibility.

IX. CONCLUSION

Ecologically designed educational buildings transcend to much more than structural constructions but to interactive dynamic spaces wherein ecology and sustainability concepts are completely embedded within. Using techniques like solar panels, rainwater harvesting facilities, and natural aeriation mechanisms within schools, not only lessen the impacts on the ecosystems, but also create physical demonstrations for a sustainable way of living. Students learn about sustainability and develop more important ecological behaviors when they also learn in settings modeling ecological principles. For instance, schools modeling sustainability raise students' understanding and commit themselves to sustainability.

With the increased challenge of climate change and resource depletion in most parts of the world today, there is a need to integrate eco-literacy into education.

In sustainable school design, educators, architects, and policymakers have the chance to build a generation for whom the practices of sustainability will be instinctive. This is the approach that prepares students for knowledge but at the same time creates values and behavior that would go well into making a sustainable future. Ultimately, architectural design along with extensive eco-literacy programs act with a great, powerful synergy to reduce the ecological footprints to the very minimum, with students participating extensively in the rules of sustainability and preparing themselves for the challenge awaiting them.

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