"By what is included or excluded or ignored, students learn that they are a part of or apart from the natural world."

— Dr. David Orr, 1995

Integrating architecture and curriculum for a sustainable school

Architectural thesis

- Thesis Student:
  Mac Williams, Spring 2003

- Design Studio Professor:
  Prof. John Wyman

- Architecture Thesis Advisor:
  Prof. Harry Eggink

- Architecture Thesis Advisor:
  Prof. Alfredo Fernandez

"As the sustainable school itself is to serve as an educational tool, visibility with respect to the ways energy, water and materials are derived from the surroundings and how they are made accessible and usable, should be made visible for the benefit of the school. Preferably the use of natural processes and the design of the school building should be matched and integrated."
integrating architecture and curriculum for a sustainable school

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"And that the earth belongeth to the Lord, and all the fullness thereof. A generation doth consume it in the earth during its course, and in its own right no generation doth contract debts greater than may be paid during the course of its own existence."
Introduction:

Project abstract:
The movement toward sustainable design in architecture seems most appropriate as an objective for our schools. Schools will play, out of necessity, a critical role in patterning new behavior. A new paradigm for a sustainable school building must not only embrace the concept of sustainability but must, in itself, be a teaching tool for sustainability. And the "green" school building will not be sufficient all of its own accord. It will require new educational strategies and curriculums that complement its objectives. With this in mind, this thesis design project attempts to apply this basic concept to an elementary school in Indianapolis. The school is intended to embody high performance characteristics. It provides a healthy and productive learning environment for students and teachers, with large amounts of daylight and fresh air ventilation. Each classroom is provided with direct access to outdoor learning areas. The entire school is surrounded by natural areas within its own grounds, as well as access to a major watershed (Fall Creek), wooded areas, city parkland, and pedestrian trails. From a design standpoint, sustainable-based design strategies were used as a guide. This allowed for a whole-building concept where energy, ventilation, daylighting, water conservation, and other measures had a direct effect on the form, layout, technology, and siting of the building. Finally, the important issue of the building as a teaching tool involved spaces and features that encourage direct involvement from students and offers opportunities to use the building's features as an integral part of the curriculum design.

Issues & ideas:
The school's program is intended for a "magnet" type or a charter school with 400 to 500 elementary age children in grades K-5. The site has been selected with access to natural areas yet is in very close proximity to the IUPUI campus, Indiana Medical Campus, and local businesses. The building will display sustainable building techniques, local materials, systems, energy and nature at work. It is expected that the school will be a model for the community and an influence on other local building projects. Therefore, the building and grounds must be noticeable by passers-by. It should make the observer stop and think -- to wonder how and why this building is different. The form and function of the school should educate both the students and the community.

Research has shown that natural lighting (daylighting) has a very positive effect on students' learning effectiveness. As well, indoor air quality (IAQ) has a similar impact. These objective measures are complemented by other strategic measures such as design energy issues (including the use of renewable energy such as passive and active solar), natural ventilation (a major contributor to both cooling needs and IAQ), and water conservation. The design intent of the school in regards to water conservation is to create a building form that allows for collection of rainwater into centralized cisterns for use in landscape irrigation. Also, a living machine is included for its ability to clean wastewater for reuse as greywater or as clean discharge to the school's engineered wetland and to the Fall Creek. These features are obviously great contributors to the educational curriculum intentions as well.
Indianapolis Northwest
design solution:

site & context analysis:

The selected site has an interesting mix of contextual elements. It is an open grassy field bordered by flood levies on high banks of the Fall Creek. The creek meanders through the immediate site to the east and is heavily wooded. This offers excellent access to natural areas containing abundant plant and animal life and interesting micro-environments. Across the creek from the site are a city park and residential neighborhoods. The area to the north is mixed with residential and light industrial use.

The site offers an interesting mix of contextual elements. It is an open grassy field bordered by flood levies on high banks of the Fall Creek. The creek meanders through the immediate area to the east and is heavily wooded. This offers excellent access to natural areas containing abundant plant and animal life and interesting micro-environments. Across the creek from the site are a city park and residential neighborhoods. The area to the north is mixed with residential and light industrial use.

Located near the intersection of West 10th Street and Stadium Drive, the site is next door to the IU Medical Center and IUPUI campus. The area to the immediate west now contains several light industrial buildings and some of the Indianapolis Water Company facilities. However, significant expansion of the IUPUI facilities has already begun within this area. The area is therefore a significant location of professional "knowledge" workers and may see additional commuters and potential new residents. The area is now served by public transportation as well as the Clarian PeopleMover monorail. This makes the site a seemingly good choice for the location of a school serving both local residents and the children of commuting workers.
The Herron School of Art (IUPUI) has their sculpture studio in this building on Stadium Drive, just northwest of the site.

