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Green School as a 3D-text book for environmental education – Precedent analysis

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Abstract
With the current environmental problems, there are international movements to-wards sustainability and greening the built environments in order to mitigate the negative environmental impacts of buildings and human activities on the environ-ment and the human health. This paper presents several K-12 Green Schools that were intentionally designed to utilize school building as a 3D-text book for Envi-ronmental Education (EE). The aim of this paper is to explore the methods and strategies of designing green school as a teaching tool through case study analysis. The cases provide a diversity of geographical locations, climates, green strategies and measures. The research depends on the descriptive analytical approach for lit-erature review, and case study analysis to investigate the attributes of green schools that teach. The results revealed a set of approaches for utilizing green schools as a 3D-textbook for EE.

Keywords
Green School, sustainability, 3D Text Book, precedent analysis

Introduction

With the rising environmental problems there are international movements towards sustainability and greening the built environments in order to mitigate the negative environmental impacts of buildings and human activities on environment and human health (Chase 1995, Graves and World Education Fellowship. 1998, Grant and Littlejohn 2001, McConnell and Ryser 2009, State Pollution Control Board (Jammu and Kashmir India) 2009, Goleman, Bennett et al. 2012, Goleman, Bennett et al. 2012, Aloian 2014, Chan 2015, Lye 2015, Kensler and Uline 2017, Russ and Krasny 2017, Singer 2017). Global sustainability has profound effects on the entire building sector, including schools. Green schools provide a healthy learning environment. Beside the major benefits of Green schools such as: financial savings, improved indoor environmental quality (IEQ), and higher students' performance, green schools has the potential to serve as pedagogical tool for environmental education, helping new generation to develop skills necessary to address the environmental problems and preserve our natural resources and environment. By designing green school buildings to serve as a teaching tool, government can support environmental education while engaging students in hands on learning; reduce the impact of the schools and create healthy and highly efficient environment.

Architecture and Education
The work of learning theorists along the years has shown the holistic and non-linear nature of the learning process. Theories like Piaget's developmental stages of learning and Gardner's multiple intelligences theories have paved the way to an insight into how people learn. The physical setting of learning is an inherent component of these processes, yet for a long time the architecture of schools has been dealt with a linear simplified approach ignoring the complexity of the processes it takes a part within. The result of

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such approaches is static spaces that takes a huge toll on the learning process and inhibits learning. (Taylor and Enggass, 2009) (Nair, Fielding et al., 2013). The traditional classroom designs exclude the active view of the learner offered by the learning processes, and the personalized understanding of the learner. Thus, these traditional classrooms cannot accommodate the instructional strategies based on such learning processes. (Taylor and Enggass, 2009). Furthermore, the school design ignores the powerful effect of the physical educational environment on teaching and learning, as they have a "hidden curriculum"(Orr, 2004). Thus, the key is to view the physical environment and its ambient quality as active and indispensable parts of the learning process. (Taylor and Enggass, 2009). A twenty-first-century learning environment views the learner as active in an active learning environment. Dent- Read and Zu.kow-Goldring have proposed a four-by-four matrix in which the learner and the environment can be understood as either active or passive (Lippman 2010). Figure 1 illustrates the four-by-four matrix.

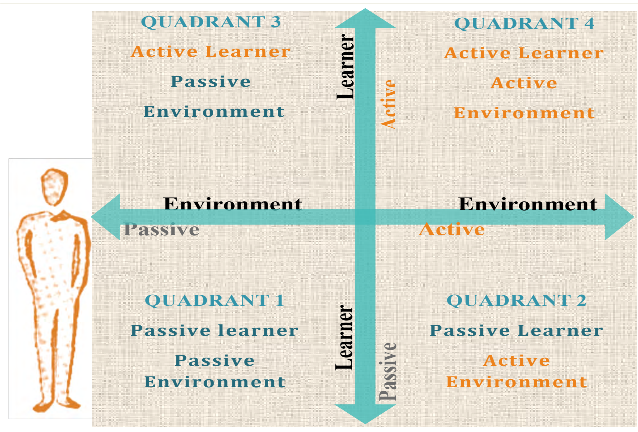

Figure 1. *A four-by-four matrix in which the learner and the environment can be understood as either active or passive, (Lippman 2010).*

Transforming the School Design

Learning is a reciprocal process between the learner, the facilitator, the pedagogical practices, the social climate, and the physical environment as shown in Figure 2 in a well-designed school, the reciprocity between learning and the learning environment would remain current and ongoing over the years. Some commonly cited changes emphasize new models of teaching and learning and corresponding ways of planning for school facilities. The second author of the current research investigated the environmental performance "particularly the thermal

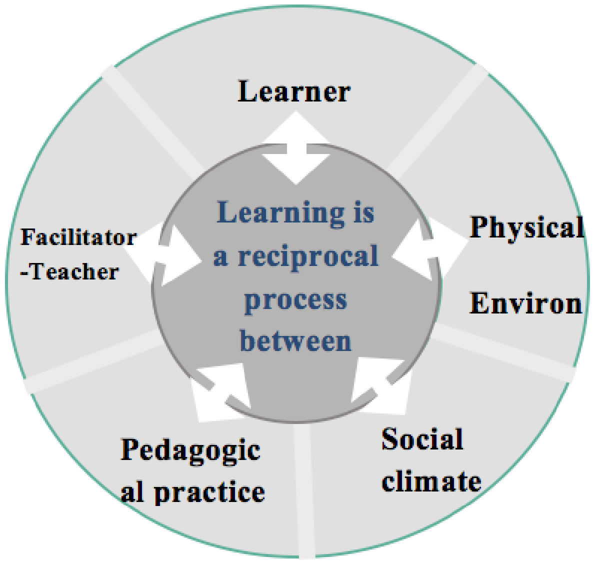

Figure 2. *The learning process. Source: illustrated by researcher, adapted from (Nair 2014), p. 6.*

performance" in primary schools in several previous research (Mohamed, Gado et al. 2005, Mohamed 2009, Mohamed and Gado 2009, Mohamed and Gado 2009, Mohamed 2014, Mohamed, Okasha et al. 2016). The following list - compiled from different references (Paul 1881, Detroit Publishing Co. 1903, Hine 1921, Chase 1995, Meena, Pandya et al. 1999, Paul Green School of Rock Music. 2006, Adler and Allen 2008, LPA (Firm) 2009, McConnell and Ryser 2009, Normore 2010, Brebbia and Beriatos 2011, Gaarder-Juntti 2011, Architecture for Humanity (Organization) 2012, Ramli, Masri et al. 2012, Cincera and Krajhanzl 2013, Iojă, Grădinaru et al. 2014, Kasai and Jabbour 2014, Powdyel 2014, Radford, Morkoç et al. 2014, Chan 2015, Huang, Huang et al. 2015, Kensler and Uline 2017, Lou, Tsang et al. 2017), shows the nexus between education and school design (Figure 3). Two of these factors (learning theories and sustainability) are related to this research, while Technology is out of the research scope.

