# Fostering Whole-Systems Thinking Through Architecture:

## Eco- School Case Studies in Europe and Japan

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# Abstract

In eco-schools, the building itself is used as a lever for environmental education. This research examines how architecture, engineering, landscaping, and educational systems are combined to make school buildings the instruments through which students learn how to lessen human impact on the environment. Through tours, interviews, archival data, and surveys with data from England, the Netherlands, Germany, Denmark, and Japan, this thesis investigates factors involved in eco-school development, and documents four eco-schools' design, activities, and students' environmental attitudes. The specific aims are:

**Aim 1. (a) What factors aid eco-school development, and (b) in what kind of social contexts does this occur?** Interviews with principals, architects, and government officials revealed that eco-schools develop quickly with enthusiastic principals who excite their students, faculty, and school board members with occasions to think and act in ecologically responsible ways.

**Aim 2. What are contemporary exemplars of eco-schools, in architecture and activities?** Four contemporary eco-school exemplars were studied in England, the Netherlands, and Japan. These schools had an average of 14 environmental features, with the most common being utilizing daylight. Average number of environmental activities was 5.5, with gardening and field trips as the most common. Eco-school activities varied considerably with curriculum integration, alternative transportation, and demand-reducing policies.

**Aim 3. Can eco-schools influence a child's way of thinking in different ways than traditional schools, in terms of environmental attitudes?** Across four schools studied, the average environmental attitudes score was 84.43, using a 28 item adapted scale from Musser and Malkus (1994). Although findings indicated that the number of environmental features in a school was not a significant predictor of environmental attitudes, this may be due in part to the fact that all schools studied were eco-schools. Future research might include schools varying more in both design and curriculum.


**Keywords**: *eco-schools, green schools, children's environmental attitudes.*

Introduction

Green schools are a growing phenomenon both in the United States and abroad. This project examines eco-schools, which are green schools with an environmental curriculum. In this introduction, three themes will be addressed. The first section addresses the current climate regarding green schools. The second section addresses the necessity of sustainable buildings and environmental education. Third, the role of architecture in context of the educational system is presented. Lastly, the research aims of this study are articulated.

## The Green School Building Climate

### What is a Green School?

Green schools are designed to be high performing, energy-efficient, environmentally-friendly buildings. These high-performing schools have features such as rainwater-catching systems, solar hot water heaters, and photovoltaics, which turn the sun's energy into electricity. All these features make buildings reduce their demand for water and energy. There are many clever ways that buildings can save energy that are not as visible, including aerated faucets, which reduce the amount of water used, but maintain pressure; orienting the building towards the south to allow more daylight and therefore more heat-called *passive solar gain;* strategically placing trees to shade the building to reduce cooling demands; natural ventilation, or opening windows at the right heights, to reduce energy costs. Green school buildings also do not use paints or carpet that have "volatile organic compounds" (VOCs) that off-gas harmful chemicals into the air and contribute to poor indoor air quality. Green buildings reduce total environmental impact, meaning that even the products and specific materials in the building do not harm the environment. For the purposes of this study, an eco-school is a green school where not only is the building employing energy-efficient technologies, but the curriculum and activities at the school incorporate environmental values and ecologically responsible life skills into daily routines. Figure 1 shows four fundamental aspects of eco-schools. From the left, a green setting is created, then demand reduction methods are considered, then green policies are instated, and finally, an environmental curriculum is established.

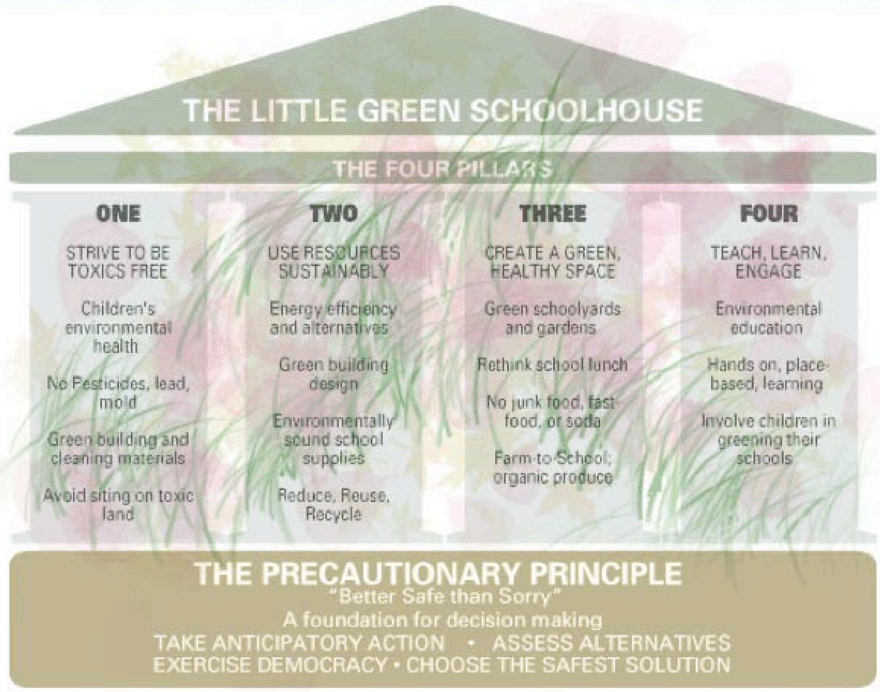


*Figure 1: The Four Pillars of a Healthy, Sustainable School. http://www.greenschools.net/report/index.html*

### Socio-Political Context

In the context of schools, there may be some ambiguity as to whether “green” refers to a nature school, which is activity-based, or whether it is highly efficient in energy performance, which engineering-based, using technology to lower net environmental impact. In the United States, green schools are receiving a lot of publicity because of their potential in reducing operation costs during this economic depression. Political action in Washington, D.C.[1], where America’s first certified LEED (Leadership in Energy and Environmental Design) Platinum school[2] was built in 2006, is evidence of the widespread understanding that greening America’s schools is fundamental to reviving the economy. The Green Schools Caucus, formed in the House of Representatives in late 2007 by Reps. Darlene Hooley, D-OR, Michael McCaul, R-TX, and Jim Matheson, D-UT, is the fastest-growing caucus on Capitol Hill (Hazel, 2008). In New York City in 2005, Mayor Bloomberg signed a law requiring city-funded capital projects to use LEED,

[1] Currently, Earth Day Network and other organizations are raising awareness to keep green schools in the economic stimulus package. R. 3021, the 21st Century Green High-Performing Public School Facilities Act already passed by the House with overwhelming bipartisan support, and would mean $6.4 billion for school construction and modernization projects, beginning with 50% green certified schools, which will improve the health, safety, learning environment, and energy efficiency of our nation's public schools.

[2] Sidwell Friends Middle School

including schools and hospitals. In 2009, the San Francisco mayor signed a law requiring that all new buildings constructed within the city must be LEED certified. California has the largest concentration of green schools, initially through progressive legislation, such as the Healthy Schools Act in 2000, and more recently with state law requiring "Environmentally Preferable Purchasing",[3] and other government mandates. The success of California's progressive green school policies shows that legislation is the first and most crucial step towards eco-schools.

In the US in 2007, about 400 schools applied for LEED ratings, but only 60 were certified (Linn, 2008). According to *Architectural Record*, "Schools of the 21st Century", in "…early November of 2007, the Clinton Climate Initiative announced it was partnering with the United States Green Building Council and at least two dozen other organizations to start a green schools program, whose ambition is to make all American schools green within a generation. The program will help schools reduce energy consumption as well as educate a new generation of students about the effects that buildings have on the environment" (Linn, 2008). This statement, incorporating a teaching aspect into building, is where this study intends to focus. Eco-schools, not mutually exclusive from both green schools and high-performance schools, include a curriculum component. There are many green school advocacy organizations[4] concentrated in the Northeast or West coast specifically promoting high-performance schools, but there is still relatively little common knowledge of eco-schools. A 2005 market study of green building by SmartMarket report, found that "educational buildings were the fastest growing sector for green building, and that school boards and administrators have the most influence in getting schools to go green. A second driver is the increasingly widespread adoption of policies that require public buildings to have green characteristics" (McGraw Hill, 2007). Green schools is a rapidly growing political movement, headed by the US Green Building Council, which has recently developed a

[3] California law requires State government to practice Environmentally Preferable Purchasing. See Public Contract Code, sections 12400-12404 for more information. This applies to California state agencies; however, local governments and school districts are encouraged to practice EPP as well, and can use California state procurement contracts to get discounts on many green products. http://greenschools.live.radicaldesigns.org/article.php?id=43

[4] Collaborative for High Performance Schools (CHPS), Alliance to Save Energy
Green Schools Project, Energy Star for Schools, EnergySmart Schools, National Clearinghouse for Educational Facilities, Northeast Sustainable Energy Association, Sustainable Buildings Industry Council (SBIC) & Massachusetts Green Schools Initiative, The Green Schools Inititative

Leadership in Energy and Environmental Design (LEED) rating system specifically for schools. In addition, the Clinton Climate Initiative in partnership with dozens of other organizations has initiated a green schools program in hopes of making all American schools green within a generation (Linn, 2008).

Currently, in advocating green construction, the political emphasis is on the public sector because it is much easier to mandate that all public buildings meet certain requirements, than privately owned corporate buildings or homes. Though all public schools fall under federal and state jurisdictions, and could benefit from greener building codes, it is more difficult to build a case, community base, and fundraise for *new* green facilities and curriculum while so many *existing* schools lack funds to serve their primary purpose: to teach to federal curriculum requirements. This means that many eco-schools are private, and cannot provide these high quality environments and education for people who cannot afford it. In this way, green schools have become an attraction for families, and a marketing point for school boards, especially those who boast the overpriced LEED certification.

### "Green" for Profit

One of the main factors in school construction has always been cost. A convincing argument for green schools is that it saves money and resources by thoroughly planning every aspect of the design to utilize renewable energy sources, e.g. the sun. By merely orienting the building to have maximum sun exposure to the south façade, or arranging the banks of lights parallel to the windows, you can save heat and electricity, and therefore, money. "If a green school saved $100,000 per year in operational costs, that's roughly enough to hire two new teachers, buy 200 new computers or purchase 5,000 new textbooks" (USGBC, 2009).

But the term "green" has been so overused in the media that many don't know the difference between the terms *green, energy-efficient, regenerative,* or *sustainable*. Consumers have been bombarded by "green" companies who more or less use the term, "green" as an advertising agent, but do not seriously seek to lessen their carbon footprint, or check the details of their operations for wasted energy. For the purposes of this study, these non-synonymous definitions will be used (Stein, Reynolds, & Kwok, 2005):

*energy-efficient:* reduces net negative energy impacts

| | |
|---|---|
| *green:* | reduces net environmental impacts |
| *sustainable:* | no net environmental impacts |
| *regenerative:* | positive environmental impacts |
| *biophilia:* | humans' inherent affinity to the natural world |
| *ecology:* | relationships between organisms and their environments |
| *passive system:* | uses renewable, non-purchased energy; multi-purpose strategy that is integrated with the structure |
| *active system:* | uses fossil fuels, single-purpose, added onto or independent of structure |
| *embodied energy:* | how much energy must be invested to mine, harvest, produce, fabricate, and transport a material |

By understanding the technical differences between these terms, we are able to distinguish purely marketable "green" intentions from entities who truly have thought through the greening process. From this brief introduction to green schools in the United States, we can now compare to our American corporate-driven greening process to advancement in other countries.