New IUPUI facilities are beginning to come to the area to the west and north of the site. This building at 16th Street is believed to be part of the Life Sciences expansion being taken by the university.

The Water Company has operational facilities (with historically significant architecture) just west of the site. This building is just north of the walking trail.
A high performance school building is **healthy and productive** for students and teachers providing acoustic, thermal, and visual comfort; has large amounts of natural daylight; superior indoor air quality; and a safe and secure environment. It is **sustainable**, because it integrates energy conservation and renewable energy strategies; uses high performance mechanical and lighting systems; includes environmentally responsive site planning; uses environmentally preferable materials and products; and water-efficient design.

A high performance school requires an integrated, whole building approach to the design process. Key systems and technologies -- the 'building blocks' of a high performance school -- must be optimized for their combined impact on the comfort and productivity of students and teachers. The result is a school that is an enduring asset to its community; one that enhances teaching and learning, reduces operating costs, and protects the environment.

The concept of the project was to follow sustainable design guidelines with an emphasis on daylighting, outdoor access, ventilation, and rainwater collection. As much as possible, didactic displays of building elements and functioning systems are intended to educate students further. Conceptual development of the building's form(s) were essentially tied to the environmentally sustainable goals, the accommodation of a modifiable K-5 programme, and engaging the unique site and context provided. There was also a desire to achieve some level of 'modularity' in the design so that each set of classrooms would not have to be designed uniquely. This created some restrictions but also an inherent economy. Therefore, the 'pod' concept of having a repeating form of grouped classrooms was used.

Building form and layout were of particular concern during design development. While sustainable design practices encourage an east-west axis with moderate to high southern exposure, the site did not have the space to do so. Instead, I chose to focus on modularity and 'equivalent' daylighting for each classroom, with more of a central hub styled circulation pattern in lieu of long axes. The design provides good circulation and adjacency for an elementary program yet seems to provide a certain level of privacy for each grade and a distinct difference between K-2 and 3-5. Also, interior courtyards were added to offer the common areas (cafeteria, library, etc.) more natural light and a skin-load dominated building. As well, the courtyards function as ideal areas for outdoor dining, reading, or formal class assembly.
classroom pods & circulation wing (1 of 2)
Design drawings:

detail plans - example spaces
Design drawings:

Building elevations
site & massing model: 1/40 scale

A monochromatic site and massing model was constructed to analyze building form and placement within the overall site. Graphic callouts within this photograph indicate important context items and ecological design strategies.
Daylighting & Design Detail Model: 1/4 Scale

This model of one ‘pod’ section (group of classrooms) was used to examine the effectiveness of natural lighting strategies for classrooms. Adjacent building pieces were added to include their shading effects. Photographs were taken at a variety of solar orientations as represented by the overall placement of pods within the site. The model was also an effective tool in evaluating roof form and overhang, skylight design, facade & window elevations, and support column detailing.
The design development of the classroom pod form took into account the desire for natural lighting, natural ventilation (cross-vent and stack effect), and the collection of rainwater from the roof structure. The design of the classroom floor plan includes a variety of informal spaces for individual activities (such as window seat "reading nooks"), common areas shared by the classrooms, and outdoor access doors for each classroom. The model was effective in evaluating the success of these design intentions.
site & context model: 1/40 scale; 32" x 40"
design character concepts:
"Education is not the filling of a pail but the lighting of a fire."

- William Butler Yeats
Design Program:

Program Objectives:

The programmatic objectives of the project are to create a school model that is capable of achieving high-performance efficiencies while demonstrating important educational principles to both direct users and the community-at-large. A key strategy is the proper development of classroom design that is optimal for new curriculum development for the school. As well, it is seen as an important criteria to make this school spatially adaptable to future changes in use, number of users, and technological changes. Particular attention will be paid to energy efficiency (including the use of renewables), water conservation and reuse, indoor air quality and comfort, high levels of daylighting (which have been shown to raise learning efficacy), and the use of local materials.

Program Concepts:

The premise of the design concept is that the school building must be a learning experience in of itself. Sustainable design elements are key to this success both from a performance standpoint as well as educational.

1. Sustainable Design:

Green design strategy planning will begin by using the framework of the US Green Building Council's LEED rating system (see checklist in Appendix) as a guideline for site analysis and design development. While the complete criteria of the system may not apply exclusively, the intent of each issue addressed in LEED can be evaluated or predicted.

Considerations for design development include:

- sustainable use of site
- renewable energy use
- water and waste efficiency
- materials and resources
- building adaptability and expandability
- indoor environmental quality (IAQ, daylighting, thermal comfort)
Many of green strategies have been demonstrated to be effective for educational facilities and beneficial to student performance and comfort. The main emphasis for design development in support of the thesis will be the interrelationships between educational spaces, expressed sustainable building elements and systems, interactivity between students and the building, and the integration of curriculum and building. In essence, the building is a comprehensive laboratory helping to link students to the natural environment.