Green Schools

The green building revolution is part of a paradigm shift toward sustainability. The revolution fuelled by the knowledge that the built environment have significant harm effects on the natural environment and human health (Yudelson 2008) According to EPA, half of total carbon related emissions that derive global climate change came from buildings and its use. Recently, there have been a movement on the way in school systems around the world,

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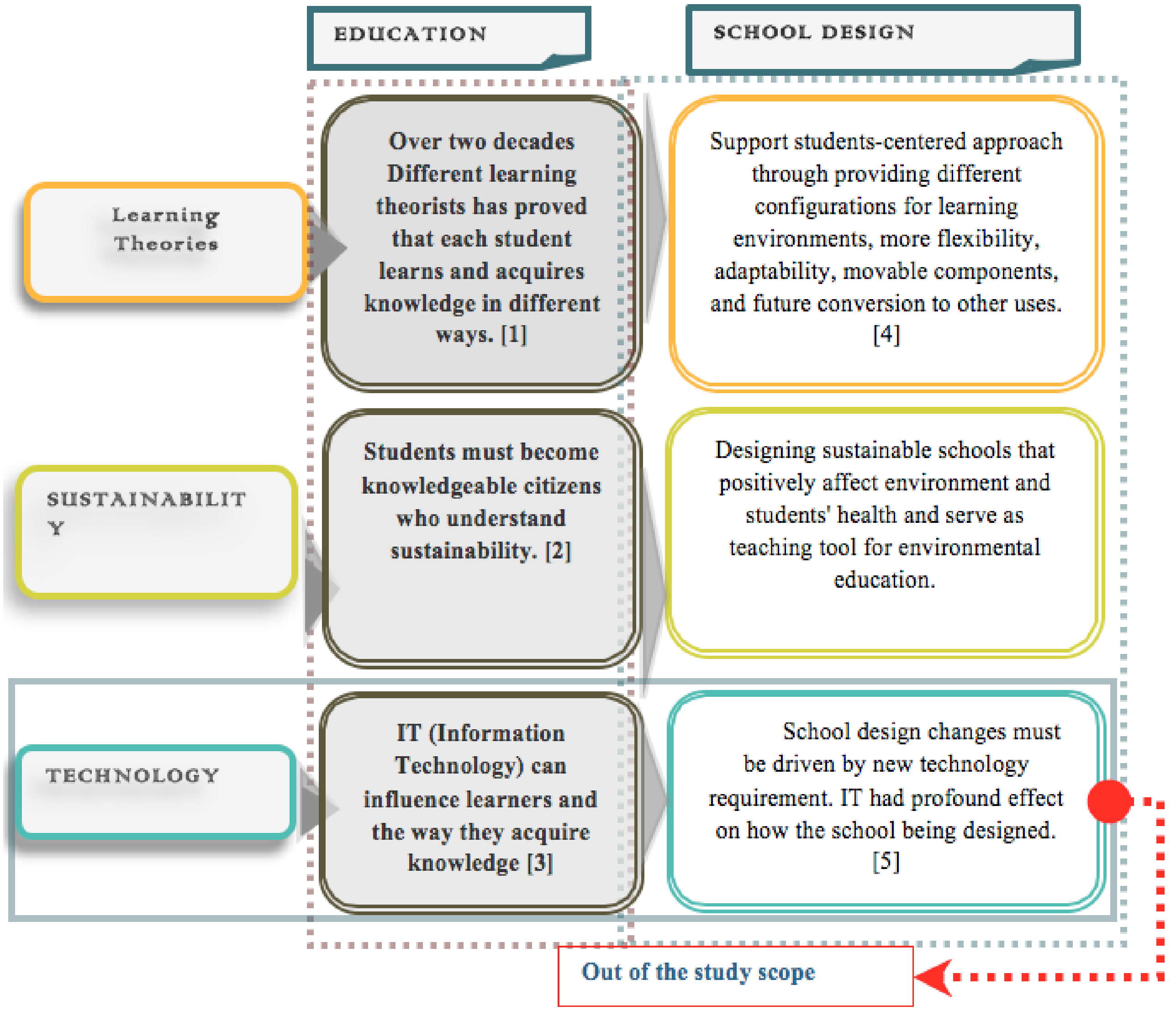

Figure 3. *Shows the nexus between education and school design, after (Taylor and Enggass. 2009), (Armstrong. 2009), (Lippman 2010, O'Donnell Wicklund Pigozzi and Peterson 2010, Nair 2014).*

where the system is being moulded to prepare students for the environmental challenges of the future. (Stone 2009). several studies showed that by green building, the environmental degradation could be reduced ((Kats 2006),(Yudelson 2008), (ASHRAE 2008) and (USGBC 2014)). In the non-residential construction industry, school buildings are the most significant sector, therefore, the change in design approach of that sector will have an intense effect on the environment. (Taylor and Enggass. 2009).

While sustainable school is based on a deep understanding of biology, on the creation of a habitat for learning instead of a machine for learning (Gelfand and Freed 2010). Green schools are educational buildings that operate in harmony with the natural environment. They are built to reduce energy costs and conserve natural resources, make use of recyclable materials, and operate in a sustainable manner. (Spake and (AFT) 2008). The U.S Green Building Council has defined green school as a facility that creates a healthy environment conducive to learning during saving energy, resources and money((USGBC) 2015). An effective green school, successfully, can integrate the green concepts into school day and serve as a laboratory for practicing conservation where distinct aspects of green design are used as subject area (Chan 2014). On the other hand Green schools contribute to make communities more sustainable, explore solutions to environmental problems, and serve as models of responsible action (Ecoliteracy 2010). Green schools provide a healthy learning environment for both students and teachers while decreasing its environmental impact, in terms

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of energy, water, materials consumption and wastes generation in construction and operation process. Additionally, integrating the schools itself in curriculum can enhance the environmental stewardship among students, and spread the awareness beyond the school wall to the whole community.

Research Aim

The research aims mainly to derive the attributes of green schools that act as pedagogical tool for environmental education.

Research Methodology

The research depends on the descriptive analytical approach for literature review; multiple-case study analysis to investigate the attributes of green schools that teach. The investigated sample consists of 8 cases meeting the following criteria:

1) K-12 Green schools
2) Described as a building that teaches, 3D textbook, learning lab, living lab, within the building's mission statement.
3) Recognized for either their progressive sustainable or educational design.
4) Availability of information on the case's facility design and educational programming.

Each case study is organized as follows:

- a general description of the project;
- school building design;
- connection to the community;
- a description of the green strategies used;
- utilizing school as a 3D Text-book.

Precedent analysis

SIDEWELL FRIENDS QUAKER SCHOOL

Location: Washington, DC - **Design team:** Kieran Timberlake Associates - **Area:** 72,200 Sq feet (54% new, 46% existing) - **Awards**: LEED Platinum, 2007 AIA COTE Top 10 Green Projects - **Client:** Sidwell Friends School - - **Completion:** 2007 - **Coast:** 28 m$.

School design

The project is a renovation and addition to a fifty-year-old educational facility which transformed the campus and surrounding landscape into a school that teaches environmental responsibility by example. In addition to, create a teaching landscape in close connection to the natural environment. Designed to foster an ethic of social and environmental responsibility in each student, the facility demonstrates a responsible relationship between the natural and the built environment (AIA, 2007) (Fig. 4).