**Greener on the Other Side?**

Currently, the United Kingdom has the most aggressive green schools initiative, with handbooks/guidelines (CEE, 2002), case studies (DES, 2006) and government standards (BBC News, 2006) already published and in place. According to an international evaluation of trends in eco-school development, there is "fluidity" in terms of defining an eco-school worldwide (Mogensen, 2005). The term originated from a UN Conference on Environment and Development of 1992 and later developed into an Eco-School organization under of the Foundation for Environmental Education (FEE), based in Copenhagen, Denmark. However none of these national reports address the importance of architecture in the framework of environmental education, but rather on the approaches to teaching the current ecological crisis.

## Necessity of School Improvement

In this section, reasons for school research, retrofitting, and new construction are presented. The most urgent issues, discussed below, include student health, energy consumption, cost, design opportunity, and the limits of contemporary environmental education.

The strongest case for building green schools is improving students' health. In the United States, "more than 53 million children and about 6 million adults spend a significant portion of their days in public and private school buildings. These school buildings may contain environmental conditions that inhibit learning and pose increased risks to the health of children and staff" (EPA 2008). This could lead to immediate extensive renovations and retrofitting of old, dilapidated and outdated schools with antiquated construction methods and toxic materials, and impact new construction standards.

Not only is physical health an issue in today's schools, but emerging research shows that children's mental health is declining with the lack of direct exposure to nature, a matter not confined to school settings (Kahn, et al., 2002; Louv, 2008). Children's disconnection from nature is not necessarily solved with eco-schools, but is considered as central to their architectural form and their articulation of the educational setting itself. Because the built environment can only model nature's systems, architecture and engineering create a visual landscape that is essentially a simulation, and as constructed representation, is inherently indirect and can never replace real outdoor experiences.

Maintaining health and meeting curriculum objectives are the bottom lines for schools. But a school shouldn't stop there: with careful design choices, children can learn from the building's features, which could serve as concrete example of things they're learning. Taking this notion a step further, children could learn to be ecologically sensitive through building systems that mimic natural systems. This is achieved at eco-schools by using accessible green technology to support an environmental curriculum. This pedagogical tectonics approach to sustainability presents an opportunity to showcase environmental systems in a tangible, child-friendly way. However, even in the newest buildings, the idea is still in its infancy in North America.

**Buildings' Influence on the Environment**

In the United States, buildings account for 65% of electricity consumption, 36% of energy use 30% of greenhouse gas emissions, 30% of raw materials use, 30% of waste output, and 12% of potable water consumption (USGBC 2008).

> “Green schools cost less to operate, freeing up resources to truly improve students’ education. Their carefully planned acoustics and abundant daylight make it easier and more comfortable for students to learn. Their clean indoor air cuts down sick days and gives our children a head start for a healthy, prosperous future. And their innovative design provides a wealth of hands-on learning opportunities (USGBC 2008).”

As noted by the US Green Building Council, green buildings not only save resources but also provide educational components not found in traditional schools. The reduced impact of a green school is not limited to the construction and operation of the building, but also includes the demand reductions that the occupants may continue to be conscious of the rest of their lives. This study intends to elaborate on this method of tactile learning in an attempt to assess whether children’s attitudes and behaviors can be influenced by the school buildings themselves.

Many are concerned with extra initial costs for higher performing schools, also known as the “green premium” which comes from higher efficiency, higher quality, sustainable materials. However, cost analysis of 10 sustainable schools in the US show that “typically green schools cost 1% to 2% more, with an average cost premium of 1.7%, or about $3/sq. ft.” Comparing this number to the quantified benefits, the net gain is $71/sq.ft. (Kats 2006).

Funding for public schools is a consistent problem. How can the focus shift from monetary savings to health benefits, if the natural, quality materials and sensitive design strategies cost more? The difference between many public schools and private schools is that the private schools do not have as many stakeholders, and therefore can achieve more because they have to please fewer people. In this way, a specific agenda can be carried through the entire school. It is logical then, that green schools, which cost significantly more in initial costs, are private. However, private schools, with tuition fees, are not accessible to the general population, and doesn’t everyone deserve a healthy school? The public school system will need the help of government mandates and financial incentives to become green, and teach the next generation about sustainable lifestyles. Decision makers must see that environmentally sensitive systems and materials are not extra-credit anymore, not even special highlights. They are fundamental to the sustainable agenda the country has embraced.

**Limitations of Environmental Education Today**

One of the challenges with Environmental Education (EE) is the separation of environmental concepts from required subject matter. The fundamental labeling of 'extra-curricular' or 'special field-day,' only reinforces the fact that environmental issues can be distinct from math, science, or social studies. The obvious answer is that ecological principles connect to everything a child is learning at school, from developing morals to calculating how much electricity the sun has provided for their classroom that day. Eco-schools take environmental education to a new level by developing a perspective that all aspects of a child's life apply to a greater context, which intertwines people, technology, and nature.

Environmental education (EE) is traditionally based on learning about the local environment. The established setting for nature-related activities is outdoors. However, this removal from the traditional learning environment again separates EE from the normal curriculum. How can we teach human health and healthy-earth strategies indoors in an unhealthy building? Eco- schools attempt to solve two problems at once. Nothing can ever replace experiences in nature, but a green school can serve as a model for natural systems, and spark curiosity. "Environmental Education must not only be recognized by students as crucial to their lives but also enable and urge them to be curious and question things around them, scientific phenomena as well as societal structures and conditions" (Mogensen, 2005). Therefore, environmentally focused content is integrated into the traditional curriculum, equally as important as math, science, or language. By showing students that their building too is a part of the system, influencing natural processes, subject to the same laws of nature, it could teach students to think in cycles, and consider their own place in this system. This cyclical, place-based thinking ties into the aspect of locality, and the importance of knowing where one is and their role(s) in the bigger picture. This larger framed, *whole-systems thinking* is the key to changing the one-way waste producing methods of the first industrial revolution.

Shifting from traditional educational systems to focus on environmental stewardship in supportive settings is the trend of eco-schools: "Changing conceptions of the educational system, which recognize the importance of the diverse contexts where education takes place, the emphasis upon equity (not equality) in educational opportunities, and an elevated sense of responsibility toward the future; values of context could lead to increased support for place-based education, which is also environmental education. An elevated sense of responsibility is really what EE is all about" (May, 2007).

However, the current green schools movement in the United States is focused solely on constructing healthy buildings. Although educational buildings are the fastest growing section of green construction mainly for the health and monetary benefits, there appears to be little attention to the efficacy of the school in terms of environmental attitudes. While this rapid green development is an aggressive move in the right direction, there is a need to understand how effective LEED certification alone is as an advertising ploy, versus say, quality education. This is a missed opportunity. With considerable funding, America can retrofit old schools with fancy expensive systems that will lower operating costs, but will not be directly accessible for children to learn from. Starting with a poorly designed building (e.g. one that does not take into consideration the location of the sun and it's heating capabilities) it is difficult to create an eco-school because no amount of technology could make it energy-efficient, much less a model for the worldwide school design community. This is why new school construction policies, which this paper intends to influence, are essential in preparation to lead the eco-school movement.

Change must also come from the training of educators in preparation to use these new types of school buildings. Teachers and instructors in public school systems, especially in inner cities, are lacking the necessary training in environmental education, or simply lack the tools and resources to achieve this. On the opposite end of the spectrum, some enthusiastic teachers who emphasize environmental awareness are labeled as too far from the norm: Teachers are "often passionate advocates and suffer from being seen as overzealous" (Henderson, 2004). Currently, teachers at the primary and secondary level are struggling to meet standards in math and reading, and view environmental education as another topic. If government-funded financial incentives were linked to greener technology and students' environmental stewardship rather than standardized test scores, there could be real momentum from the top down, as in many European countries. At an eco-school, sustainable living strategies are incorporated into every subject matter, rather than introduced as different course or separated as an extracurricular activity.

## The Role of Architecture

### Design Humility

The concept of creating buildings that provide services above and beyond the performance standards, even beyond green performance standards, is a new movement in architecture, led by William McDonough. Architecture of the 21st-century, will soon have to be regenerative. This means that buildings can no longer be a source of pollution or strain the natural resources of its context. They must have elements that attempt to restore what existing buildings have depleted, and replicate natural cycles of the local biosphere. McDonough and partners have led the way in redefining the purpose of buildings. We can apply this approach specifically to schools to combat the negative idea that what we have done is irreversible, a notion that could be extremely distressing to a young child. To use this optimistic standpoint, that we have solutions if we admit our reliance and fragile relationship to nature, instilling humility in those who reap the benefits, we can repair the destruction and wastefulness.

I believe that this idea of human humility begins with the architect, who mediates the relationship between people and nature. His or her design intentions and will resonate with the users inside the building. If the architect is more concerned with making a sculpture of his own recognizable trademark rather than promoting life at the site, the people will undeniably be affected by the egotistical intention. It is this mentality that begins with the training of contemporary architects- striving to standout, making a name for him or herself, rather than serving the people who will be using the building. What is lacking is the necessary humility that the architect is not omniscient or omnipotent especially in the larger context of natural systems.

With the understanding that we cannot know all the implications of our structures and our behavior within them, “we must act cautiously and with a sense of our fallibility” (Orr, 2002). David Orr begins his discussion of ecological design by first describing the present circumstances of ‘economic obesity’ (in Lewis Mumford’s terms) and calling for a “deep revolution of thinking” to be able to solve our dilemma of justified (rightful?) over expenditure. He goes on to say that to avoid catastrophe, we must “transform human intentions" from prioritizing productivity to learning the 'arts of longevity,' his way of phrasing 'sustainability' in a way that is not affected by the overuse of the word. It is necessary to change the way we work and construct systems, to change the way we serve needs as responsible human beings. This necessity for change can begin at the elementary school level, cultivating responsible behaviors with concern for distant future generations. In this way, the green revolution is shifting the way people think about buildings; can it change the way buildings influence people?

Realizing that the building sector comprises almost half the nation's energy consumption, we cannot afford to cultivate "starchitects" whose egos blind them from serving the public first. Starchitecture is not design humility, it is not practical, nor sustainable to believe that an image could come at the expense of users' health (e.g. an architect's "signature material" which actually has toxic off-gasses and harms people in the manufacturing process.) Service to and functionality for all people, or universal design, should be a concern for all professionals, in any discipline. We are in need of a shift from individual prosperity to collective prosperity, not just for our lifetimes, but for the lifetimes of the children who are not yet born. An expansive view of the world is the only way to truly pursue sustainability.

### Sustainable Buildings

Referring to the definitions above (Stein, Reynolds, & Kwok, 2005) *sustainable* buildings are those that do not impact the natural environment; their operations could continue on for centuries without affecting the resources of future generations. The concept of sustainability therefore demands that people shift their thinking to a long-term model, thinking beyond themselves, beyond their children, beyond just the building materials. However demanding sustainability is not even as direct and involved as pushing for *regenerative* design. How do we construct buildings that not only leave no trace, but actually attempt to repair hundreds of years of damage?

## Research Aims

The general purpose of this research is to examine how architecture can positively affect people's lives. Many studies have been published on how the built environment can hurt human beings- they poison us (Greenguard, 2008), keep us away from nature (Wilshire, 1998), waste energy (Mazria, 2007), and pollute the planet (EPA, 2009), but how can we take this great investment (a place of shelter, a place of resource, of interaction, of work,) and ensure it is a useful, efficient, and healthy place to spend our time? How can we turn the necessity of shelter into a regenerative place for all organisms to use? Where are the buildings that are not just safe to occupy, but healthy for people (Frumkin, 2001) and the local species of plants and animals? Imagine buildings integrated into the landscape they rest in, not on, not only in the aesthetic, vernacular sense, but in the physical, measurable, ecospherical sense. This integration of natural systems, turning buildings into models of steady ecological processes (Kellert, 2008), fuels discussion not only on the development of sustainable practices (McDonough, 2006), but also on the practice of architecture: how can the constructed environment grow out of and alongside the natural environment, rather than smothering it (Orr, 2002)?