Considerations for interactive elements and display technologies:

- renewable energy generation using solar and wind
- natural systems such as living machines and roof gardens
- weather/climatic monitoring and observation elements
- rainwater catchment
- exposed building systems equipment such as HVAC, plumbing, fire suppression, etc.
### Program Space Summary:

<table>
<thead>
<tr>
<th>Space Name</th>
<th>No. Occurring</th>
<th>Int. Area Total</th>
<th>Ext. Area Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom (K)</td>
<td>4@ 1050 sf</td>
<td>4200 sf</td>
<td>---</td>
</tr>
<tr>
<td>Classroom (G1)</td>
<td>4@ 1050</td>
<td>4200</td>
<td>---</td>
</tr>
<tr>
<td>Classroom (G2)</td>
<td>4@ 1050</td>
<td>4200</td>
<td>---</td>
</tr>
<tr>
<td>Classroom (G3)</td>
<td>4@ 1050</td>
<td>4200</td>
<td>---</td>
</tr>
<tr>
<td>Classroom (G4)</td>
<td>4@ 1050</td>
<td>4200</td>
<td>---</td>
</tr>
<tr>
<td>Classroom (G5)</td>
<td>4@ 1050</td>
<td>4200</td>
<td>---</td>
</tr>
<tr>
<td>Computer/Media Center</td>
<td>1@ 1260</td>
<td>1250</td>
<td>---</td>
</tr>
<tr>
<td>Music+Expression Lab</td>
<td>1@ 1640</td>
<td>1640</td>
<td>---</td>
</tr>
<tr>
<td>Art Studio</td>
<td>1@ 1200</td>
<td>1200</td>
<td>---</td>
</tr>
<tr>
<td>Library</td>
<td>1@ 2400</td>
<td>2400</td>
<td>---</td>
</tr>
<tr>
<td>Gymnatorium</td>
<td>1@ 6500</td>
<td>6500</td>
<td>---</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>1@ 2600</td>
<td>2800</td>
<td>---</td>
</tr>
<tr>
<td>Kitchen/Serving Area</td>
<td>1@ 780</td>
<td>780</td>
<td>---</td>
</tr>
<tr>
<td>Natural Science Lab</td>
<td>1@ 1500</td>
<td>1500</td>
<td>---</td>
</tr>
<tr>
<td>Greenhouse/Living Machine</td>
<td>1@ 2600</td>
<td>2600</td>
<td>---</td>
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<tr>
<td>Community Room</td>
<td>1@ 900</td>
<td>900</td>
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<tr>
<td>Admin. Offices (Pvt.+Open)</td>
<td>6@ varies</td>
<td>1000</td>
<td>---</td>
</tr>
<tr>
<td>Admin. Conference Room</td>
<td>1@ 400</td>
<td>400</td>
<td>---</td>
</tr>
<tr>
<td>Admin. Nurse/Infirmary</td>
<td>1@ 500</td>
<td>500</td>
<td>---</td>
</tr>
<tr>
<td>Admin. Teacher Resource</td>
<td>1@ 520</td>
<td>520</td>
<td>---</td>
</tr>
<tr>
<td>Admin. Teacher Lounge</td>
<td>1@ 400</td>
<td>400</td>
<td>---</td>
</tr>
</tbody>
</table>

**Net TotalAssignable**

49600

**Circulation/Efficiency**

(30% x 49600)

14880

**Gross Total**

64480 sf

<table>
<thead>
<tr>
<th>Space Name</th>
<th>No. Occurring</th>
<th>Int. Area Total</th>
<th>Ext. Area Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor Courtyards</td>
<td>2@ varies</td>
<td>---</td>
<td>7860 sf</td>
</tr>
<tr>
<td>Outdoor Education</td>
<td>6@ varies</td>
<td>---</td>
<td>6000</td>
</tr>
<tr>
<td>Outdoor Play/Recreation</td>
<td>4@ varies</td>
<td>---</td>
<td>10000</td>
</tr>
<tr>
<td>Natural Areas/Trails</td>
<td></td>
<td>---</td>
<td>???</td>
</tr>
<tr>
<td>Parking / Drop-off</td>
<td></td>
<td>---</td>
<td>15000</td>
</tr>
</tbody>
</table>
"Instead of building schools for 1950, let us build schools for 2050. We need schools that are healthy, energy smart, environmentally sensitive, using up to date technology that complement and enhance academic excellence. Schools designed by the community and with the students and community in mind."