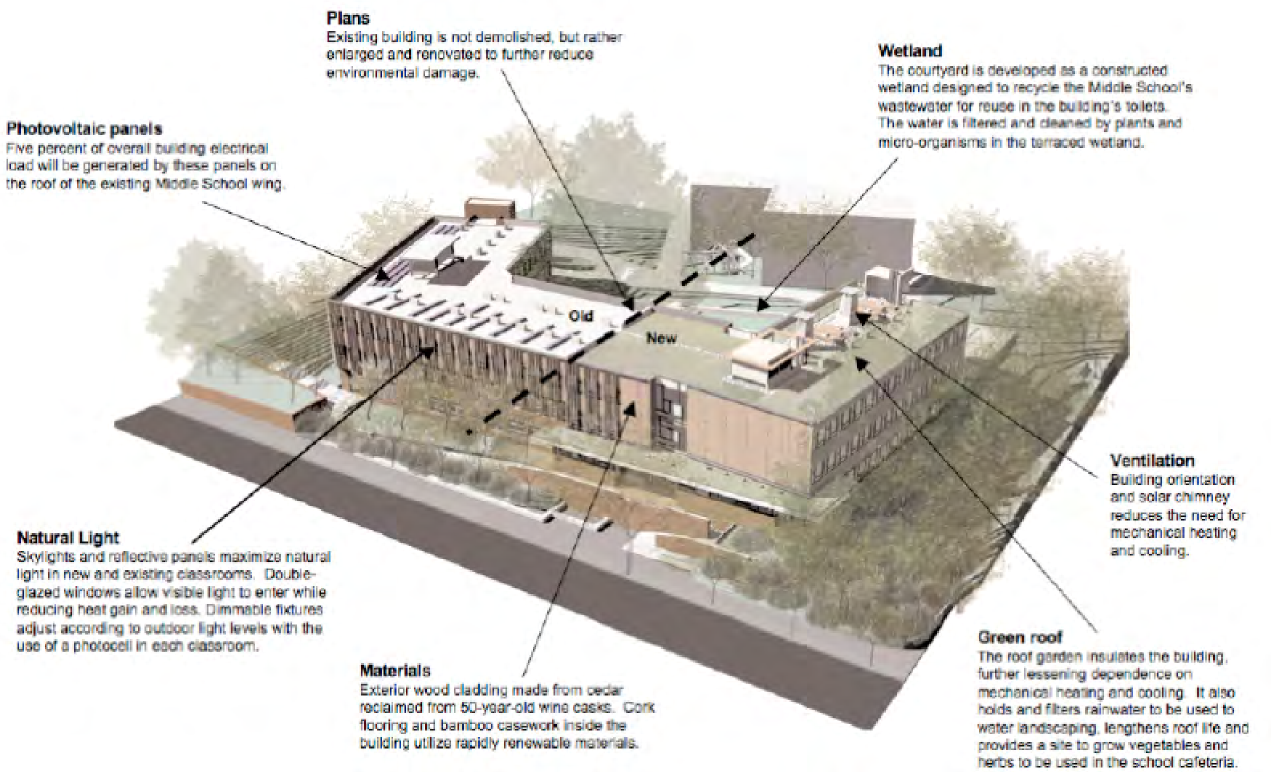

Figure 4. *The entire school becomes a 360 degree learning textbook and educational tool for sustainability. (Drake et al., 2009-2010)*

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The new first floor contains a music wing (drama, chorus, and instrumental), and an art wing in addition to support spaces. The outdoor courtyard is emphasized by the circulation which connects the two wings and classroom spaces. This circulation joint has several functions for the building including serving as a main entrance and lobby, for administrative offices and reception space, and to serve as a library and computer lab. The second floor contains a science wing and fifth and sixth grade classrooms. The classrooms were placed along the courtyard wall to allow visual access to the space below. The joint of the two wings houses offices and learning services (Fig. 5).

Figure 5. *The different spaces in the school and the connection between indoors and outdoors is apparent on the courtyard side, where classrooms are opened up with multiple windows (Visual connection) and accessibility. source(Drake, Goyak et al. 2009-2010).*

The roof has been integrated into a usable learning space, incorporating photovoltaic panels and planted roof garden space which becomes available for hands-on learning activities. The technology housed on the roof allows for a programmed space for students to learn about mechanical systems as well as passive and active green strategies (Fig. 6).

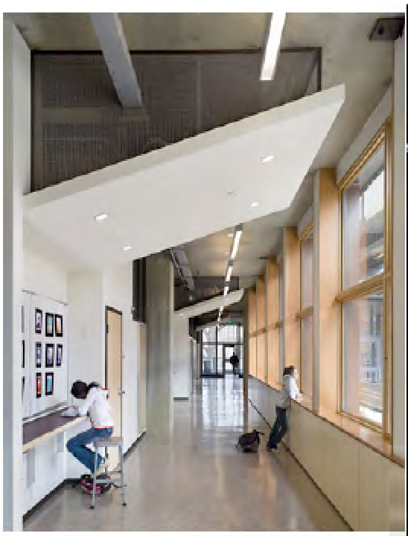

Figure 6. *Utilizing the corridor by creating students work spaces along the corridor (Drake et al. 2009-2010).*

Connection to the community

The school have established a tour and signage program for the community to share lessons of green design strategies. Historical and real-time information about the building's energy and water use are displayed to the public through an online application. Communities considering similar investments can use the data offered by this establishment as a benchmark for the technology of this period and as hard data input (AIA, 2007). Subway and bus systems allow community access to the grounds and outdoor recreation areas, making the school a community center and increasing its function. Local species were selected for landscaping the site. Some surrounding neighborhoods, inspired by the school's work have begun planting local flora in their areas as well. Surrounding neighbourhoods have access to utilize the drainage area of the schools constructed wetland, helping the entire community to live more sustainability. (Drake et al., 2009-2010).

Green strategies

Site. The building is located within walking distance of a subway stop and several bus stops - Bicycle storage and showers are provided. Parking is available in an underground lot with a green roof - The school offers $35 each month to any faculty or staff member who reduces his or her car use by 80%.

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Landscaping. Peripheral areas were converted from lawns to "micro-restoration areas" intended to showcase native ecosystems such as oak-beech woodlands and wet meadows. More than 80 regionally appropriate species were introduced into the campus landscape (AIA, 2007) - Addition to the renovated middle school forms a courtyard that is used as constructed wetlands in a grey water purification and reuse project (Fig. 7). This courtyard is accessible to all visitors.(Drake et al., 2009-2010).

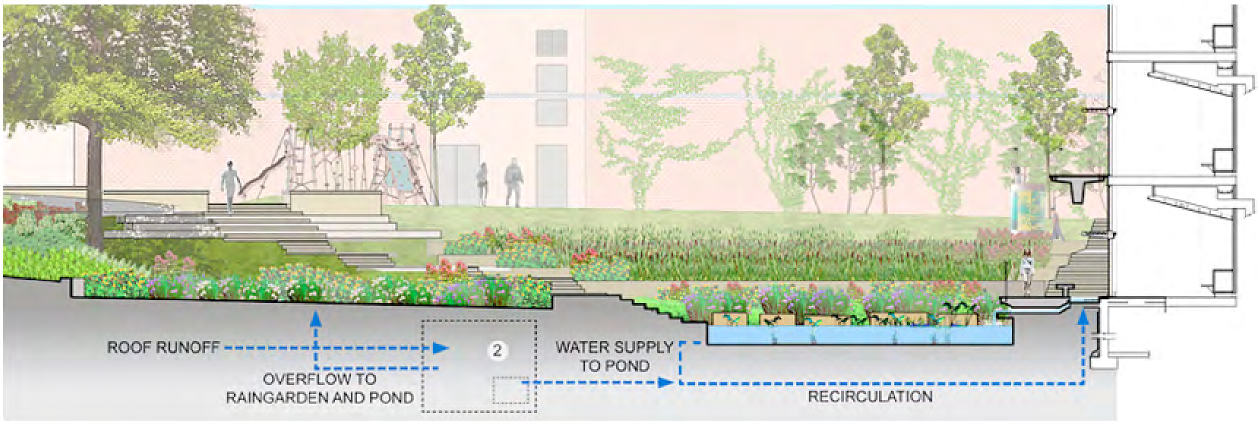

Figure 7. *Constructed wetland designed to utilize storm and wastewater for both ecological and educational purposes. Source: https://www.asla.org/sustainablelandscapes/sidwell.html*

Water. A green roof and constructed wetland reduce storm water runoff, improve the quality of infiltrated runoff, and reduce municipal water use. The wetland naturally treats wastewater for reuse in the toilets and cooling towers (Fig. 8). Thus, substantially reducing the school's use of potable water. In addition, sensor-operated water-conserving lavatory faucets are used (AIA, 2007).

Figure 8. *The pond and rain garden prevent storm water runoff. Source: http://www.sidwell.edu/middle_school/ms-green-building/index.asps*

The wetland reduces the use of the district water supply by 94%.- Rainwater is collected on roof and is diverted to the courtyard to a biology pond, creating a habitat for plant and animal life (Fig. 9).