By asking this broad research question in terms of a specific building type, schools, this study explores whether there are aspects about green school buildings can offer more than just any green building. Because school buildings are intended to be places of learning, this study focuses on the effects of a green (energy-efficient) building in addition to an environmentally focused curriculum (which constitutes an eco-school) on the environmental attitudes of the students. However, there are numerous factors that influence children's environmental attitudes over their lifespan, thus this study specifically investigates active efforts in the school setting.  The specific aims of this study are:

1. (a) What factors aid eco-school development, and (b) in what kind of social contexts this occurs?
2. What are contemporary exemplars of eco-schools, in architecture and activities?
3. Can eco-schools influence a child's way of thinking in different ways than traditional schools, in terms of environmental attitudes?

These questions will be addressed from both an architectural standpoint, addressing the key physical components of eco-schools, as well as the behavioral standpoint, analyzing the different activities and curriculum approaches that successfully use the green school building as a tangible example of environmental effects. This study will contribute to our understanding of children's relationship to nature, and the influence of the physical setting on learning. This study could also help to improve school design around the world by providing much-needed information about existing models and trends in ecologically-friendly education and architecture. Since the study attempts to broaden the purpose of buildings beyond basic functions, its results could potentially impact architectural and environmental technology fields.

## Literature Review

In order to examine environmental attitudes of students in the context of green schools, it is essential to first consider the prior research on the effects of the built environment on children, intentions of architects in previous studies, and the notion of the building as a pedagogical instrument. Here, the following research will be briefly reviewed: 1) Effects of the built environment on children, 2) negative effects in schools 3) positive effects in schools, 4) architects' explicitness, and 5) building as a teaching tool.

### Effects of the Built Environment on Children

Many studies show how the physical aspects of buildings can affect psychological or biological aspects of humans. Research in this area ranges from quantitative studies of low dose lead poisoning (in paint and particles in the soil) impairing development in young children (Bellinger, Stiles, & Needleman, 1992; Murata, 2009) to qualitative studies of quiet private nooks in school is important for coping with stress (Fein, Schwartz, Jacobson, & Jacobson, 1983; Lowry, 1993). However, there is little research on how the physical school environment itself (as opposed to curricula) can affect long-term environmental attitudes and behaviors. Influencing attitudes and behaviors has been studied using participatory activities, incentives, brochures, and community-level action which require a human example or instruction (Reid, Jensen, Nikel, & Simovska, 2008). It is rare to find research on how the school building itself can affect attitude, except in the case of museums, which will be discussed later in this section.

### Existing Research on Negative Effects in Schools

Perhaps one of the most researched areas of environmental effects on student health in schools is indoor air quality (IAQ) on asthma rates (Frumkin, 2006). The recent dramatic increase of asthma in children and young adults has led to further investigation of possible causes, especially within schools (Cameron, 2007).  According to the American Lung Association, asthma is the third leading cause of hospitalization among children under the age of 15, and is one of the leading causes of school absenteeism (Center for Disease Control, 2007). Indoor air quality is quantitatively evaluated and therefore can be measured very precisely, including the quantity, type of chemicals or size, of particulates. Therefore school IAQ research has progressed to correlating greener schools with reduced asthma rates, some studies, such as those conducted by Carnegie

Mellon University, have found a 38.5% reduction with physical school improvements (Kats, 2006).

However, the discussion of environmental toxins, chemical off-gassing, and substandard ventilation in schools is not a recent occurrence, for the first articles on “sick building syndrome” date back to the 1980s. Nor is air quality the most serious physical problem in schools today- temperature control and lighting affect productivity and wellness (NRC, 2006; Kats, 2006). In addition to building quality, poor environmental conditions relating to the presence of others, such as crowding and noise have been correlated with depression, increased stress, increased blood pressure, and in some cases, learned helplessness (Lepore, Evans, & Palsane, 1991; Bell, Greene, Fisher, & Baum, 2005).

Recently however, with the political, social and economic movement towards energy independence, coupled with a commercial obsession with healthier, cleaner living, the high-performance green school is marketable. Most of the literature available about high-performance schools, green schools and eco-schools relates to how to start a green school, retrofit a school with green technology, or implement environmental lesson plans. The extensive research on high-performing schools provided by the National Clearinghouse for Educational Facilities[5] is based solely on health, productivity, and saving money. While a high-performing school may be a component of an eco-school, it lacks the fundamental users' *awareness of the systems*, thereby introducing the notion that users can learn from the building, or pedagogic tectonics.

### Existing Research on Positive Effects of Schools on Children

Other environmental aspects have shown remarkable positive effects for human health, such as daylight, and improved productivity with temperature control (Kats, 2006). The Heschong Mahone Group (2003) showed that increasing the amount of natural light in classrooms can improve overall performance in math and reading. Currently, with the growing interest in greening schools to save money, research in the area of positive affects of the school environment is growing. At Sidwell Friends Middle School in Washington, D.C., the first certified LEED Platinum school in the United States, there are ongoing studies conducted by Stephen Kellert, Professor of Social

[5] http://www.edfacilities.org/rl/high_performance.cfm

Ecology at Yale University's School of Forestry and Environmental Studies. Currently, Kellert is assessing the physical, emotional, intellectual, and interpersonal impacts of Sidwell Friends' new green middle school on its students, teachers, and staff (Sidwell Friends Website 2007). This case study is particularly interesting because the architects, KieranTimberlake, believe that "behavior modification" is possible through built environments. This means using real-time feedback loops to change behavior patterns. For green schools, one of the overall goals is to get kids to think and act sustainably. Kieran explains that the display in his Toyota *Prius* informs his next action, and that this information-guided behavior reasoning can be applied to architectural systems and occupants (Chen, 2007). Sidwell Friends has features like the *Building Dashboard,* an online real-time energy monitoring system designed to be accessible and comprehensible to middle-schoolers. It displays how much solar electricity is being generated compared to consumption from the grid. They can also change the units of measurement from kilowatt hours to dollars, tons of carbon dioxide, cars, or even number of hairdryers. While this is an intangible software display that may not have immediate behavioral responses, having this kind of accountability may bring more long-term environmental attitude changes.

However, Wells and Lekies (2006) have identified that the path to adult environmental behavior is correlated to experience in nature as a child. If children spend more and more time in school buildings formally learning about natural systems, when will they have time to explore it for themselves? Children who are not actively thinking or formally taught about greener behaviors but are interacting with nature on their own playful level will "will grow up to cherish and protect it" (Louv, 2008). One could argue that this viewpoint opposes Kieran's architecturally mediated and information-based perspective. Even though Sidwell Friends' playground is not the typical manicured lawn or blacktop, the local species of trees and shrubs were planted, essentially planned, and inherently *unnatural*. Does a created landscape substitute for the wilderness? Is learning more productive when what they see and experience confirms their teachings or when what they see and experience inspires academic interest? Other researchers exploring the children-nature relationship have not yet defined the role of progressive green architecture. At this point, it is a movement to get kids to go outdoors, primarily for health. Eco-schools' influence on environmental attitudes and behavior is an area that has not been thoroughly examined.

Ultimately, the eco-schools aim to promote a long-term natural development of green behavior through context and opportunities for discovery. Can this be likened to a children's museum? At places of learning, it can be argued that there are two purposes for the building: to increase knowledge, increase engagement, giving students purposeful activities. However, museums differentiate themselves by incorporating the aspect of play or experimentation into educational material (Piaget, 1929; Hein, 1998). Hein cites articles supporting the theory that experience, interaction, manual manipulation, or "hands-on" learning is the important for intellectual development and is preferred by children. In addition, it been shown that hands-on activities which involve children are more effective in developing "environmental competencies" (Heft & Chawla, 2006). How would a school, with the distinct purpose to increase knowledge, also be able to incorporate more participatory activities to support the environmental mission? The answer may be with the school building itself, as an interactive model, with real-time controls for students to learn that their actions have immediate consequences.

No one can deny that increased knowledge of an issue affects an attitude, but does the attitude affect behavior? Specifically, does greater environmental knowledge lead to environmentally responsible behaviors? Dutch researchers found that attitudes affect behavior in the long term, but do not determine immediate actions (Kuhlemeier, et al. 1999). This notion has also been extensively explored by Ajzen and Fishbein (1980), and is quite an elusive subject because so many independent factors may inhibit actions and override intentions (Oreg & Katz-Gerro, 2006). However, this study does not aim to show that children's environmental attitudes directly translate to environmental behaviors, especially when students at eco-schools regularly practice environmental behaviors. The path to behavior is not in one's own obligation to a cause, but by repetitive practice, or instilling a norm for responsible behavior, much the same way children learn to share or take turns (Scott, 1971).

**Architects' Explicitness**

Architects have a unique opportunity to design the way we live and work, and potentially to affect the way we learn. Designers implicitly shape our visual landscape, in which the passersby rarely stop to think beyond the face value, e.g. where did this material come from? Today, facing the peril of our planet, we must think beyond ourselves, and beyond our routine practices. *Embodied energy* is the concept that every finished product is the sum of all the raw materials and processes that were employed to create it. It begins with the cost of labor to excavate the natural resource from the ground, which was used to make the raw material, which was shaped into *x*, which gave off bi-product *y*, which was harmful to location *z*... etc. The interconnectivity of our world is not overt or easily understood. However in searching for the "back story" for everything we consume, we can hold people accountable for the irresponsible actions that are commonplace today. By revealing their systems and displaying its own resource and waste, green buildings may inspire the new generation to think in broader, consequential terms, or *whole-systems thinking* (Rocky Mountain Institute, 2009; Sterling, 2003). The components of this term, which are outlined below, draw from various sources in the literature.

Developing Whole-Systems Thinking: For School-Wide Edification & Cultivation of Environmental Norms

1. Begin with reducing the demand by using energy efficient practices (McDonough, 2002)
2. Understand the local ecosystem and one's own direct influence (Louv, 2008)
3. Understand the societal context and the general attitude of the local community
4. Facilitate people to indulge in biophilic tendencies, unregulated play in nature to attach their own meanings and memories (Louv, 2008)
5. Display concepts in cycles to identify the self in the system
6. Cultivate awareness of "back-stories" and processes: what is out of sight is *more interesting*, not out of mind
7. Introduce the concept of scarcity of resources and regenerative activities (avoid hopelessness)

For example, architects designing a school can help eliminate the concept of waste (McDonough & Braungart, 2006) by showing students that almost everything they use, and excess materials they don't use, can be used for something else. For instance, when dealing with stormwater runoff or grey water from faucets, architects can choose the traditional sewer system with drains and grates, utilizing an underground, unseen system of pipes. In contrast, designing a bioswale, a densely vegetated open channel design to attenuate and *treat* runoff (Kwok & Grondzik, 2007), is intended to cleanse and direct water, but could also add landscape variety to a paved parking lot, as well as providing another lesson in the school's science class. Today, there are numerous techniques that reveal typically unnoticed building systems, and actually lessen the structure's impact on the environment. Other examples include rainwater catchment, *Living Machines®* (a wastewater purification strategy using plant life), green roofs, shading devices, active solar thermal devices, turbines, and photovoltaic panels.

At an eco-school, the definition for *economic prosperity* would be slightly different than at a traditional school. For example, students at a traditional school may be learning about the stock market or the relationship between efficiency of people (to almost a mechanized state) while students at an eco-school would see that one day, their school is producing more energy (via solar panels) than they are consuming. Which example will affect a child's understanding of natural resources? Is a resource precious or *undervalued?* What are products that are good for the earth? How are we using our natural resources, such as the sun, most effectively, locally?