Richard W. Riley
U.S. Secretary of Education
October 13, 1999
Buildings designed with an overall strategy to lessen their impact on the environment were considered as ideal precedents for the design project. These ‘green’ buildings were analyzed in terms of their use of site, building materials (including source and content), energy efficiency, use of natural lighting, use of renewable energy, water conservation, air quality, and more. Specific buildings that were examined include the Lewis Center at Oberlin College, the Cambria Office Building in Pennsylvania, the Conserve School in Minnesota, and Strawberry Vale Primary School in Vancouver. Each of these green projects also offer a tangible educational value.

Much of ‘green’ architecture is now evaluated by programs such as the Leadership in Energy & Environmental Design (LEED™) rating system for its construction and performance. I used the LEED Project Checklist as a general guideline in forming a design strategy. (See checkist on page 38).
High Performance Schools (HPS):

Precedent analyses specific to school design involved many examples covering a wide range of grade levels, enrollment size, and climate types. The High Performance Schools (HPS) Partnership Program, a non-profit entity that works with school districts and the building industry to promote sustainable school buildings and superior educational environments, provides a vast array of information, statistics, design strategies, and case studies providing valuable precedent examples specific to school design.

Some of the examples shown include the Roy L. Walker School in McKinney, TX and designs by Integrated Design out of Raleigh, NC. These examples emphasize a high quality learning atmosphere that embodies concepts of daylighting, energy efficiency, indoor air quality and comfort, as well as engaging design concepts that teach children about sustaining the local environment.

High Performance Strategies:

A high performance school building is healthy and productive for students and teachers providing acoustic, thermal, and visual comfort; has large amounts of natural daylight; superior indoor air quality; and a safe and secure environment. It is sustainable, because it integrates energy conservation and renewable energy strategies; uses high performance mechanical and lighting systems; includes environmentally responsive site planning; uses environmentally preferable materials and products; and water-efficient design. A high performance school requires an integrated, whole building approach to the design process. Key systems and technologies -- the 'building blocks' of a high performance school -- must be optimized for their combined impact on the comfort and productivity of students and teachers. The result is a school that is an enduring asset to its community; one that enhances teaching and learning, reduces operating costs, and protects the environment.
HPS Strategic Building Blocks:

Acoustic Comfort
Students and teachers can hear one another without shouting. Noise from inside and outside the classroom is minimized.

Daylighting
As much natural daylight as possible is provided particularly in classrooms where studies have shown its beneficial effects on student learning and performance. Daylighting systems are to be designed to avoid excessive heat loss or gain and to minimize glare.

Energy Efficient Building Shell
The walls, floors, roofs, and windows of the school are as energy efficient as economically practical. The building shell integrates and optimizes insulation levels, glazing, shading, thermal mass, air leakage, and light-colored exterior surfaces.

Environmentally Preferable Materials and Products
The school incorporates materials and products that are durable, non-toxic, derived from sustainable-yield processes, high in recycled content, and easily recycled themselves.

Environmentally Responsive Site Planning
The school's site conserves existing natural areas and restores damaged ones, minimizes stormwater runoff and controls erosion, and enhances the building's high performance features.

High Performance HVAC
The school's heating/ventilating/air conditioning (HVAC) system uses high efficiency equipment, and includes controls that boost system performance. Systems that provide superior thermal comfort are preferable.

High Performance Lighting
Students and teachers work in a high quality visual environment that stimulates learning while saving energy. The school's lighting system uses high efficiency lamps and ballasts, optimizes the number of fixtures in each room, incorporates controls that ensure peak system performance, and successfully integrates electric lighting and daylighting strategies.

Renewable Energy
The school maximizes the cost-effective use of renewable systems to meet its energy needs. During the design process, the following systems are systematically evaluated and considered: passive solar heating, solar hot water, active solar (for space heating), geothermal heat pumps, natural ventilation, wind-generated electricity, photovoltaically generated electricity, and green power.

Safety and Security
Students and teachers feel safe anywhere in the building or on the grounds. A secure environment is created primarily by design: opportunities for natural surveillance are optimized, a sense of territoriality is reinforced, and access is controlled. Security technology is used to enhance, rather than substitute for, the design features.

Superior Indoor Air Quality
Students and teachers suffer no ill effects from the air inside the school. Sources of contamination are controlled, adequate ventilation is provided, and moisture accumulation is prevented.

Thermal Comfort
Occupants are comfortable at all times. Temperature and humidity remain in the 'comfort zone'. Hot, stuffy rooms and cold, drafty ones are eliminated. Teachers have control over thermal conditions in individual classrooms.