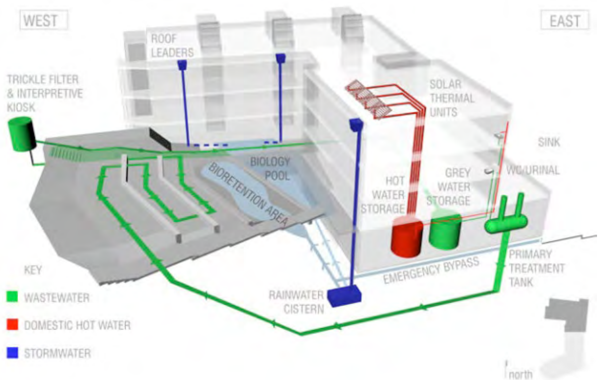

Figure 9. *An environmental diagram showing the wastewater and storm water filtration and treatment process (AIA, 2007).*

Energy. The building will use 60% less energy than a comparable building designed in minimal compliance with ASHRAE 90.1-1999 (ASHRAE, 2019). While, 50% of the energy purchase is generated from renewable sources via local green energy plants - A photovoltaic array that generates 5% of the electrical demand for the building (Fig. 10) - The building's exterior sunscreens were designed to balance thermal performance with optimum daylighting - High-performance operable windows, skylights, and ceiling fans minimize the need for artificial cooling. Solar chimneys with south-facing glass provide passive ventilation. The building automation system prevent mechanical heating or

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cooling when windows are open (Fig. 11) – Solar water heaters are placed on the roof of the existing building - Thermostats are installed densely throughout the complex to provide for a high degree of local environmental control.

Figure 10. *Students calculate and monitor solar power by having access to photovoltaic panels. Source: Drake et al. 2009-2010.*

Figure 11. *Solar chimneys enhance natural ventilation in the classrooms.* Source: http://www.sidwell.edu/middle_school/ms-greenbuilding/index.aspx

Indoor environmental quality. The two wings of the main complex have respectively long north/south and east/west facades. Thus there are Different treatment of façades according to orientation and solar aspects in order to provide daylight (Fig. 12) - The new wings incorporate solar chimneys above the classrooms in order to enhance the natural stack ventilation in the building. In addition, both wings are equipped with operable windows that provide a natural cross-ventilation - Three glazed towers on the roof passively heat up the air, thus creating a convection current that draws up cooler air through the building from open north-facing windows in the classrooms below - The air quality of the building is systematically monitored to ensure a healthy and low CO_2 - VOCs (Volatile Organic Compound) and other contaminants have been reduced by favouring natural over synthetic materials.

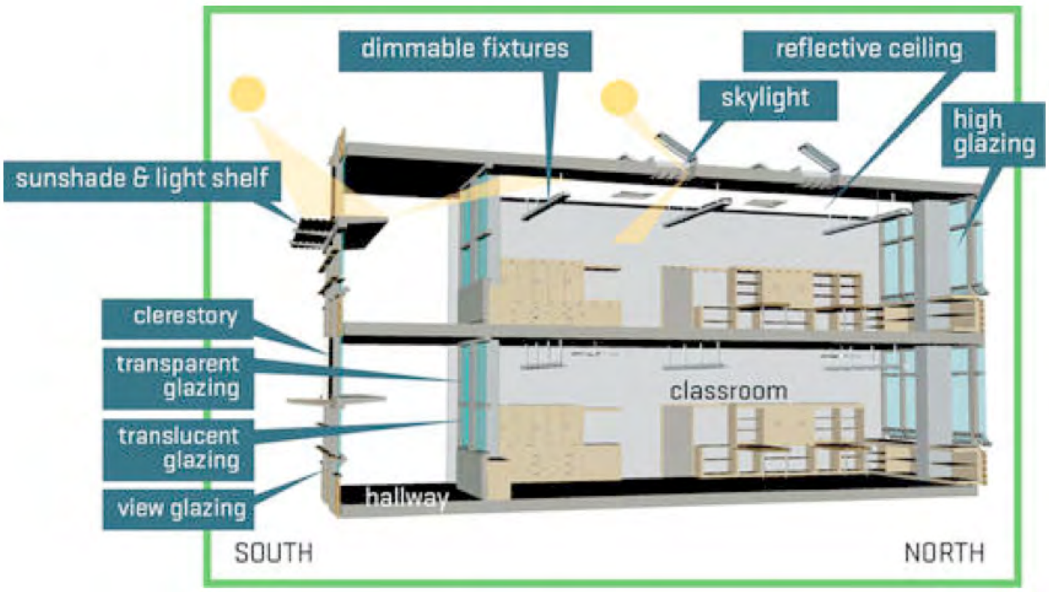

Figure 12. *Diagram shows daylighting strategies for classroom. Source: http://vi.sualize.us/sidwell_friends_school_washington_d_c_usa_photo_by_michael_moran_for_metropolis_sustainable_building_natural_ventilation_graphics_wastewater_treatment_picture_4Ues.html*

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Material and resources. 78% of the building materials were manufactured within a distance of 500 miles from the school. While, 11% came directly from recycled sources - Reclaimed materials include exterior cladding made from 100-year-old western red cedar wine barrels, greenheart flooring and decking from pilings in the Baltimore Harbor, and all of the stone used to construct the wetland and other outdoor walks and walls. The building includes two central recycling stations for plastics, metals, cardboard, and glass (AIA, 2007) (Fig. 13) - The use of raw materials such as cork flooring and bamboo casework which can be recycled, contains recycled components or which are readily renewable.

Figure 13. *The building's "skin" is made from reclaimed wine casks. The decking wood came from pilings from the Baltimore Harbor. Source: http://www.sidwell.edu/middle_school/ms-green-building/index.aspx*

Utilizing school as a 3D textbook

The approach to ecological master planning is reflected in the approach to the design of the new wing, thereby integrating site and building. This integration extends to the curriculum, which exploits the habitats, water courses and architecture as interrelated teaching resources. Different treatment of the façade is another area where architecture is used in teaching pupils about physics and ecological principles. Wind chimes in the air shaft allow students to hear the air moving up through the chimneys.

Learning landscape. Integrate educational opportunities into the campus landscape, to create a unified campus, and to provide spaces for individual reflection and large-group assembly (AIA, 2007) - The wetland becomes an important teaching tool by demonstrating the food-waste-food cycle that forms the base of all natural systems.

Poster information. Conspicuously located poster information to illustrate different green strategies for students and visitors (Fig. 14).

Figure 14. *An interpretive diagram of the constructed wetland and water management wraps around its trickling filter. Source: http://www.sidwell.edu/middle_school/ms-green-building/index.aspx*

Exposure. The use of natural, local and recycled materials and the wide range of passive energy initiatives represent a visible and understandable catalogue of means for the pupils to use in their studies - The PV panels and the solar chimneys are clearly visible - The existence of the grey water within the building is made clear through the use of blue color when flushing the toilet pans.

Web page. Through the web page of the school, direct access to a "building dashboard" reveals real time and historical data on energy consumption and production, water use, reuse and waste recycling, and weather information.

Display board. In the hallway of the new building, a display board explains the ecological profile of the key materials used in the construction, thus teaching the students about the importance of knowing the source, environmental impacts and qualities of each material.

HPA ENERGY LAB

Location: Kamuela, Hawaii (Figure 14) - **Client:** Hawaiian Preparatory Academy - **Design team:** Flansburgh Architects,Boston, Mass.- **Completion:** 2010 - **Area:** 6.1 SF - **Coast:** $4 million - **Awards**: LEED for Schools Platinum, Living Building Challenge, Learning by design 2010 Grand Prize winner.

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Figure 15. *A traditional "Tropical Three Pitch Roof" design features a shaded lanai facing south. Source: http://www.hpa.edu/academics/energylab*

Figure 17. *Outdoor class room integrated into the building with overhead shading. Source: http://www.archdaily.com/64732/hawaii-preparatory-academy-energy-laboratory-flansburgh-architects*

School design

The design of teaching spaces is based on team learning, project learning, concentric source of spaces instead of the traditional factory model of education.