The Lewis Center for Environmental Studies at Oberlin College is referenced frequently in discussions of sustainable educational buildings. Not only does this building utilize the latest technology for energy and water efficiency and recovery, but it also allows students to make adjustments to the system. The key component is the monitoring equipment that allows the occupants to track and control energy usage, and make changes based on this information. At the school, faculty wondered if "it is possible to build without compromising human or environmental health somewhere else or at some later time?" (Orr, 2003). With this sustainable mindset and the one of the leading green buildings in the country, the faculty can teach environmental studies in a hands-on way, allowing the students to learn and take responsibility for harvesting energy from the building.

This example demonstrates how the combination of teachers and buildings (schools) can influence the way occupants think. The current study examines ways that architectural elements of school buildings themselves are integrated into a sustainable design curriculum for elementary school students. Furthermore, in an investigation of display strategies which reveal the embodied energy of materials, this study looks for evidence of whole-systems thinking in students. Fundamental to this “instructive structures” approach to design is the idea that the learning environment itself should incorporate the green design principles being taught in the school. This means that the administration, faculty, community members, school board, and federal government should believe in and facilitate the activities of the school. This research includes a discussion of stakeholders in eco-schools, sources of funding and government support in varying countries, children’s environmental attitudes, and architectural features that enhance a green curriculum.

**Building as a Teaching Tool**

Research has for many years, shown that young students learn material when they can link it to a concrete sensory experience (Piaget, 1929; Bransford, 2003; Hein, 1998). Therefore, a student with the direct association of lesson and experience will understand and internalize concepts. This notion is discussed in the context of environmental education by Danish education researcher and professor, Finn Mogensen (2007) with *action knowledge.* Action knowledge is gained through a cyclical learning pattern of participation and reflection, using students’ reasoning and judgment abilities to rationalize the intentions of their actions. With this model of teaching environmental education, he explicitly objects to the “behavior modification” that Kieran Timberlake architects strive to achieve. Rather, Mogensen favors cultivating critical thinkers who have as much information about their choices as possible, instead of providing a biased space for a specific behavior. Figure 2 shows four dimensions of knowledge that affect environmental behaviors. Building design could facilitate further understanding of any of these constructs.

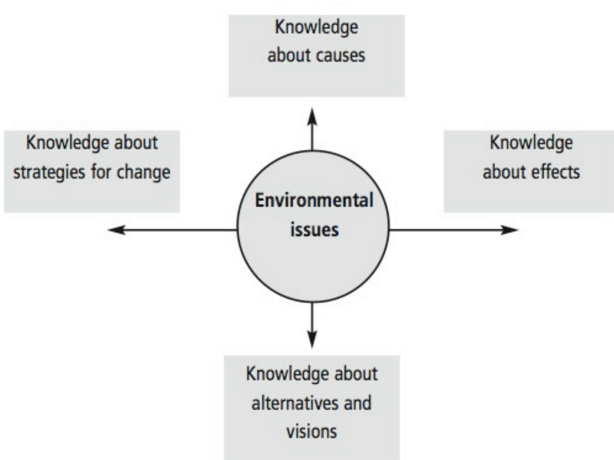


*Figure 2: Action- Knowledge (Simovska & Jensen, 2003 cited in Mogensen, 2007)*

This contention between spaces designed with the purpose of changing attitudes and behaviors with or without the user's awareness is illustrated in a fully automated green school in Canada. In an article about the newly opened Thomas L. Wells School in Toronto, "Though the students are unaware of most of the school's green features, they love the space. [The principal] notes that the green design, and especially the daylighting, "seems to spark a curiosity in them." The principal says he hopes that the teachers will incorporate some of the building's green aspects into their lesson plans" (Boehland, 2008). This shows that even the newest green schools are not intended to teach children about its systems, with or without the help of their teachers. They may have the best school building in the city, but how much of the users' behavior is driven by the design of the building?

There are few educational settings that have been designed to be teaching tools for overall environmental education, but even less for sustainable life skills. However, the Nueva School, in Hillsborough, California, had the curriculum carefully designed alongside the building. The students grow their own food on site and use the solar panels, green roofs, and water-harvesting systems in daily learning exercises. At IslandWood, an educational facility for school environmental retreats on Bainbridge Island, Washington, students spend the majority of their time outdoors experiencing nature and accumulating qualitative data about their surroundings. The classrooms on the 255-acre site offer students a quantitative way to view and learn from nature; the building itself is a pedagogical tool in understanding interconnectivity, site-specificity, and sustainability.

This study attempts to show how architectural, informational, and educational systems can be combined to make school buildings the instruments through which students learn how to lessen human impact on the environment. Easily implemented examples of this instrumental approach include exposed greywater systems (rainwater to flush toilets) or built-in features that facilitate cafeteria composting, which could help students develop a whole-systems understanding early on by active participation (Hart, 1992; McCallum, et. al., 2000). It could also include interactive display systems that let children monitor and control the functions of their building, thereby internalizing the process and their role in the system. This depth of comprehension at a young age could be the turning point for the next generation to learn sustainable and cyclical consumption (Fien, et. al., 2008).

Methods

## Specific Aims

1. (a) To understand what factors aid eco-school development, and (b) in what kind of social contexts this occurs? (Interviews, Archival data)

2. To document contemporary exemplars of eco-schools, in architecture and activities. (Tours, Interviews)

3. To investigate whether eco-schools influence a child's way of thinking in different ways than traditional schools, in terms of environmental attitudes. (Surveys)

## Design

Four types of research methods were employed: interviews, surveys, tours, and archival data. Five schools were studied.

**Independent variables:**

- Green school buildings were selected based on the presence of any or all of the following:
    - energy monitoring displays for students
    - building controls operable by students
    - energy-saving passive design (solar gain, daylighting, orientation)
    - energy-generating active design (photovoltaics, wind turbines)
    - sustainable materials
- Integrated environmental curriculum
    - activities that bring students closer to nature
    - core subjects taught using natural models
    - practicing sustainable life skills outside formal classroom setting

**Dependent variables:**

- Children's environmental attitudes
    - Affect
    - Belief
    - Behavior

## Sites and Participants

**Sites: Schools Studied**

Schools were initially identified based on internet research, eco-school and architectural publications, and newsletters that showcased schools' visible sustainable practices. Selection criteria such as energy display features, a focus on environmental education and sustainable lifestyles, location (i.e., England, The Netherland, Germany, Japan), and the availability of both the architect and principal were all practical constraints. References from other architects, academics, and ergonomists connected the researcher to eco-school directors.

Ultimately, six schools were visited: Kingsmead Elementary School, Northwich, England; Spoorzoeker, Den Haag, Netherlands; Sokkerwei, Castricum, Netherlands; Daltonschool Columbus, Heerhugowaard, Netherlands; Fuji Youchien, Tachikawa, Japan, Shinanodai Shogakko, Seto, Japan

**Participants: Students Surveyed**

As shown in Table 1, from the four schools visited, a total of 72 students were surveyed. Thirty-one British 6th grade students were recruited from Kingsmead Elementary School in rural Northwich, England. Three who participated identified themselves as part of the Eco-council of their elementary school. Seven Dutch students from grades 3-7 volunteered (answering the principal's request) to take the environmental attitudes survey at the Daltonschool Columbus in suburban Heerhugoward, Netherlands.[6] A class of sixteen Dutch 3rd grade students was asked to participate in the survey by the principal of Sokkerwei school in suburban Castricum, Netherlands. Eighteen Japanese students in the 6th grade were surveyed by the Vice Principal at Shinanodai Elementary School in rural Seto City, Japan.

Though surveying students in Germany had been planned, no newly constructed eco-schools fitting the criteria for this study could be found. According to Robert Lorenz, the Eco-schools Director of Germany, this was attributed to the fact that Germany's population is decreasing and the focus is on renovating and retrofitting old schools; there is little to no new school construction.

[6] Originally, there were thirteen who began the survey, but recess began and the children preferred to play outdoors.

*Table 1: Summary of Sites and Participants*

| School | Country | Students Surveyed | Interviews |
|---|---|---|---|
| Kingsmead | England | 31 | 3 |
| Daltonschool Columbus | The Netherlands | 7 | 3 |
| Sokkerwei school | The Netherlands | 16 | 3 |
| Shinanodai Elementary School | Japan | 18 | 1 |

**Participants: Professionals Interviewed**

Seventeen professionals related to the design, construction, or operation of eco-schools were interviewed as part of this study. Seven[7] people from the Netherlands, three[8] from England, three[9] from Japan, two[10] from Germany, one[11] from Denmark, and one person from Australia[12] were interviewed. Four were architects or design professionals: including three who had designed the two Dutch buildings and the British school included in this study, and one Dutch ergonomist specializing in green renovation. Three were design academics: one architect in Danish academia, one engineer teaching building technology in Germany, and one architect teaching sustainable construction in Japan. Six interviews were with principals of eco-schools that had been designed and built as a progressive, experimental building in their area (England, Netherlands, Japan, and Australia.) In addition, there were several special case interviews: a city government official in charge of adapting older schools with federally funded solar panels in Den Haag, Netherlands; the German Eco-school activities coordinator in Erfurt, Germany. Many professionals noted the progressiveness of Scandinavian and Australian schools in the context of community-wide sustainability efforts. Though this study does not include any Scandinavian or Australian schools, supplemental insight from both a Danish architect and an Australian eco-school principal provided broader information about the state of eco-school construction worldwide.

[7] Van Weenen, Boerstra, Overtoom, van Wickeren, Kristensen, Boerema, van Leeuwen.
[8] Bates, Stewart, Noble
[9] Yashiro, Kato, Ohtsuka
[10] Altendorf, Lorenz
[11] Coynes-Jensen
[12] Best

Interviews with professionals frequently led to further contacts at eco-schools, the government, and architects abroad. These contributors to the specific eco-school studied were asked similar questions (described below) via email (England, Netherlands). Initial contact was made with eco-school principals, architects, engineers via detailed email explaining the scope of the study. Prospective schools were contacted through recommendations by architects and authors and the International Eco-school Organization online, which is part of the Foundation for Environmental Education. This email was forwarded to other interested parties by environmental education advocates all over Europe. The researcher received inquiries from Scotland, Malta, and Canada.

## Procedure

The four types of research methods employed (survey, interview, tours, and archival data) are described in detail below.

### Surveys with Students

Surveys, consent forms, and instructions were all translated to the appropriate language (Dutch and Japanese). In each case, across all countries, the instructor read aloud the assent form, directions, and each question to the students, who were seated in their homeroom classroom. A familiar voice who could also read in the appropriate language was necessary, therefore special instructions were given to the instructor to keep a neutral tone.

### Interviews with Professionals

In these semi-structured interviews with principals, teachers, government officials, and architects, questions were based on specific aims of the study, focusing on how the school came to fruition. Topics included initial concepts, funding, community support, government incentives, and establishment of environmental curriculum. The purpose of the interviews was to determine a) if the person believed school buildings influenced long-term sustainable behavior in children, b) what factors are essential to starting a successful eco-school, and c) how mainstream green schools are in that particular country. Questions about implications and broader sustainability issues opened up more informal conversation with school directors and architects. These questions were directed towards perceived influence of the building on children's environmental attitudes.

### School Tours

Observation at each of the facilities began with a guided tour with the school principal, or on in one case, the Eco-Council, which was a group of students who volunteer to be responsible for their class' environmental initiatives. Three students at Kingsmead Primary School were able to leave their class and give a tour of their facility, giving details of how displays and visible systems make the building work. Photo documentation and the architect's commentary were important in understanding what was specifically designed for some purpose.