Water Efficiency
The school uses as little off-site water as possible to meet its needs. The school controls and reduces water run-off from its site, consumes fresh water as efficiently as possible, and recovers and reuses graywater to the extent feasible.
GREEN BUILDING/ENERGY FACTS:

- Buildings now account for 1/3 of all US energy use

- Buildings consume an extraordinary amount of material resources and produce an estimated 30% of all greenhouse gas

- 66% of annual electricity usage is for construction and operation of buildings

- People spend more than 80% of their lives indoors

- Buildings can be designed and constructed with advanced technologies that can reduce energy usage by 30% - 70%

Source: www.usgbc.com
Sustainable Technology Precedents:

Technology is considered to be a key component in the pursuit of sustainable architecture. Technology can greatly enhance performance and efficiency of our buildings. Therefore, the potential use of technology in aspects such as renewable energy, water conservation, natural lighting, ventilation, "smart" controls, and non-polluting materials can be significant to the design character. Fitting with the theme of the school project, technology should be articulated and plainly seen by the students. Every means should be made to make the functional technology of the building a teaching tool for students, teachers, and community users.

Precedent examples included high profile technologies such as windmills, photovoltaic panels, roof gardens, rainwater collection systems, and living machines. Complementary technologies may include geothermal systems, high-performance glazings, and greywater recycling.
Natural & Recycled Materials

Natural materials are inherently sustainable (provided they are managed properly as a resource). Therefore, a materials palette for the design of a sustainable school may involve wood, stone, concrete, strawboard, glass, etc. The use of non-renewable materials such as certain metals, plastics, and synthetic materials should be minimized where possible. Locally produced materials are preferable over imported or long-hauled delivered. Wood products should exclude old growth species while encouraging the use of engineered lumber that promotes harvest efficiency and waste/recycled content.

Precedent examples where wood structural members were chosen over steel seemed appropriate. However, this could be complemented with the potential use of recycled steel members.

Natural and recycled materials are also significant to interior finishes and landscape design. Ideal materials express a natural aesthetic and are non-toxic.
5 Educational / Didactic Design

A school design that intends to instruct students about sustainability must be like a wholly-integrated classroom. Resources should be noticeably conserved and recycled. Construction materials should be tactile and inherently safe. Energy generation and efficiency strategies should be articulated and highly visible. Monitoring equipment and display devices should be set up where students can review building systems and energy performance. In essence, the school building itself should be seen as a potentially valuable teaching tool. Complementary relationships to subject areas such as math, science, and even art can make the design features of a school an important element to a 21st-century curriculum design.
The US Green Building Council provides the below LEED worksheet as a summary for designers seeking certification.

### Project Research:

#### Strategies

<table>
<thead>
<tr>
<th>Sustainable Sites</th>
<th>14 Possible Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Efficiency &amp; Site Management</strong></td>
<td>2 Points</td>
</tr>
<tr>
<td><strong>Energy &amp; Atmosphere</strong></td>
<td>17 Possible Points</td>
</tr>
<tr>
<td><strong>Water Efficiency</strong></td>
<td>5 Possible Points</td>
</tr>
<tr>
<td><strong>Indoor Environmental Quality</strong></td>
<td>10 Possible Points</td>
</tr>
<tr>
<td><strong>Materials &amp; Resources</strong></td>
<td>15 Possible Points</td>
</tr>
<tr>
<td><strong>Innovation &amp; Design</strong></td>
<td>5 Possible Points</td>
</tr>
</tbody>
</table>

#### Materials & Resources

- **Storage & Collection of Recyclables**: 1 Point
- **Reduction in Energy Consumption**: 1 Point
- **Water Resource Conservation**: 1 Point
- **Biodiversity**: 1 Point
- **Low-Emitting Materials**: 1 Point
- **Certiﬁed Wood**: 1 Point
- **Certified Materials**: 1 Point

#### Indoor Environmental Quality

- **Minimum LEQ Performance**: 5 Points
- **Indoor Chemical & Pollutant Source Control**: 1 Point
- **Controllability of Systems**: 1 Point
- **Thermal Comfort**: 1 Point
- **Daylighting & Ventilation**: 1 Point

#### Innovation & Design

- **Innovative Design**: 5 Points
- **LEED Accredited Professional**: 5 Points

**Project Totals**: 5 Possible Points

- **Certified 2.0 Points**: 0 Points
- **Certified 2.5 Points**: 0 Points
- **Certified 3.0 Points**: 0 Points
- **Certified 3.5 Points**: 0 Points
- **Certified 4.0 Points**: 0 Points
Green building technology can help make buildings more efficient and environmentally responsive while reducing physical demands on the planet. Environmentally responsive development can significantly improve the comfort, aesthetics, resource efficiency and value of properties while reducing pollution and saving money. The following is a checklist extracted from Environmental Building News.

The Design Process

**Small is better:**
- Optimize use of interior spaces through careful design so that the overall building size and resource use in construction and future operations, are kept to a minimum.