Connection to the community

- The outreach component extending beyond local communities and schools to hosting national and international summer conferences, which is a natural extension of the Lab's mission of education, monitoring, and outreach
- The Terrace Farm serves as an educational, cultural and community resource (Hawai'i, 2011)

Green strategies

Site. The land of the building was previously used as the campus bio waste (and other materials) dumping area - The building was intentionally located at the windward edge of campus to take full advantage of the abundant trade winds that accelerate down from the hillside above - Direct connections to the outdoors are enhanced via operable glass doors - A large teaching porch opens directly south, and a wind-sheltered court to the west sponsors an outdoor, covered classroom (Fig. 17) (Institute, 2019).

Landscaping. Restoring native Quaya trees Grew Hawaiian crops such as sweet potato in the hill.

Water. 100% of water comes from precipitation - 100% wastewater treated on site and dispersed in leaching field infiltration system (Serra, 2011) - Water demand is reduced via low-volume sink and toilet fixtures (Institute, 2019).

Energy. The lab is 100% energy neutral, uses about 20% of the energy they produce while giving 2000$ monthly electricity back to the rest of the campus (Fig. 16) shows how the school utilize the site and building's roof to generate renewable energy through photovoltaic - The campus uses the local grid as a battery in times of overproduction (Serra, 2011) - The building is entirely naturally ventilated, and employs a radiant cooling system as an alternative to conventional air conditioning (Fig. 18) - All spaces had access to daylight with minimum solar heat gains (Fig. 19) – A solar water heating system, and a planned wind farm (Hawai'i, 2011) - Sensors will monitor and control artificial lighting and natural air flow. The building's performance will be shown on monitors at the lab and around campus.

Figure 16. *Utilize the site and building's roof to generate renewable energy through photovoltaic. Source: http://www.hpa.edu/academics/energylab*

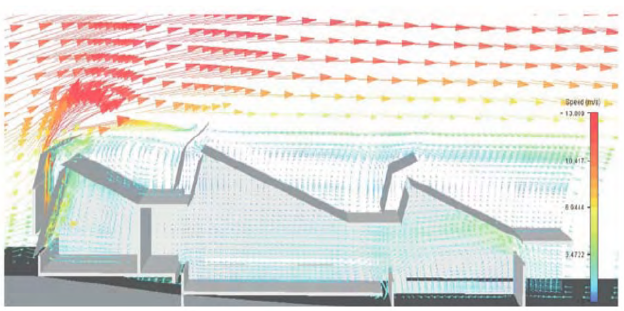

Figure 18. *Natural ventilation was the key design driver for the project. Computational fluid dynamics analysis helped evaluate the effectiveness of the design to provide thermal comfort and proper heat exhaust.*

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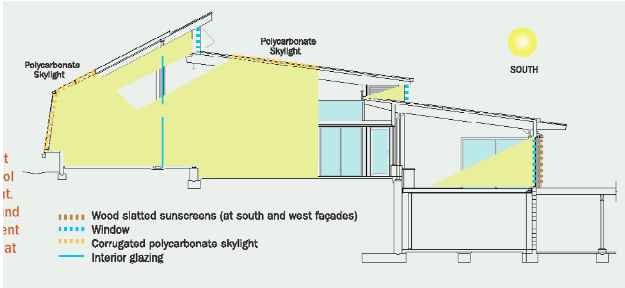

Figure 19. Section shows the daylighting strategy for the lab to eliminate the need for artificial lighting Source: (Serra, 2011).

Indoor environmental quality. Building automated louvers maintain temperature and relative humidity levels with adequate levels of natural light to maintain interior comfort. If necessary, exhaust fans are activated to induce airflow (Fig. 19) (Institute, 2019) - - Conditions in the lab have not required the use of fans or air conditioning since its opening in January 2010 - Deep overhangs and sliding wood shutters provide shading, prevent direct solar exposure, but make the building permeable to breezes and light winds from the south - A comprehensive and custom BAS optimizes the lab's performance by monitoring internal and external conditions and controlling all energy systems to provide the highest level of thermal comfort while consuming the least amount of power (Serra, 2011).

Material and resources. All wood is Forest Stewardship Council (FSC) Certified or from salvaged (Fig. 20) - The building does not use any Red List materials, such as PVC, formaldehyde or halogenated flame retardants - The use of few native material, regional product - Lava rocks from the area are embedded in this poured concrete wall (Fig. 21).

Figure 20. *The south-facing outdoor classroom is supported by a salvaged native ohia wood column. Source: Institute, 2019.*

Figure 21. *The local lava rocks in the poured concrete walls. Sources: Serra, 2011.*

Utilizing school as a 3D textbook. Outreach component extending beyond local communities and schools to hosting national and international summer conferences, which is a natural extension of the Lab's mission of education, monitoring, and outreach.

Learning landscape. Students participate in planting and harvesting the crops, as well as in the restoration of the native trees.

Curriculum. Offering a hands-on learning approach to sustainability, HPA students from grades 6-12 will be able to build, test, and monitor the Energy Lab's alternative energy technologies.(Hawai'i, 2011) - They use 3 different kinds of solar p*anels so the students would have the* opportunity to make a comparison.

Poster information and signage. The faculty has encouraged energy conservation through the curriculum and by posting signage throughout the building.

Exposure. The radiant cooling tank is visible and accessible to students - The steel piping is visible throughout the building - The Energy Lab hosted several tours.

Monitoring systems. An advanced telemetry system for energy monitoring gives students a window into the Energy Lab as a living building (Academy, 2017).

REDDING SCHOOL OF THE ARTS

Location: California, USA (Fig. 23) - **Client:** The McConnell Foundation - **Design team:** Trilogy Architecture - **Completion:** 2011- **Area:** 7,153m2 - **Coast:** $28 million - **Awards**: In 2012, RSA became the first school campus in the world to be certified

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Platinum under LEED for Schools 2009 standards. 2012 American Institute of Architects Design Excellence Award 2013 U.S. Department of Education Green Ribbon School Award 2013 Edison Award for Environmental Design.

Figure 22. *Redding School of the Arts Powered by PV and Wind Energy. Source: http://www.solardesign.com/SDA_Today/renewable-energy-serves-redding-school-of-the-arts/?toperStarEhJUS=1*

School design

Half the learning spaces in this establishment are outdoors. The outdoor hallways are well lit and are transformed to "learning streets"; small-scale "theme" cafes, a series of dance and exercise studios, and music rooms that open up to outdoor theatre. Central outdoor theater is a gathering space for socialization. Everywhere there are opportunities for student exhibits. The outdoor area is a balance between creative play and unstructured open spaces, whether it's the playground, the gardens or the outdoor classrooms (WBDG, 2012) (Fig. 24).

Figure 23. *3D model and section illustrate the design of the school and central outdoor theatre. Source: Arts, 2011.*

Classroom design. Creative learning spaces alter the traditional rectangular classroom shape into a multi-purpose space that allow for flexibility in different teaching styles that can range from formal lecture to informal studio. Each classroom has primary learning area with adjacent accessory space for small group learning (Figg. 25 and 26). But learning in the school is designed to go beyond the general classroom as: the hallways have been designed as "learning streets", with space for sitting, talking and studying (Theimer, 2009); classrooms are also used as sound studios, able to broadcast over the internet and to other classrooms (RSA, 2013).

Figure 24. *The design of the classroom supports different teaching styles. Source: http://openbuildings.com/buildings/redding-school-of-the-arts-profile-42566/media#!buildings-media/10*

Figure 25. *Plan of classroom. Source: Arts, 2011.*

Connection to the community

- The facility serves as a national model of energy efficiency and sustainability.
- The entire school annually visits both national & state parks to engage with park rangers in outdoor activities including bird, plant and rock identification, Native American life and their relationship to the environment.
- Ecology Club, including teachers, students, parents & maintenance staff to share learning about implementing green efforts at the school.
- Additionally, the cooking, after-school, and some general teachers use the gardens and chicken coops to illustrate sources of healthy, organic foods, soils science, often working in tandem with community volunteers (RSA, 2013).