### Archival Data

To assess how favorable and widespread eco-school design and construction is in different countries, various magazine articles, newspaper coverage, and modern school design literature relevant to green schools were collected. Using this information, including previous case studies, the researcher was able to focus interviews with professionals.

## Dependent Measures

To address aim #3: whether eco-schools influence a child's way of thinking in different ways than traditional schools, in terms of environmental attitudes, thinking in cyclical patterns, and believing in harmony with natural systems, surveys were administered to 72 students. The survey was based on the *Children's Attitude Toward the Environment Scale* by Musser and Malkus (1994) (Appendix). The 25 question survey on environmental affect, belief and behavior, took approximately 20 minutes to complete. Three new questions were added to this survey (total 28 questions) to focus on school behaviors and renewable energy, which the experimenter created. Reliability and validity of these last three questions has not been determined however, the original survey had a test-retest reliability of .68, $p < .0001$. Cronbach's alpha for the scale was .70. In 2007, a study of 247 students across 12 schools reported test-retest reliability of only 0.47 after 3 weeks, but Cronbach alpha of .83.

## Results

In this section, the findings regarding each of the three specific aims will be presented in turn. These aims are:

1. (a) What factors aid eco-school development, and (b) in what kind of social contexts this occurs?
2. What are contemporary exemplars of eco-schools, in architecture and activities?
3. Can eco-schools influence a child's way of thinking in different ways than traditional schools, in terms of environmental attitudes?

**Specific Aim 1: (a) What factors (financial, federal, professional) aid eco-school development, and (b) in what kind of social contexts (roles, purpose, responsibility) this occurs?**

Interviews with school principals, architects, researchers in academia, government officials, and community members were used to address the question how eco- schools are started, including concept germination, financial support, building a case to the board/government, and community involvement.

### Roles in Eco-school Development

#### School Principals

The principals of all five eco-schools in England, the Netherlands, and Japan were interviewed. Additionally, one eco-school principal from Australia contributed to this study. Of the five groups of professionals interviewed, school principals were arguably the most influential in eco-school development. Enthusiasm for not just environmentalism but societal change in general made these people stand out from the rest. School principals' desires for a sustainable future were much broader than others' in terms of lasting impact. They recognized their profound role and responsibility to cultivate an active and ardent posterity: "We are agents of change… as our sphere of concern grows, so must our sphere of influence" (Best, 2008). Principals made statements about society in general: "Our children will be the first generation to not have more than their parents... We will have to find meaning and value in other ways than materials" (Stewart, 2008). As leaders in their communities, principals understandably stressed the importance of locality and social cohesion, not just in the context of schools, but also in consumer behavior and employment. The principal of Kingsmead expressed that when people work in the same community they live in, they become more aware of and active in local issues. She hopes to see areas where people work to survive solely on what they can grow and make locally. This self-sustaining, connection to place is also a theme in some architects' philosophies, including William McDonough, who speaks of far-sighted, locally based decision making as a responsibility of designers and consumers alike.

In this way, an eco-school is not separate from its economic context, nor is it just another institution: a school depends on the kind of community it serves. A self-sustaining population would provide evidence that green principles from the school do work. In addition, the principal's ability to implement new green activities and generate excitement and/or incentives for faculty, students, and families is critical to a community-wide change. In the Netherlands, one principal pointed out that there is a lack of teacher training in environmentally-focused curricula, and even if the building is green, teachers may be just as clueless as students. He explained that he wishes to hire persons who are already prepared with green ideas that fit the mission of his school, thus he seeks to recruit from new green teacher training schools that have sprung up in Holland. Eco-schools have become the vessel for the slow progression towards greener living. Knowledge from research is passed to teachers, whose creativity and enthusiasm inspires young students, who become influential forces in their families. According to two principals in England and Australia, some parents have reported to school officials that their kids have shown such commitment and responsibility to address environmental problems that they suggest changes based on activities at school (e.g. composting, compact fluorescent light bulbs, and less car use) (Stewart, 2008; Best, 2008).

**Community Members**

Interviewees included two government officials (England & Netherlands), two ergonomists (Netherlands), one International Eco-School coordinator (Germany) and one parent (Netherlands). For both Sokkerwei (Netherlands) and Kingsmead (England) schools, I was able to interview the person who was credited for turning normal school plans into an eco-school project. In the former case, this was a parent and in the latter, it was a leader from the municipal government. Information directly from the ideation source proved most useful regarding the challenges faced while promoting an eco agenda. In the case of Sokkerwei, a parent of one of the students is a professor of Sustainable Technology at universities across Holland. He has written a book on the process of developing Sokkerwei, *Discovery journey towards sustainability* which has raised international interest (Van Weenen, 2003). “We must revive, rediscover and respect the links with people and with nature,” he begins. Van Weenen discusses his research process, communication efforts, and navigation through building codes and municipality requirements. Through this eco-school, academics and researchers were able to directly affect the architecture, curriculum, and their own children’s futures. Further details about each school are presented in the case studies section.

Government officials explained how the green features in the eco-school projects were prioritized based on cost alone. In an interview in Den Haag, Netherlands, a municipal government member who had acquired funding for solar arrays for many of the schools in the district offered his thoughts on greener schools in the context of funding. For example, external shading devices such as a horizontal screen above a window (a passive strategy) at Spoorzoeker Openbare, a small public school in Den Haag, Netherlands, were not an option because the shade could become goals for soccer games on the playground. Windows would break regularly, and thus as a precautionary action, single glazing was used, which is cheaper to replace, but has no thermal properties. This illustrates the common tradeoff between green strategies and maintenance costs, an issue that people who decide schools’ budgets face. Similarly in England, a county council member expressed in an email conversation the importance of direct federal funding as the main facilitator for these innovative and extraordinary teaching tools (Bate, 2008). Even if the intention is to design an environmental school, municipal leaders must often cut some of the most important features for reasons the architect or school principal may not have considered. The discussion showed that maintenance costs remain high on municipal governments’ list of considerations (Boerema, 2008).

According to two ergonomists interviewed in Rotterdam, Dutch schools’ main problem is indoor air quality. Because this is a health issue, it becomes a priority to retrofit old, dilapidated schools rather than building brand new ones. This is a recurring obstacle for the advancement of new eco-school construction, however with extensive renovation and sensitive design, an updated school is generally more sustainable than breaking new ground. Because ergonomists are trained in identifying problems of indoor environmental quality of buildings, they are able to specify and prioritize a school's future needs. However, some forward-thinking ergonomists question their role and place in the design process: "Post-occupancy evaluations and inspections identify problems *after* it is built; what about *before* the building is built?" (Boerstra, 2008). What effect would the information an ergonomist produces have on new school designs? What if schools were designed to be evaluated, instead of remaining as unchecked hypotheses until some health problem occurs? It so happens that many of the health issues can be addressed using green building strategies. In this way, ergonomists and health inspectors can provide professional expertise (e.g. problematic case studies) for the advocacy of eco-schools. One ergonomist recounts the story of proving the necessity for school renovation: "It took me ten years to convince people that schools have worse air quality than some prisons- they're like submarines. You learn how bold you must be" (Boerstra, 2008). He believed that the evidence needs to be presented comparatively to effectively communicate with non-professionals. This surprising fact was the tipping point for many of the school renovation projects in the area, and also inspired many schools to apply for federal incentives to add solar panels, or more insulation.

In an interview with the International Eco-Schools coordinator for Germany and a meeting with a group of researchers at the Technical Institute of Braunschweig (TIB), the sentiment about prioritizing renovation of schools was evident. In Germany, the school-age population is decreasing, therefore hardly any new schools are being built (Lorenz, 2008; Altendorf, 2008). The existing 600 or so schools built in the 1950s are undergoing many changes, including more insulation, higher quality windows, and more compact forms which have less surface area from which to lose heat, which are all staples of the German *passivhaus* building technique (Altendorf, 2008). TIB is also conducting post-occupancy surveys and advocating for energy-efficiency placards and *passivhaus* standards in all public buildings, including schools.

In and around Erfurt where Mr. Lorenz directs 80 eco-school curricula, in which about 30% focus on renewable energy, mainly in monitoring photovoltaic panels, 50% collect rainwater, and approximately 25% use rainwater for uses other than landscaping.

This small snapshot of retrofitted green schools is in congruence with the fact that renewable energy constitutes 11-12% of all of Germany's energy needs, mostly in wind power (Lorenz, 2008). The progressiveness of the state is reflected in the kind of education they provide. Lorenz also believes that investment in renewable energy to generate operational savings is the way to make eco-schools more economically viable. This perspective is supportive of the 'new flashy technology' that is used to advertise eco-schools, because they also provide real, measurable, and significant sources of energy.

The German eco-schools.org program is twelve years old now, and provides opportunities for teachers to network and exchange environmental lesson plans around the world. The established framework of the eco-school organization allows the recognition and evaluation method of achieving a Green Flag Award, which legitimizes the greening of curricula process: "They have the feeling they're taking part in a well coordinated project, supported by media, student presentations, a jury session and an awards ceremony" (Lorenz, 2008). Lorenz goes on to say that the influence of the eco-school organization is inarguable: "I'm completely convinced they have a totally different attitude [than students at traditional schools]… we're raising practitioners."

**Architects**

Architects tended to see eco-schools as an opportunity, but money is always the number one issue when it comes to green features, which are not typically seen as necessity. The biggest challenge is making sure the decision-makers understand that the long-term benefits far outweigh the initial costs, and do not cut items from the program too quickly.  A Dutch architect deferred this responsibility of the architect entirely: "the problem is the money, and green schools are not the standard. We design green if it's an issue *for the client*" [emphasis added] (Kristensen, 2008). But the eco-school movement is definitively moving forward: a British architect projected that "schools are going to be the first wave of zero carbon" because of their inherent experimental nature (Noble, 2008). A Danish architect stressed that *greenwashing* (using green as purely a marketing scheme) is prevalent because people are starting to understand the problem, but are fooled by the quick fix solution: BUY green rather than *be* green. She says, "You must be *dark green* because green today is only in money bills" (Coynes- Jensen, 2008). This suggests that there is still skepticism of people's motives: green for sustainability or green for profit. This is also held true in Japan, where Tokyo University professor noted, that "Eco" is a prefix to many products, degraded to a commercial trend (Yashiro, 2008).

Nevertheless, architects interviewed made a point of the importance of green integrity (having noble intents) using passive strategies, which are often not as noticeable as active ones. Ecological responsibility is not a conspicuous technological quick fix, which is now coming to typify "green schools." There is also a tradeoff: more complex systems requires more maintenance and higher skilled maintenance staff, which could ultimately cost more, especially if the building relies on these active strategies as sources of energy. "The things that are really successful are passive," said David Noble in regard to the strategies used at Kingsmead Primary School, which he designed. Though Kingsmead has a few solar panels on the roof, they are not the defining features of the eco-school. Rather, the layout of the building, its reception or shading of the sun, tells more about the environmental sensitivity than the technology does. In Germany, the birthplace of the *passivhaus* strategy, passive design is widely accepted as the way to ultra-low energy buildings. The European Union has adopted their building code from Germany's rigorous standards because they promote passive strategies before active, recognizing that the first step is to reduce energy demands (Altendorf, 2008). Danish architect, Courtney Coynes-Jensen agreed in an interview about sustainable initiatives in Denmark weeks later: "the orientation [passive design] is the greenest thing you can do."