**Design buildings to use renewable energy:**
- Use high levels of insulation, high performance windows, and tight construction. In warm climates, choose glazings with low solar heat gain.
- Passive solar heating, daylighting, and natural cooling can be incorporated cost effectively into most buildings. Also consider solar water heating and photovoltaics; or design buildings for future panel installation. If wood heating is an option, specify low-emission wood stove or pellet stove.

**Optimize material use:**
- Minimize waste by designing for standard sizes. Avoid waste from structural over-design (use optimum-value engineering/advanced framing).

**Design water-efficient, low maintenance landscaping (sustainable landscapes):**
- Conventional lawns have a high impact because of water use, pesticide use, and pollution generated from mowing. Landscape with drought resistant native plants and perennial ground covers.

**Make it easy for occupants to recycle waste:**
- Make provisions for storage and processing of recyclables: recycle bins near the kitchen, under sink door mounted bucket with lid for food waste, etc.
- Look into the feasibility of gray water and roof top water catchment systems: Water that has been used for bathing, dish washing, or clothes washing can be used for flushing toilets or irrigation. If current codes prevent graywater recycling, consider designing the plumbing for future water adaption. Rooftop water catchment for outdoor watering should be considered in many regions.

**Design for future reuse:**
- Make the structure adaptable to other uses, and choose materials and components that can be reused or recycled. Avoid potential health hazards: radon, EMF, pesticides.
- Follow recommend practices to minimize radon entry into the building and provide for future mitigation if necessary. Plan electrical wiring and placement of electrical equipment to minimize electromagnetic field exposure. Design insect resistant detailing that will require a minimal use of pesticides.
The Site:

Sustainable building:
- Consistently renovating existing buildings is the most sustainable construction.

Evaluate site resources:
- Early in the siting process carry out a careful site evaluation: solar access, soils, vegetation, important natural areas, etc.

Locate buildings to minimize environmental impact:
- Cluster buildings or build attached units to preserve open space and wildlife habitats, avoid especially sensitive areas including wetlands, and keep roads and service lines short. Leave the most pristine areas untouched, and look for areas that have been previously damaged to build on.

Pay attention to solar orientation:
- Reduce energy use by orientating buildings to make optimal use of passive solar heating, daylighting, and natural cooling.

Situate buildings to benefit from existing vegetation:
- Trees on the east and west sides of a building can dramatically reduce cooling loads. Hedge rows and shrubbery can block cold winter winds or help channel cool summer breezes into the building.

Minimize transportation requirements:
- Locate buildings to provide access to public transportation, bicycle paths, and walking access to basic services. Commuting can also be reduced by working at home. Consider home office needs with layout and wiring.

Materials:

Avoid ozone-depleting chemicals in mechanical equipment and insulation:
- CFC's have largely been phased out, but their primary replacements, HCFC's, also damage the ozone layer and should be avoided where possible. Reclaim CFC's when servicing or disposing of equipment, and if possible, take CFC based foam insulation to a recycler who can capture CFC's.

Use durable products and materials:
- Because manufacturing is very energy-intensive, a product that lasts longer or requires less maintenance usually saves energy. Durable products also contribute less to our solid waste problems.

Choose building materials with low embodied energy:
- One estimate of the relative energy intensity of various materials (by weight) is as follows: Lumber=1 / Brick=2 / Cement=2 / Glass=3 / Fiberglass=7 Steel=8 Plastic=30 Aluminum=80

Buy locally produced building materials:
- Transportation is costly in both energy use and pollution generation. Look for locally produced materials (local softwoods or hardwoods, for example) to replace products imported to your area.
Materials (continued)

Consider using alternative building materials either alone or in combination with traditional materials:

* Explore the possibility of building with rammed earth technology or straw bale construction. Explore steel frame & composite beam construction. Often the combined techniques are overlooked in favor of one alternative. Perhaps the use of rammed earth for solar massing can be utilized in the design in conjunction with traditional building materials.

Used salvaged building materials when possible:

* Reduce landfill pressure and save natural resources by using salvaged materials: lumber, millwork, certain plumbing fixtures, and hardware, for example. Make sure these materials are safe and don’t sacrifice energy efficiency or water efficiency by reusing old windows or toilets.

Minimize old growth timber:

* Avoid lumber products produced from old-growth timber when acceptable alternatives exist. You may not need clear narrow-grained cedar or redwood siding, for example, when using opaque stain or paint as long as proper detailing is used to avoid rot. Laminated wood timbers can be substituted for old growth Douglas fir. Don’t buy tropical hardwoods unless the seller can document that the wood comes from well managed forests.

Avoid materials that will off-gas pollutants:

* Solvent based finishes, adhesives, carpeting, particle board, and many other building products release formaldehyde and volatile organic compounds (VOCs) into the air. These chemicals can effect workers’ and occupants’ health as well as contribute to smog and ground-level ozone pollution outside.