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Green strategies

Site. Buffer the school from the street by almost 600ft. Half of them for existing stand of trees and the other for parking lot designed around existing trees (Fig. 27) (Theimer 2009) - More than half of the learning spaces are outdoors.

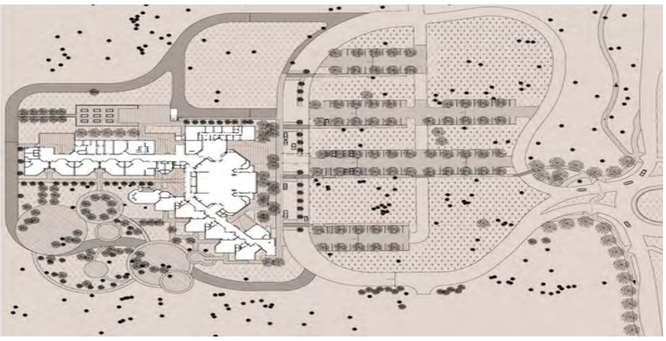

Figure 26. *School site that show the buffer zone between the school and street. Source: Arts, 2011.*

Landscaping. Maintain most of the existing mature oak trees within the new parking and playground - New trees will be planted at the rate of one per two automobiles.

Water. Located in a region where there is little rainfall for seven months, an aggressive water-saving design has been combined with a 175,000 gallon underground storage tank for rainwater collected from the roof to provide for 100% of yearly irrigation needs (WBDG, 2012) - Water saving fixtures such as waterless urinals and dual flush toilets, drip irrigation and drought tolerant landscape (Theimer, 2009).

Energy. 100% of the general classrooms are oriented to the north, to allow for maximum natural daylighting and cross ventilation with the prevailing breezes -
- Energy use was 75% less than the ASHRAE baseline building in the first year of operation - The HVAC system is based on a geothermal heat pump design - Renewable energy is provided by a PV panel, a vertical axis wind turbine, and solar thermal water heating - Motion sensors trigger exterior lighting - The outdoor areas in this school have been "semi-conditioned" with radiant heating in the winter and evaporative cooling in the summer (WBDG, 2012).

Indoor environmental quality. All the general class rooms provide daylighting and cross-ventilation (Fig. 28) - Outdoor spaces are protected from extreme weather condition by the building envelop (roof overhangs and operable garage-style doors), and air temperature is moderated by evaporative cooling fans and strategically located radiant heaters.(WBDG 2012)
- Custom designed acoustical walls for hallways which successfully dampen the sound.

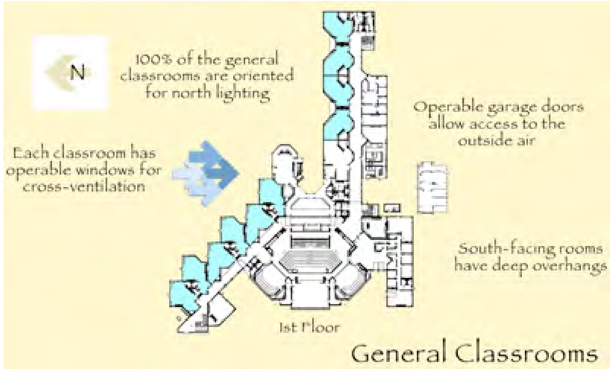

Figure 27. *North orientation to provide natural lighting and ventilation for each classroom. Source: http://reallyredding.com/wp-content/uploads/2012/01/Trilogy5.jpg*

Material and resources. Eco-friendly insulated walls - West-facing rammed earth walls are combined with more high-tech solutions such as ultra-efficient glazing - Interior walls, floors, and ceilings are comprised of recycled materials such a rubber flooring and toilet partitions made from recycled soda bottles, rapidly renewable resources such as bamboo flooring, and zero VOC paint for all interior finishes. One hundred year old recycled redwood highlighting the outdoor learning streets (WBDG, 2012) - Durable materials and low maintenance building systems that show the concept of life-cycle design (Theimer, 2009).

Utilizing school as a 3D textbook

- Decisions have consistently been made to explore as many examples of environmentally friendly ideas as possible for student learning opportunities, even when those decisions haven't necessarily contributed to the LEED score card. K–8 school has been incorporated into the teaching curriculum as "a tool for teaching green", for its children, parents and teachers, as well as the local community and beyond (Arts, 2011).
- More than seventy green features included in the school's design has been assembled for use with the ongoing education curriculum, and divided into six separate categories: food for thought; earth, water and the air we breathe; a healthy discussion; energy: conserve and create, reduce and recycle; how buildings work; creativity and learning together (WBDG, 2012).

Learning landscape. Gardens and chicken run are student-designed ideas that have been incorporated into the building plan to educate students about healthy

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eating and connecting with the sources of food - An extensive outdoor area was conceived as an “almost natural” playground, with areas of grass, rocks, and water - Outdoor classrooms.

Poster information and monitoring systems. A Building Dashboard is accessible to anyone to show a daily basis energy use, generation, and water use. In addition to that, two separate dashboards for PV and light controls was installed to provide specific and detailed data - Dar sky monitor to measure night-time light pollution.

Visibility. Visible storm water bio-filtration is combined with reduced irrigation and rainwater storage to teach the importance of water management to students - - Exposed structure and building materials.

Transparency. Transparency will occur with windows into every mechanical space as well as windows into classrooms. Such as students can look through a window into the elevator shaft to see how an elevator works - With a series of panelized doors, the galleries connecting those classrooms can be opened to outdoor classrooms surrounded by landscaped screen walls - A dual-flush toilet, low flow sink or high efficiency hand dryer turns an ordinary restroom into a teaching opportunity (Theimer, 2009).

Tours. Students frequently provide public tours about the building’s green features and sustainable practices & curriculum development (RSA 2013).

Dashboard. Everyone with a computer should be able to log onto an internet-based “building dashboard” to observe how efficiently the building is operating. The dashboard will monitor the building’s energy systems and hopefully modify student and teacher behaviors with regard to more effective energy use.(Theimer, 2009).

Hands on:

- Recycling will be evident everywhere, through recycled building materials, or every day composting and recycling done by the students and teachers.
- Providing gardens for school children and cooking class to demonstrate to them how to apply new skills (Theimer, 2009).

PINE JOG ELEMENTARY SCHOLL

Location: Florida, USA - **Client:** The School District of Palm Beach County and Florida - **Design team:** Zyscovich Architects - **Completion:** 2008 - **Area:** 155,000 sq.ft.- **Cost:** 29.3 m$ - **Awards**: LEED Gold 2009.

School design

The design for the elementary school includes numerous break-out project rooms and alcoves, storytelling areas, wet areas and outdoor interactive learning environments, located for joint use by multiple classrooms as well as the environmental educational center (Fig. 28).

Figure 28. *School building and courtyards that function as classroom space. Source: DesignShare, 2008.*

Classrooms configurations are catering to various learning styles (Figg. 29 and 30).

Figure 29. *Ground floor plan of the school. Source: DesignShare, 2008.*

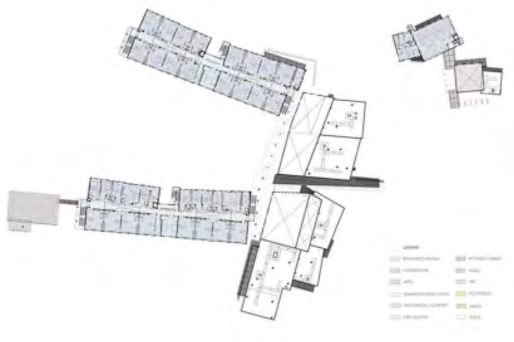

Figure 30. *Show Typical floor plan of the school. Source: DesignShare, 2008.*

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Connection to the community
Provide a program of ecological awareness and stewardship.