## Designers' Purpose & Responsibility

The second theme that emerged from the twelve eco-school interviews concerned the issue of the designers' purpose and responsibility. This theme was revealed by the interviews with architects in particular. Architects discussed their personal struggles with designing with ecological responsibly or designing for the client, which is a tradeoff that many seek to resolve.

> It's my duty as an architect, it's my choice- it's no choice- it's something I always think about. I have the ability to make a difference and I can't understand why architects *don't.* They're wrapped up in aesthetics about craft- but to understand the mechanisms is more (Noble, 2008).

This claim about mechanisms can also be translated from the engineering sense to the societal sense, or understanding how decisions are made. An interview with a Japanese sustainable systems engineer revealed that misinformation can begin with the process itself: the client is usually the government, and the school principal is merely invited to attend the decisive meetings. He concurs with the above claim that an extremely proactive principal is necessary for successful eco-school construction: “the keen principals do not accept the given situation- they know how to change the education but not the [government] system” (Yashiro, 2008).

In purely user-centered design, architects are an instrument in the realization of the building, an interpreter between the client’s functional needs/expectations and client’s built reality. However, to what degree do the architect’s intents manifest themselves in buildings? While this is too complex a question to address in this study, it is important to note that the role of green designers does not exist without demand. In other words, an architect cannot “put on a cape and tights and save the world” (Coynes-Jensen, 2008). Architects with grand societal agendas cannot work apart from the public, or beyond the influences of members of government or academia. It is not enough to build one brilliant case study and collect on fame and glory. Movements are built on ambitions of masses. In order to transition to *deep* green thinking, designers are attempting to persuade people that they need less, because they can design with less, and people can survive and thrive with less. Essentially, the individualistic American dream of living in excess must be reversed. Such unpopular notions are met with cynicism from within and of the design field: “anyone thinking about sustainability must come to terms with their own mortality” (Coynes-Jensen, 2008).

An eco-school, unlike a merely green school, has educative building components that tie the green design into the curriculum. Displays designed specifically for child-accessibility of environmental principles are qualifications of eco-schools in this study. “No one respects what they do not understand,” said Noble, reiterating his earlier point about the importance of revealing mechanisms. However, the effectiveness of designs and interventions is difficult to measure in children because oftentimes the effects are delayed and are not realized for years. Designers expressed in interviews that rewarding consequences of purposeful architecture are not visible until later on: “[A green school] is an indirect investment, and the children will have a never-ending awareness…children's education is the biggest investment you can do, [comparatively] the costs are very low" (Overtoom, 2008). The quote reminds us that the beneficial impacts of eco-schools, though distant, significantly outweigh the initial costs. However, there was also opposition to the notion that buildings can directly teach occupants.

> It's naïve to think that a building can do that. It's not the building, it's person to person interaction. Buildings can act as a signpost, an image...trying to show who they are. Especially for primary schools, it's what the teachers and what the children *are told* that make the difference (Kristensen, 2008).

In this interview, the architect denied that the physical structure has any role in changing attitudes, but rather, suggests that the people within determine the building's meaning.

**Summary of Lessons Learned from Interviews**

Across all 12 people interviewed in five countries, Netherlands, England, Germany, Denmark, Japan, four themes emerged regarding the eco-school movement:

1. There is more financial support (e.g. government incentives) for active systems (e.g. photovoltaic array) than passive systems (e.g. thermal mass) because the school becomes more marketable with visibly green systems. There are fewer incentives (e.g. promising lower operating costs and green building certification) for architects just to design responsibly (e.g. simple passive strategies).
2. "Green" has now become a marketing term applied to many products, including buildings, and we must seek out those that protect or revive the environment from those that only *reduce their harm.*
3. Eco-school development is facilitated by federal standards that pressure local governments to renovate or upgrade. In countries that have more rigorous building standards and more ambitious goals set by leaders, more schools are applying for government incentives.
4. The excitement is on new schools with flashy technology, which attracts media and public attention, but practically, the focus needs to be on renovation projects.

Generally speaking, eco-school construction requires a member of the community with influence at the municipal level to garner support from school board members and parents. If the school is public, then opportunities for additional financial incentives from the government must be investigated, as money is typically the number one barrier to green design. Hiring an architect and contractor with the skills to carry out these green initiatives is becoming easier because of society's overall trend towards more sustainable practices.

The findings of this study suggest that the school's success is not solely defined in terms of energy efficiency, monetary savings, economy of materials, or occupant health or performance, but rather in its ability to translate environmental systems to its students. The desired outcome is a conscious behavior change, such as a demand reduction, due to a whole-systems understanding of natural processes facilitated by deliberate design intentions of building technology.

**Specific Aim 2. What are contemporary exemplars of eco-school architecture and activities?**

In this section brief case studies are presented of the four eco-schools examined, which is then followed by a summary of eco-school features.

*Case Study 1*: Kingsmead Primary School
*School Location*: Northwich, England
*Architect*: David Noble, White Design
*Firm Location*: Bristol, England
*Area*: 1 story (14,057 sq ft)
*Completed*: July 2004
*Serves*: 210 students in K-6 grades

*Figure 3: Kingsmead Primary School's winter garden and inverted roof. (Photo credit White Design)*

**Community**

The rural town of Northwich (pop. 19,259 in 2001) is about an hour by local train from metropolitan Manchester. Northwich is known for producing salt, and has a large working class population. Although Northwich is not known for any famous architecture or progressive social movements, Kingsmead Primary School is the first green school in the area, and considered by many to be a flagship school for the region.

*Figure 4: Kingsmead student describes color-coded building systems in front of rainwater collection tube in lobby.*

**Concept Development**

Cheshire County Council's (CCC) mission to create an exemplar sustainable community began in the 1990s, but did not take off until the eco-school ideation of Kingsmead in 2001. According to the Head of Property Strategy from CCC, both the architect's experience in green design and a capital grant as part of the 'Teaching Environments for the Future Programme' through the UK Department of Children, Schools & Families, were key to its success as both a low-energy school and teaching tool (Bate, 2008). Because of the long waitlist and popularity of Kingsmead, more eco-schools are nearing completion in the area. The primary goal of CCC at the time was to create a 21st century facility that would "inspire children to learn about and love the environment" (Bate, 2004). Fostering attachment or delight in a school building is reflected in a statement about material selection by the architect, "No one ever hugs a steel beam - the wood beams are something beautiful" (Noble, 2008).


*Figure 5: Kingsmead student points out how much water has been collected so far that year.*

**Green Design Features**

1. Sun. Extensive daylighting strategies in north-facing classrooms employ skylights on solar sensors and clerestories. Additionally, classroom luminaires are fitted with daylight sensors that automatically dim the artificial lighting when daylight is sufficient. On the roof, a small photovoltaic array is meant primarily for display purposes- it only provides 15% of the electricity demand. The solar hot water heaters provide between 20-30% of the hot water demand. By collecting solar gain, unheated glazed "winter gardens" help buffer the classroom from outdoor temperatures, and are utilized as mud rooms for each classroom.

2. Water & Display. The form of the structure is called a "butterfly roof" because the roof ridge is inverted, like wings. This serves to harvest rainwater and also provides overhang for shading. These structural timbers were sustainably harvested from Denmark, and are typically used for local salt storage facilities. Three clear rainwater catchment tubes run through the school to the underground storage tanks, which then route the greywater to toilets. All the while, the students can monitor water consumption and collection on the child-friendly display. Color-coded pipes and wires allow students to see the complex building systems working together. In addition, the site was designed to manage water runoff and promote walking around the nature path, which includes recycled tire walkways, a pond, and willow enclaves.

3. Wind. Kingsmead's clerestories automatically open when carbon dioxide levels reach undesirable levels. This enables hot air to rise and exhaust at the top of the building, creating natural ventilation. Hybrid windows can be manually operated to individually control temperature.

4. Earth. Concrete block work acts as thermal mass and slowly releases collected solar gain throughout the day. Behind the school, a biomass boiler, which burns wood pellets made from waste timber from a local factory, provides the main source of heat for the school. At the time of the visit, there was technical difficulty with integrating the biomass boilers with the main system.

*Figure 6: Kingsmead students get a hot lunch with produce from the school garden.*

**Green Activities**

As each student enters a new grade, he or she makes a sustainability pledge and hangs it on a long banner across the corridors. Classes also compete for the weekly green flag award, which is given to the class with the largest percentage of students coming to school without a car. “Walk to School Week” is a further incentive. During lunchtime, students learn how to calculate “food miles” or the embodied energy of the growth, harvesting, processing, packaging, and distribution of their food items. In addition, the school garden, maintained primarily by students, produces potatoes and vegetables used in cafeteria. Students learn of the cycle of organic materials through cafeteria composting and a wormery.

*Figure 7: The Kingsmead wormery.*

The maintenance staff also participates in lowering energy demands by switching transformers to standby when not in use so as not to draw power, often called “vampire loads.” Even the toilet paper is a learning tool: it is supplied in sheets rather than rolls so that students use less and are conscious of how many squares they take. With regular maintenance, the building is expected to last 65 years (15 years longer than average buildings).

*Case Study 2*: Daltonbasisschool Columbus
*School Location*: Heerhugowaard, Netherlands
*Architect*: Dorte Kristensen, Atelier Pro
*Firm Location*: Den Haag, Netherlands
*Area*: 3 stories (32,507 sq ft)
*Completed*: 2007
*Serves*: 280 students in Pre-K-6 grades

*Figure 8: View from the grass hill left over from construction. Note the exterior shading. (Photo credit Stef van Wickeren)*

**Community**

Heerhugowaard (pop. 49,833 in 2007) is known as the "Sun city" in the Netherlands, and many of the surrounding houses have photovoltaic panels installed on their roofs. The city's renewable energy initiative is very visible to passersby.

**Concept Development**

The Dalton School follows an approach to education developed by Helen Parkhurst, a friend of Maria Montessori. Like a Montessori school, it has specific objectives that guide the curriculum and activities. It also informs the built environment of occupant needs and affordances the space should provide. While the Dalton principles are more about exploration and cooperation, Columbus' principal has shaped them to encompass ecological issues: including exploring the earth oneself, and taking responsibility for the environment. He believes that the building fits with these concepts and has developed activities to incorporate them. However, the building is somewhat out of touch with the school objectives. The modern feel and complete automation of

*Figure 9: South facing facade-integrated photovoltaic cells. (Photo credit Atelier Pro)*

*Figure 10: Lack of site irrigation can result in a more natural playscape.(Photo credit Stef van Wickeren)*

building systems does not encourage student exploration or responsibility. This user-designer gap may be attributed to the architect who is not known for green design, nor is she supportive of the idea that the building should be used as a teaching tool. “It’s much more important for teachers and parents to communicate their environmental focus, rather than the school building” (Kristensen, 2008).