Minimize the use of pressure treated lumber:

* Use detailing that will prevent soil contact and rot. Where possible, use alternatives such as recycled plastic lumber. Take measures to protect workers when cutting and handling pressure treated wood, and never burn the scraps.

Minimize packaging waste:

* Avoid excess packaging, such as plastic wrapped plumbing fixtures or fasteners that aren’t available in bulk. Tell your supplier why you are avoiding over packaged products. Keep in mind, however, that some products must be carefully wrapped to prevent damaged and resulting waste.

Equipment:

Install high efficiency heating and cooling equipment:

* Well designed high efficiency furnaces, boilers, and air conditioning (and distribution systems) not only save the building occupants money, but also produce less pollution during operation. Install equipment with minimal risk of combustion gas spillage, such as sealed combustion appliances.

Install high efficiency lights and appliances:

* Fluorescent lighting has improved dramatically in recent years and is now suitable for homes. High efficiency appliances offer both economic and environmental advantages over their conventional counterparts.
On the Job Site:

Protect trees and topsoil during site work:
- Protect trees from damage during construction by fencing off the "drip line" around them and avoiding major changes to surface grade.

Avoid use of pesticides and other chemicals that may leach into the groundwater:
- Look into less toxic termite treatments, and keep exposed frost walls free from obstruction to discourage insects. When backfilling a foundation or grading around a house, do not bury construction debris.

Minimize job waste:
- Centralize cutting operations to reduce waste and simplify sorting. Set up clearly marked bins or trash cans for different types of usable waste (wood scraps for kindling, sawdust for composting, cans, glass and paper for typical recycling). Find out where different materials can be taken for recycling, and educate your crew and sub's about recycling.

Make your business operations more environmentally responsible:
- Make your office as energy efficient as possible, purchase energy efficient vehicles, arrange carpools to job sites, and schedule site visits and errands to minimize unnecessary driving. In your office, purchase recycled office paper and supplies, recycle office paper, use coffee mugs instead of disposable cups. On the job, recycle beverage containers.

**Integrated Design - National Best Practices Manual**

Integrated design is the consideration and design of all building systems and components together. It brings together the various disciplines involved in designing a building and reviews their recommendations as a whole. The following are excerpts from this design guide pertaining to visual comfort, energy efficiency, water efficiency, and materials efficiency – critical issues with this design project:
Energy Efficiency:

Avoid direct beam sunlight and glare
- Consider interior (shades, louvers, or blinds) and exterior (overhangs, trees) strategies to control glare and filter daylight.
- Consider skylights (horizontal glass), roof monitors (vertical glass), light from two sides, and/or clerestory windows.
- Lay out the room to take advantage of daylight. Consider sloped ceilings. Consider light-colored ceiling surfaces to help reflect daylight within the room.

Design for diffuse, uniform daylight that penetrates deep into the space
- Design windows to allow daylight to penetrate as far as possible into a room. Consider using light shelves to reflect daylight deep into a room.
- Integrate daylight with the electric lighting system

Building Enclosures
- Specify high-performance glazing
- Control heat gain and glare
- Consider high mass materials, like brick or concrete

Water Efficiency:
- Design landscaping to use water efficiently
- Specify water conserving fixtures and equipment
- Consider using recycled or rainwater for non-potable uses

Material Efficiency:
- Design to facilitate recycling
- Specify salvaged or refurbished materials
- Maximize recycled content of all new materials
- Eliminate materials that may introduce indoor air pollutants
"The three great inspirations are the inspiration to learn, the inspiration to meet, and the inspiration for well-being. They all serve, really, the will to be, to express."

— Louis Kahn

"In the end, we will conserve only what we love. We will love only what we understand. We will understand only what we are taught."

— Lao-Tzu
Project Research:

Educational Curriculum Issues:

(This information is provided as a brief overview of educational curriculum topics discovered during the research phase.)

The EIC Model™: Using the Environment as an Integrating Context for improving student learning

Learning based on the EIC Model™ is about using a school’s surroundings and community as a framework within which students can construct their own learning, guided by teachers and administrators using proven educational practices.

The EIC Model™ uses:

- integrated-interdisciplinary instruction that breaks down traditional boundaries between disciplines;
- community-based investigations as learning experiences that offer both minds-on and hands-on experiences;
- collaborative instruction so teachers, parents, students and community members can connect together instruction and learning;
- learner-centered, constructivist approaches adapted to the needs and unique abilities of individual students;
- combinations of independent and cooperative learning; and,
- local natural and community surroundings, as the “venue” for connecting together these proven pedagogies, to improve teaching and learning.