Green strategies
Site. The regenerative site design includes habitat and tree preservation, native pineland landscape, wildlife habitats, storm water collection and conservation, soil composting, an interactive sundial and Solar Plaza (Fig. 31).

Figure 31. *Campus site plan. Source: DesignShare, 2008.*

Landscaping. Restoring the natural landscape - Butterfly gardens, mitigation/restoration areas, and biological life cycle study areas of slash pines, gopher tortoises, native grasses, insects, lizards, and other native amphibians (DesignShare, 2008).

Water. Water efficient plumbing - Dual-flush toilets - Rainwater harvesting of over 14,000 gallons.

Energy. Photovoltaic panels - Solar system for hot water - Classroom lighting with occupancy sensors.

Indoor environmental quality. The school design offered for all the classrooms daylight and good views (Fig. 32).

Material and resources. Local materials - Materials with recycled content -Recycled more than 85% of the construction waste - Recycling stations.

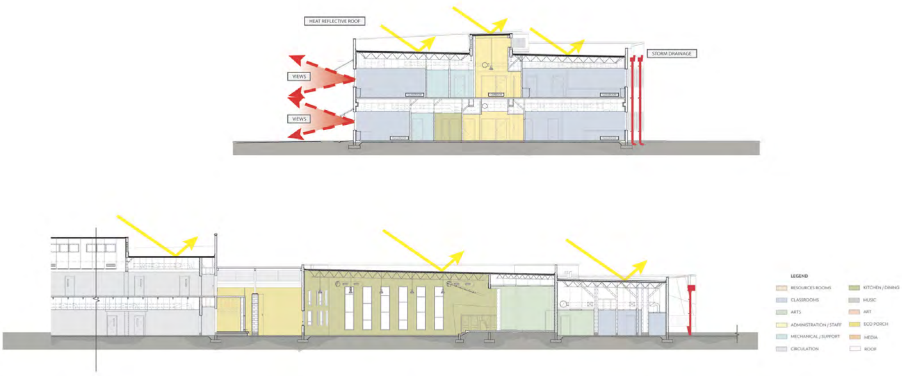

Figure 32. *Section shows heat reflective roof and classroom views. Source: DesignShare, 2008.*

Utilizing school as a 3D text-book

Learning landscape. Restoring the natural landscape.

Outdoor classroom. The entire 150-acre parcel serves as an outdoor classroom - The site education curriculum utilizes the entire preserve with designed learning places in and around the structures that bring the outdoors inside and vice versa.

Exposed systems and monitoring. the Solar Plaza combines solar technologies (photovoltaic and hot water) for students to see and monitor with computers - A rooftop weather station - Highly efficient and visible mechanical equipment - Windows into the mechanical spaces.

Real-time data. Students, staff and the greater community will be able to interact with building performance information via the internet through "green-screen" energy monitoring.(DesignShare, 2008) - - Monitors displaying live data about water consumption - - Green elements are visible to students and visitors.

Signage. Distributed throughout the campus to explains the buildings' LEED features, including preferred alternative-fuel and carpool vehicle parking; water re-use demonstration areas; recycling stations, and the use of recycled and locally available construction materials; and polished concrete floors at high-use areas.

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Tours. Visitors to the Environmental Education Center will be able to tour the school grounds, participate in site stewardship activities and learn from the interactive displays associated with each of the buildings' renewable energy systems (DesignShare, 2008).

Conclusion

Green school design provides an extraordinarily cost-effective way to enhance student learning, reduce health and operational costs and, ultimately, increase school quality and competitiveness. Utilizing the green school as a teaching tool, will encourage environmental stewardship among students while spreading the awareness of sustainable issues in the whole community. Figure 33 presents the proposed framework for green schools that teaches.

There are common attributes can be derived. Each case study was differently designed to serve as living illustration of inventive and sustainable solutions. However, Case study analyses revealed variety of approaches for utilizing green schools as a 3D-textbook for EE. Table 1 illustrates the most common attributes, their description and related design features.