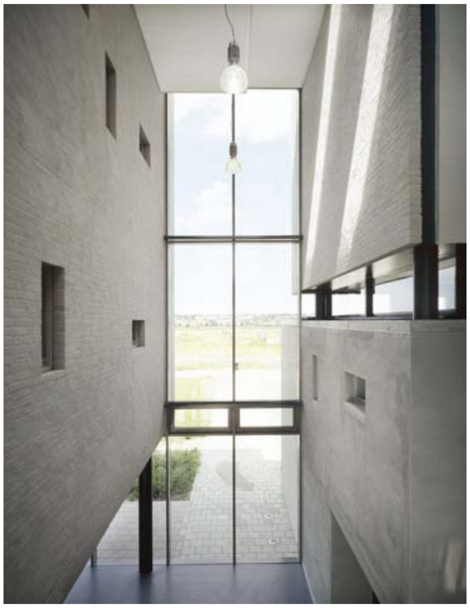

*Figure 12: Daylighting of the atrium at Columbus. (Photo credit Atelier Pro)*

### Green Design Features

In terms of “dark green” intentions defined earlier, this school is least sensitive to the site and opportunities that a supportive green community could have provided. It’s systems, form, and (lack of) landscaping or irrigation suggest that the green features were an afterthought, pulled from a list of established, cost-effective practices, and applied to the project. This may explain why Columbus is not attracting international media or seeking eco-school recognition. The most unique and remarkable feature of this building is the façade-integrated photovoltaics, which create an ephemeral grid pattern on the floors. Additionally, the radiant floor heating allows children to walk around in socked feet, which reduces noise levels and creates an atmosphere much like a home. The school was at the time of the tour, acquiring federal funding for a lobby display system that would show the electricity, gas, and water consumption, as well as solar generation of the building. Horizontal exterior shading devices above windows protect the façade from unwanted heat gain, but daylighting strategies appear to be more of an art form than functional.

*Figure 11: Children play with natural objects they find outside. (Photo credit Stef van Wickeren)*

### Green Activities

This school is essentially a green school rather than an eco-school. All of the building's systems are automated (e.g. no switches for toilets or lights) and there is virtually no didactic interaction between the building and the students. Green activities are limited to off-site field trips to animal farms and nature parks. However, in observation, there were opportunities for children to create their own natural playscapes due to the lack of playground equipment and survival of a large dirt hill that had been leftover from the construction of the school. The intentions of principal van Wickeren may shape the school into an eco-school later on however. He expressed plans for a curriculum with more connection to nature, "[The students] should be able to explore the earth themselves and ask, 'how do we get along here?'" (van Wickeren, 2008).

*Case Study 3*: De Sokkerwei

*School Location*: Castricum, Netherlands

*Architect*: Marten Overtoom, BBHD Architects

*Firm Location*: Schagen, Netherlands

*Area*: 2 stories (17,975 sq ft)

*Completed*: 2000

*Serves*: 260 students in K-8 grades

*Figure 13: Sokkerwei's rainwater collection. (Photo credit BBHD Architecten)*

**Community**

Castricum (pop. 34,830 in 2007) is a tourist community north of Amsterdam. On the city's website,[13] one can find information on how the municipality considers sustainability a high priority across all sectors- business, education, management, and residences. City-wide composting, energy audits, and other resources are available in Castricum that are not typical in all Dutch regions. The researcher assumes that these green initiatives are correlated to the founding of the first eco-school in the Netherlands.

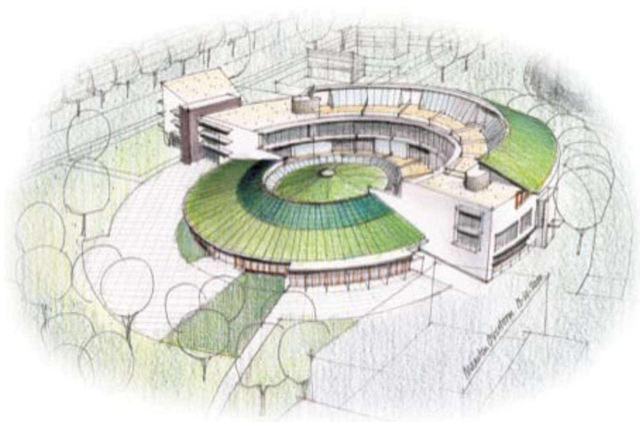

*Figure 14: Conceptual drawing of Sokkerwei and housing units. (Marten Overtoom)*

**Concept Development**

In a national magazine published by the ministry of education they called De Sokkerwei "The greenest and most affordable school of The Netherlands." Its ideation and design process has been thoroughly documented by Hans Van Weenen, a parent of a student in the school system in 1999. His expertise in sustainable building technology, his ability to communicate as a professor, his membership on the school board, and his role as a parent were significant factors in the origination of Sokkerwei. In his article 'Dutch sustainable building policy and practice: Sustainable Schools,' Van Weenen discusses Dutch sustainable building

[13] Translated from Dutch using Google Translate Webpage feature

policy at the time, financial challenges, and the final push towards zero-energy. Interestingly, the objectives weren't only in terms of the energy savings, but also creating a community: "the original idea was to build at the Sokkerwei location a combined school and after school care centre, with apartment buildings on top, integrated with a practice of two family doctors, a dentist practice, 7 residences and 2 pond dwellings."

*Figure 15: Sedum roof and skylights of Sokkerwei. (Photo credit BBHD Architecten)*

**Green Design Features**

Sokkerwei is an incredible school on paper, boasting almost every kind of green consideration possible. However upon arrival, these features aren't readily apparent. This is because many of the systems employed are passive. Insulation, locally certified wood finishes, and natural ventilation aren't publicized in this area, but expected. Health and cleanliness considerations go as far as specifying white boards rather than chalkboards to reduce asthma rates. High frequency lights, which flicker faster than the eye can detect, and occupancy sensors in the bathrooms reduce energy consumption. Sustainable materials such as linoleum made of cork, jute, and linseed oil were used because of their low-embodied energy, but also because they do not off gas harmful chemicals into the air.  On the roof, the sedum plants acts as a thermal buffer, while the photovoltaic array generates electricity for the students to monitor the rate and total production. Trees around the schoolyard are also positioned to shade in the summer. In the winter, when the leaves are gone, the tree allows light to penetrate the building and passively heat it. "Wood is playful and not too damaging to the natural environment. It's visually and tactically pleasing, including the smell" (Overtoom, 2008).

### Green Activities

Parents are asked to invest 50 Euros in a wind farm during the time their child is at Sokkerwei. Upon graduating from the school, the money is returned with "wind interest." Students usually lead building tours for visitors, as it is their duty to know how their environment works. Classes regularly go on field trips to waste management sites and are encouraged to explore positive new green technologies. The principal does not believe in teaching the concept of scarcity to children: "it's not for children to think they're spoiling the environment" (Van Leeuwen, 2008). Rather he chooses to focus their attention to greener alternative means. The researcher had the impression that this school was driven by monetary incentives and goals- the principal reiterated that to achieve zero-energy, they compensate through wind certificates, and the money saved in reducing energy demands with higher efficiency products he allocates to books and more teaching hours.

*Case Study 4*: Shinanodai Shogakko

*School Location*: Seto, Japan

*Architect*: Nikken Sekkei

*Firm Location*: Tokyo, Japan

*Completed*: 2001

*Area*: 1 story (60,810 sq ft)

*Serves*: 130 students in 1st-6th grades

*Figure 16: Direct solar gain and daylighting at Shinanodai.*

**Community**

Seto (pop. 133,412 as of 2009) is a very rural town in the hills of Gifu, known for ancient pottery techniques. The population is decreasing, yet the government had to build a new school because the existing elementary was planned for demolition to make way for a bypass. Nearly everyone walks or rides bikes for transport within community.

*Figure 17: Skylights and roof monitors with south-facing photovoltaic arrays and clerestories.*


*Figure 18: Classroom daylighting, interior shading, facade-parallel artificial lighting.*

**Concept Development**

This eco-school project was initiated by government officials who had decided in the mid to late 1990s that Seto would become "Eco." When asked about the experimental nature of the project, Tokyo University professor, Tomonari Yashiro who had also visited the school, replied that Shinanodai is one case of approximately 20-30 schools in many different prefectures that got federal funding for green school initiatives in 1995. "The local ministries are much more integrated because of weak leadership," he responded. Politically, all parties are supportive of green design, but the myth of higher investment deters many from pursuing this avenue.

**Green Design Features**

1. Sun. This large open plan school uses a series of roof monitors to create north-facing clerestories and a surface for south-facing photovoltaic arrays. Indirect natural light from the north allows the entire building to be daylit most of the time without the unnecessary thermal gain. When needed, fluorescent lighting on dimmable ballasts provide additional light in classrooms, which are parallel to the facade. This is particularly important because the banks of lights can be controlled in accordance with the natural light.

*Figure 19: Automated skylights in the library.*

2. Water. Rainwater is collected in the pool to flush toilets, and according to a *Kids Web Japan,* maintained by the Ministry of Foreign Affairs, this water is also treated to become potable water.[14] This outdoor water storage was also designed to be available for extinguishing a fire.

3. Wind. Natural ventilation is achieved via clerestories and operable windows.

4. Earth. Manually operated, zoned radiant floor heating saves energy because the entire floor acts an enormous thermal mass, and areas can be individually controlled while in use. The building is *not* set on a thermostat, rather, the Vice Principal revealed that he adjusts the temperature throughout the day according to class schedules. It also allows children to utilize the carpeted floor more, which is a custom in Japanese homes. Students are expected to change from their outdoor shoes to slippers at the entrance. This practice also encourages floor use while providing the entire school with a healthier environment. Also at the entrance is an exhibit *specifically for visitors* about the energy savings of the school and how the radiant floor heating works. The architect deemed this was necessary for professionals and community members interested in the building, but the language indicated that it was not for the students' understanding. This is an example of a missed opportunity for children to their engage in their surroundings. However the Vice Principal showed us onto the roof, where there was a special display of solar panels at

[14] Not discussed during the researcher's visit.

child-height for the students to touch. He said that the pupils are taught about solar income and electricity generation, but not in terms of *monetary savings.* Solar hot water heaters are also mounted above the kitchen, which provide hot water for cafeteria use.

### Green Activities

Students are taught to separate the waste materials when they are finished with lunch. Among other materials, milk cartons are recycled and leftover food is composted. Though this is an open plan school, each classroom is situated in a nook, with its own egress to the outdoors and the class garden, where cabbage and radishes grow. Students are also responsible for maintaining a communal rice paddy on site, an ancient practice that many small rural communities in Japan still rely on today. This is a labor-intensive operation, but yields many of the common rice-based staples in the Japanese diet, including *mochi*, or pounded rice cake. After seven months, students are able to use the rice grown in their field to make *mochi*.

*Figure 18: Exterior of gymnasium with light diffusing glazing.*

*Figure 19: Interior of gymnasium, 100% daylit.*

*Case Study 5*: Fuji Youchien[15]

*School Location*: Tachikawa, Tokyo, Japan

*Architect*: Tezuka Architects

*Completed*: 2007

*Area*: 1 story (11,775 sq ft)

*Serves*: 560 Kindergarteners

*Figure 20: Tea bushes delineate the cafeteria (separate building, left) and the main school (right).*

**Community**

Tachikawa (pop. 174,605 in 2004) is an urban community near Tokyo. It is not known for any particular green movement or progressive attitude. However upon visiting the area, some subtle green design features stood out. For instance, trees along the sidewalk were identified with placards, sewer covers were decorated with natural motifs, and fountains led to small wading pools around parks.

*Figure 21: Child-height fountain in Fuji Youchien's vicinity.*

**Concept Development**

This school design was a creation of the principal, whose father had founded the original Fuji Kindergarten. The new school was necessary because of poor condition of the existing building and the opportunity for expansion. With the help of an artistic director and inspiration from Germany, the principal was able to create a built environment that promoted a Montessori learning method. Sekiichi Kato believes that children need to explore, touch, play, and feel things to understand them. The low-tech school emphasizes cooperation and nearness to nature, symbolized by the trees that grow through the classrooms.

[15] Fuji Kindergarten is a private school unlike the other schools in this study, and is not considered an eco-school. However, it is included in the case study report because the purpose of this school, and some of its features, can be attributed to the "deep green thinking."