The EIC Model™ is a system of educational practices, developed, copyrighted and trademarked by SEER.
The terms "EIC Model™" and "using the Environment as an Integrating Context for learning (EIC Model™)", Copyright © 1997-2002

Key Components of the BEES K-12 Environmental Education Integration Project

- Activities are interdisciplinary in nature
- We emphasize hands-on, inquiry-based learning
- Teachers learn how to maximize the outdoor classroom opportunities offered by their school grounds
- We provide in-class lessons that support the activities implemented in the outdoor classroom.
- Teachers are introduced to a variety of outdoor and community resources which could serve as fieldtrip destinations, and potential field trips are correlated with the Bordentown curriculum
- BEES teachers become mentors for their peers
- We encourage cross-grade education
- We incorporate the use of current technologies
- The BEES model may be used by other schools worldwide
Curriculum Issues (continued)

Fostering a School Approach to Environmental Education

Introduction

The effectiveness of environmental education is dependent upon the entire school community being aware of, and actively contributing to, the careful use of the environment. Traditionally, much of the focus of environmental education in schools involved developing knowledge about the environment. It is essential that, as well as developing knowledge, the education process also guides the development of attitudes and values which influence behavior and affect lifestyles.

Attitudes and Values

The fostering of positive attitudes and values is at the core of environmental education. The kinds of relationships we develop with the environment will determine the values we hold in relation to it, just as the kinds of values we hold shape our relationships with the environment. Essential features of environmental education include:

- an aesthetic appreciation of the natural and built environment;
- a sense of belonging to and ownership of the global environment;
- an awareness of the interdependence of people and people and nature; and
- an awareness of individual social responsibility and the need to respect the collective good.

These features should underpin all teaching and learning in whatever context environmental education takes place. Every part of the school environment and the day-to-day life of the school can be used as a context for teaching and learning about the environment.

Learning Contexts for Environmental Education

The five identified contexts for learning form a framework for developing a whole school approach to environmental education. Many schools may have developed one or more of these areas already, while some schools may be about to start. Schools will select an area or areas for development, depending upon their particular needs and circumstances.

Teaching and Learning Approaches

Effective environmental education moves away from teaching and learning approaches based solely on the transmission of knowledge, and moves towards approaches which encourage the development of qualities, such as initiative, reflection and responsibility in relation to the environment and the fostering of attitudes and values which influence behavior and action. Teaching and learning approaches, such as group work, discussion, debate, role-play and problem-solving can be effective techniques for stimulating and maintaining pupils' interest in the environment.

The range of approaches and strategies offered are examples of how teachers might provide opportunities for learning about, in, through and for the environment.

- Use of real issues: Pupils respond best to real situations. Issues, such as the impact of a new housing development or the
pollution of a local stream can engender interest and encourage pupils to reflect upon real environmental issues.

> **Use of the school grounds:** Pupils need opportunities to realise that responsibility for the earth begins at a local level and that environments can be managed in a manner which promotes sustainability, introducing pupils to the management of a small area, such as the school grounds, can help to develop understanding of how similar principles can be applied to larger scales and that actions and decisions at a local level can have meaning in a global context.

> **Enquiry-based learning:** The environment can be a context for hypothesis-testing or conducting surveys, where pupils can develop skills of recording information, analysis, interpretation and evaluation.

> **Action-based fieldwork:** This involves pupils in practical caring for, or improvement to, the school grounds or the local area. It is a method of raising awareness to the quality of the surrounding environment. It can also provide the challenge of applying principles learned to regional and global contexts.

> **Field trips / fieldwork:** These build on, reinforce and provide first-hand experience of topics or issues explored in the classroom. They involve preparation and follow-up activity, and can include a range of experiences, such as

  > aesthetic and sensory experiences
  > outdoor pursuits
  > enquiry-based learning
  > action in the environment

> **Residential experience:** A residential experience can provide opportunities for a holistic approach to environmental awareness and appreciation. It offers pupils extended opportunities to be part of, and to engage with, the environment over a period of time.
"To meet the challenges of the 21st century, the present generation of students must learn how to:

- run civilization on sunshine;
- stabilize then reduce global population;
- protect remaining biological diversity;
- prevent pollution;
- manage agriculture and forests sustainably;
- repair ecosystems damaged in the industrial era;

and do all of these things while improving basic equity and fairness."

-David Orr, 1996
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www.edfacilities.org, National Clearinghouse for Educational Facilities. K-12 school planning, design, construction, operations information including news and information sources.

www.SBICouncil.org, Sustainable Buildings Industries Council. SBIC is a non-profit organization dedicated toward advancing the design and performance of sustainable buildings nationwide.

www.neef.org, National Environmental Education and Training Foundation, Wash., DC. Site offers information for curriculum design for teaching students about environmental issues.