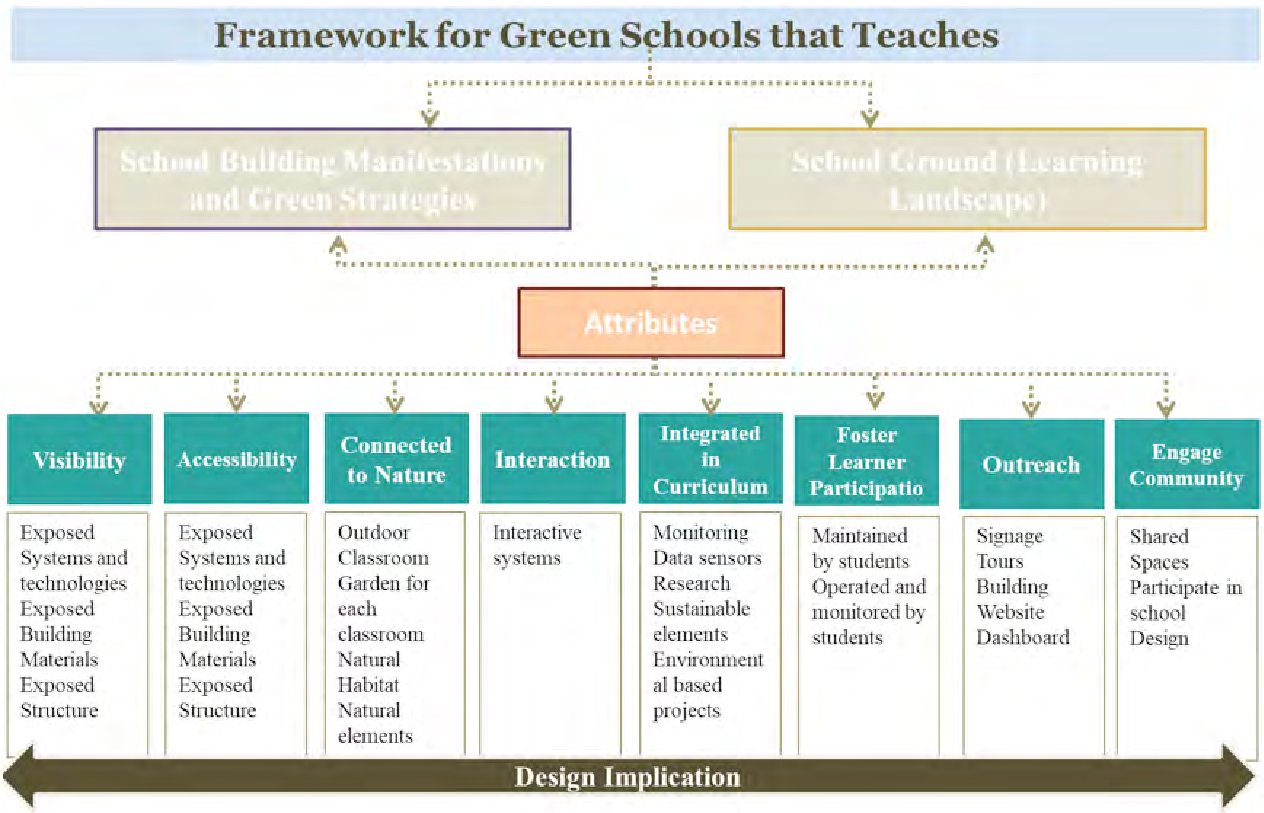

Figure 33. *Proposed framework for Green Schools that teaches, by the authors.*

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Attributes			***Case studies***					
Item	***Score %***	***Approaches for Design /Design Implication or features***	***Sidewell Friends Quaker School***	***HPA Energy Lab***	***Redding School of the Arts***	***Pine Jog Elementary School***	***Approach score 75%***	***Description***
Visibility	*91.6*	*Exposed Systems and technologies*	√	√	√	√	*100*	*To show students different aspects of the building that normally remains hidden. Students exposed to these aspects while moving in the school campus.*
		Exposed Building Materials	√	√	√	√	*100*	
		Exposed Structure	√	√	√		*75*	
Accessibility	*75*	*Mechanical Rooms*	√	√	√		*75*	*Access to mechanical rooms, systems and technologies that will show students how building work. Such as Redesign mechanical rooms to accommodate informative visits by students*
		Systems	√	√	√		*75*	
Connected to Nature	*50*	*Outdoor Classroom (classroom, weather station, sundails, natural trails, recycling lab, etc.)*		√	√	√	*75*	*incorporating nature into school design could be an important factor for helping students to*
		Different Gardens		√	√		*50*	
		Large Opening	√	√	√		*75*	
Interaction	*75*	*Interactive systems*		√	√	√	*75*	*When the building provide feedback on its performance students will interact with the building and understand the environmental impact of their action*
Integrated in Curriculum	*65*	*Sustainable elements are part of the EE syllabus*	√	√	√	√	*100*	*Study aspects of the building site, design, and systems through curriculum content*
		Monitoring	√	√	√		*75*	
		Data sensors	√	√	√		*75*	*Verify building design, performance and impact on occupants. Thus the green school would become reference for the concept of sustainability*
		Environmental-based projects		√	√		*50*	
		Research		√			*25*	
Foster Learner Participation	*100*	*Students maintain the school building and ground*	√	√	√	√	*100*	*To engage and inspire learners and tutors*
		Operated and monitored by students	√	√	√	√	*100*	
Outreach	*91.6*	*Informative / interpretative Signage*	√	√	√	√	*100*	
		Tour of the school by students or teachers	√	√	√		*75*	
		Building Website	√	√	√	√	*100*	*Provide detailed information on the building's design, technologies, and performance*
		Display real time data of resources consumption and production	√	√	√	√	*100*	
Engage Community	*25*	*Shared Spaces*			√		*25*	*Area used by the community engagement and contributions within the school*

Table 1. *The design attributes and approaches and their implementation in each school to transform the school environment to a learning source, by the authors.*

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Several recommendations could be drawn from this research. Figure 34 shows the different recommendations under four categories. These are: on the administrative level "Government", for architects and designers, for teachers and for the community.

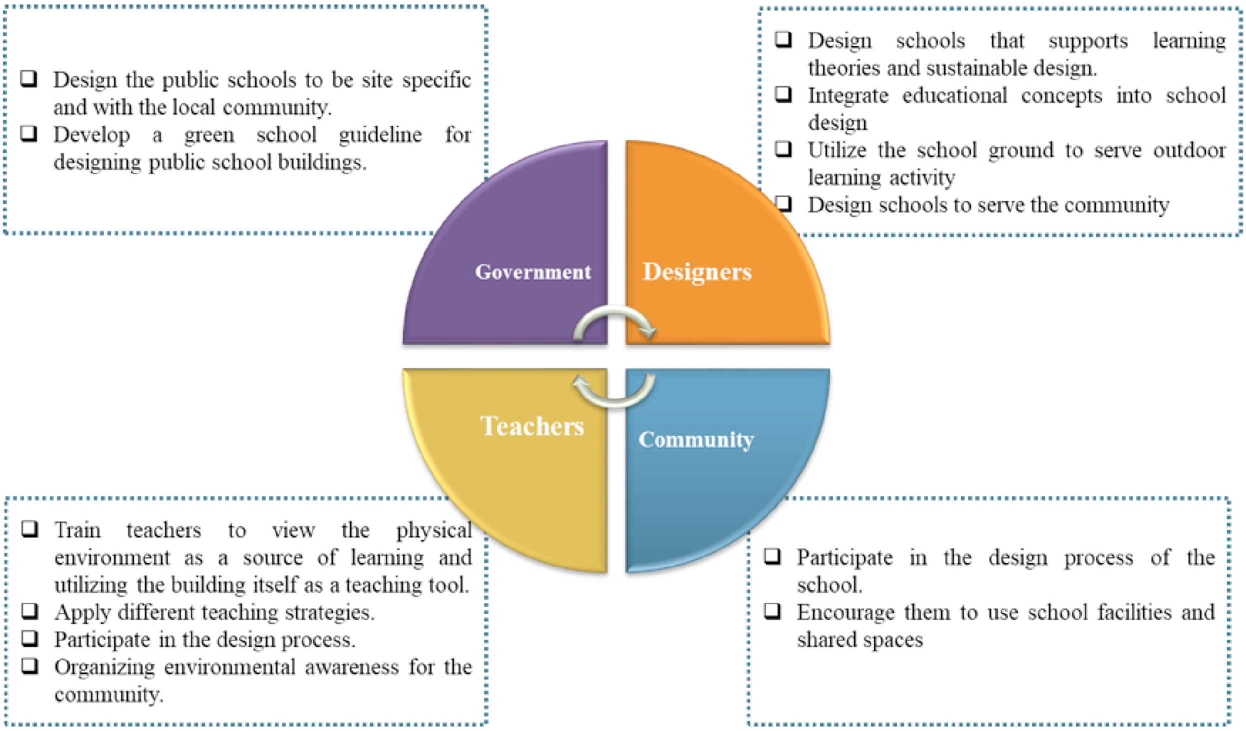

Figure 34. *Design recommendations to achieve the green school concept, by the authors.*

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L'école verte en tant que livre de texte en 3D pour l'éducation environnementale - Analyse préalable

Résumé
Avec les problèmes environnementaux croissants, il existe des mouvements internationaux vers la durabilité et l'écologisation des environnements bâtis afin d'atténuer les impacts environnementaux négatifs des bâtiments et des activités humaines sur l'environnement et la santé humaine. Cet article présente une gamme d'écoles vertes K-12 qui ont été intentionnellement conçues pour utiliser le bâtiment scolaire comme un livre de texte 3D pour l'éducation environnementale (EE). Le but de cet article est d'examiner les méthodes et stratégies de conception d'une école verte comme outil d'enseignement à travers l'analyse d'études de cas des écoles sélectionnées. Les cas fournissent une diversité d'emplacements géographiques, de climats, de stratégies vertes et de côtes. La recherche dépend de l'approche analytique descriptive pour la revue de la littérature; analyse d'études de cas multiples pour étudier les attributs des écoles vertes qui enseignent. Les résultats ont révélé un ensemble d'approches pour utiliser les écoles vertes comme manuel 3D pour l'EE.

Mots-clés: *École Verte, durabilité, manuel 3D, analyse précédente*

Scuola Verde come un libro di testo 3D per l'educazione ambientale - Analisi precedenti

Riassunto
Con i crescenti problemi ambientali ci sono movimenti internazionali verso la sostenibilità e l'inverdimento degli ambienti costruiti al fine di mitigare gli impatti ambientali negativi degli edifici e delle attività umane sull'ambiente e sulla salute umana. Questo documento presenta una gamma di scuole verdi K-12 che sono state progettate intenzionalmente per utilizzare l'edificio scolastico come un libro di testo 3D per l'educazione ambientale (EE). Lo scopo di questo documento è di esaminare i metodi e le strategie per progettare la scuola verde come strumento di insegnamento attraverso l'analisi di casi studio delle scuole selezionate. I casi offrono una varietà di posizioni geografiche, climi, strategie ecologiche e coste. La ricerca dipende dall'approccio analitico descrittivo per la revisione della letteratura; analisi di casi multipli per studiare gli attributi delle scuole verdi che insegnano. I risultati hanno rivelato una serie di approcci per l'utilizzo delle scuole verdi come libro di testo 3D per EE.

Parole chiave: *Scuola verde, sostenibilità, libro di testo 3D, analisi precedenti*