### Green Design Features

Kato does not consider Fuji Youchien a green school. In fact, he says they don't make too much of an effort to be “eco,” the overused term for conserving energy. Rather, in a nostalgic tone, he expressed that he would like to see children grow in congruence with nature, something he called *ki no nagare*, roughly translated as the flow of trees: a self-sufficient, technology-free lifestyle. He tells the story of how the four-year-olds approach the faucets in the schoolyard and wait for the non-existent sensors to turn on the water. He is afraid that future generations are losing cognitive abilities, such as hand-eye coordination and understanding of interconnectivity. To reverse what our modern technology-dependency has caused, Kato is prepared to teach children the processes and community of living things. He has refused fancy technology that some have suggested can help his cause. “I don't want anything luxurious,” he remarks, as he pulls the chain on one of the exposed incandescent light bulbs that speckle the ceiling. Even the lights are a learning tool: when they’re off (which they frequently are because of the daylighting) children can see right to the filament. Skylights are scattered across the roof and give children a new perspective on their classroom.

The open plan school is so unique in that the spaces are very flexible: teachers can move their classroom space according to the position of the sun. Much of the furniture was reused from the old building, and all of it is made from pine. Both the fully glazed inner and outer walls are removable- they slide alongside so that eventually the entire school can be open to the weather, which results in extreme cross ventilation. The principal reported that they rarely use the mechanical heating system.

The wooden decked roofscape doubles the play space and allows children to climb and explore ancient trees’ leaves at eyelevel. The slight incline of the roof also resembles a racetrack, which encourages kids to run around the circular deck (which they do.) The only constructed play equipment is a slide from the roof to the ground level. Everything else available for play has real world functions, such as chestnuts in a basket or rainwater, which is not contained in a downspout, but allowed to drain off the roof like a waterfall.

**Green Activities**

Visible from the roof is a nearby radish farm, which the children visit and tend to radishes. Ducks, chickens, rabbits and turtles have a home on-site, but are not fenced in. Keeping with the intention to foster a communal, cooperative atmosphere, parents and grandparents are welcome to eat lunch with their child.

*Figure 22: Radishes from the neighboring farm are used in the cafeteria.*

*Figure 23: A tree grows through the classroom.*

**Summary of Eco-School Features**

Table 1 provides an overview of the green features found at the four schools in this study. The 24 features observed are categorized by sun, water, wind, earth, and display. Table 2 compares 9 environmental activities found at each of the four schools.

*Table 1: Summary of Eco- School Strategies of Four Schools at which Surveys were Administered*

| Eco- School Strategies | Schools | | | |
|---|---|---|---|---|
| | Kingsmead | Columbus | Sokkerwei | Shinanodai |
| SUN | | | | |
| Daylighting | X | X | X | X |
| Automated Light/Occupant Sensors | X | X | X | X |
| Photovoltaics | X | X | X | X |
| Solar Hot Water Heater | X | | | X |
| Exterior Shading | | X | | X |
| Passive Solar Heating | X | | X | X |
| WATER | | | | |
| Lo-flow fixtures | | X | | |
| Rainwater Collection | X | | X | X |
| Greywater Treatment | | | | |
| Landscaping & Site Irrigation | X | | X | X |
| WIND | | | | |
| Natural Ventilation | X | | X | |
| Operable Windows | X | | X | X |
| Wind Breaks | X | | | X |
| Air Quality Monitors/ sensors | X | X | | |
| Off-site Renewable Energy | | | X | |
| EARTH | | | | |
| Biomimicry | | | X | |
| Renewable Materials | X | | X | |
| Thermal Mass | X | | X | |
| Biomass Fuel | X | | | |
| Composting & Gardening | X | X | X | X |
| Vegetative Roofs & Facades | | | X | |
| Zoned Radiant Floor Heating | | X | | X |
| DISPLAY | | | | |
| Solar Generation/Consumption | X | X | X | X |
| Rainwater Collection | X | | | |
| TOTAL | 18 | 9 | 16 | 13 |

Sun. Across all five schools visited and studied photovoltaic panels were the most common roof covering for various reasons, including the visibility, potential for offsetting operating costs, use in shading, energy display opportunity, and school image. For these reasons, this active system is more popular than for instance, a green roof, which could have latent effects arguably closer to the goal of connecting children with nature.

Daylighting is a requirement for green school qualification; as mentioned above, the orientation of a building affects so many other building systems that ignoring this strategy is simply careless. Managing daylight can: increase solar gain, which lowers heating loads in the winter; shade the building in the summer, lowering cooling demands; increase the amount of natural light on work surfaces, which lowers the artificial lighting demand; provide a source of renewable energy; and increase occupant's performance. All these consequences of designing with regard to the sun can save money. All schools visited were mostly naturally lit, and had systems in place to harvest the power of the sun.

Water. Rainwater collection is another opportunity to bring nature closer to children. Whether it is the visual excitement of moving parts or the functionality of rerouting water to toilets or ponds, rainwater collection serves as a tangible exhibit for demonstrating the water cycle. While rainwater harvesting is considered an active system, it is relatively low-tech. Pumps and treatment processes are not out of reach for a typical maintenance staff. It can eliminate the need for gutters and downspouts, like at Kingsmead, but it also be a creative way to mimic nature, such as the waterfall system at Fuji Youchien.

Wind. Natural ventilation is a common strategy is many eco-schools because it is a relatively low cost strategy that can reduce energy demands of mechanical systems. Two types of natural ventilation are most common: *stack*- which utilizes clerestories and the principle that hot air rises, or *cross*- which considers prevailing winds and narrower building plans.

Earth. Most common activities at eco-schools are gardening and cafeteria composting. Not only are school gardens a way to freshen and enrich the cafeteria menu, but tending to plants also stimulates a sense of responsibility in children. By showing students how their lunch waste becomes food for other organisms and ultimately themselves is another step to fostering whole-systems thinking.

Displays & Occupant Involvement. Many components of green schools require not only more skilled maintenance, but also regular manual operation (e.g. interior blinds). With this trend towards high-tech active systems, comes more automated operations, such as shading devices that can track the sun, automated opening/closure of clerestories for ventilation, or daylight sensors that will dim the artificial light to maintain a constant light level. But in terms of eco-schools, we must ask, do students still learn from automated operations and or rely on sensors to do the job? This is a question addressed by the Japanese principal of Fuji Youchien, who incorporates faucet activities into his Montessori school. He fears that children in Japan are too reliant on sensors and are losing hand-eye coordination. Therefore interactive displays and child-accessible exhibits of green features may be essential to their understanding of building-environment relations.

*Table 2: Summary of Eco-School Activities of Four Schools at which Surveys were Administered*

| Eco- School Activities | Schools | | | |
|---|---|---|---|---|
| | Kingsmead | Columbus | Sokkerwei | Shinanodai |
| Sustainability Pledge | X | | | |
| Green School Award | X | | X | X |
| Advocate Alternative Transport | X | | X | X |
| Lunchbox Mileage | X | | X | |
| Student Gardening | X | X | X | X |
| Utilization of Building Displays in Curriculum | X | | | |
| Green Products & Supplies | X | | X | |
| Eco-oriented Field Trips | X | X | X | X |
| Student-led Building Tours | X | | X | |
| TOTAL | 9 | 2 | 7 | 4 |

Composting and gardening were the most prevalent activities at eco-schools because of the potential for student involvement outdoors and closed-loop connections: lunch waste turns to soil which becomes food for produce which is used in lunch. Field trips are also a common activity at eco-schools because many of the principles learned in the classroom can be applied in real working settings. A hands-on pedagogy demands that students are able to see, touch, and understand how processes work, many of which are not located at school.

**Specific Aim 3. Can eco-schools influence a child's way of thinking in different ways than traditional schools in terms of environmental attitudes?**

To answer this question, I documented the green technologies of the schools and compared this information with the results of a children's environmental attitudes scale (Musser & Malkus, 2004). In this section, results of the environmental attitudes survey will first be summarized. Second, associations between eco-school features and environmental attitudes will be examined.

## Environmental Attitudes Summary

Total Environmental Attitudes scores of 72 students surveyed across all schools in all countries ranged from 39 to 106, with a mean of 84.43, and standard deviation of 12.44. The lowest possible score was 28, and the highest was 112. As shown in Table 3, across the four schools the mean only varied by 3 points, with Columbus (86.43) scoring the highest, Sokkerwei next (84.29), Shinanodai (83.72), and finally Kingsmead slightly lower (83.27). Interestingly, Kingsmead, with the largest sample size also had the greatest variance.

### Category Areas: Belief, Behavior, Affect

The total Environmental Attitudes scores can be further analyzed by examining the three subscales. Table 3 shows the mean scores and standard deviations by school for belief (9 items) (e.g. *Some kids think we should build more landfills to hold our garbage*), behavior (9 items) (e.g. *Some kids turn off the lights when they leave*), and affect (10 items) (e.g. *Some kids worry about air pollution*). The pattern of the subscale scores mirrors the total attitude scores with Columbus consistently highest, followed by Sokkerwei, Shinanodai and then Kingsmead.

*Table 3: Environmental Attitudes total score and subscales, by school (mean (sd))*

| | | Subscales | | |
|---|---|---|---|---|
| | Total Environmental Attitudes (28 items) | Belief (9 items) | Behavior (9 items) | Affect (10 items) |
| Kingsmead | 83.27 (14.52) | 2.88 (.59) | 3.01(.55) | 3.39 (.60) |
| Columbus | 86.43 (13.18) | 3.30 (.45) | 3.28(.29) | 3.72 (.26) |
| Sokkerwei | 84.29 (9.29) | 2.97 (.35) | 3.10(.39) | 3.48 (.49) |
| Shinanodai | 83.72 (11.87) | 2.93 (.25) | 3.21(.21) | 3.46 (.28) |
| Total | 84.43 (1.39) | 3.02 (.19) | 3.15(.16) | 3.51 (.14) |

*In increments of one, 1 was the lowest environmental score, and 4 was the highest.

**Content Areas: Conservation, Recycling, Animal Rights, Nature, Pollution**

The same 28 item scale can be broken down by subject area: conservation (8 items), recycling (3 items), animal rights (7 items), nature appreciation (5 items), and pollution (5 items). The means and standard deviations for each of these areas by school are presented in Table 4. These subscales did not reflect patterns in overall environmental attitude scores across schools. Most noticeably, Shinanodai scored highest in recycling with the least variability, but significantly lower on animal rights. Kingsmead did not score highest in any of the subject areas.

*Table 4: Mean environmental attitude content subscales by school (mean (sd))*

| | Conservation (8 items) | Recycling (3 items) | Animal Rights (7 items) | Nature Appreciation (5 items) | Pollution (5 items) |
|---|---|---|---|---|---|
| Kingsmead | 2.67 (.30) | 3.01 (.86) | 3.22 (.56) | 2.79 (.61) | 2.94 (.65) |
| Columbus | 2.70 (.28) | 2.89 (.69) | 3.55 (.27) | 3.38 (.21) | 3.00 (.68) |
| Sokkerwei | 2.67 (.26) | 2.88 (.63) | 3.42 (.34) | 2.92 (.52) | 3.09 (.37) |
| Shinanodai | 2.52 (.25) | 3.35 (.34) | 2.93 (.23) | 3.15 (.41) | 2.89 (.30) |
| Total Average | 2.64 (.08) | 3.03 (.22) | 3.28 (.28) | 3.06 (.26) | 2.98 (.09) |

## Green School Features' Relation to Environmental Attitude

In this section, we focus more explicitly on specific aim #3 by examining the relation between eco school characteristics and children's environmental attitudes.

*Table 5: Green Features Compared to Surveys Collected and Average Environmental Score by School*

| | # of Green Design Features | # Surveys | Grade | Average Environmental Score |
|---|---|---|---|---|
| Kingsmead | 18 | 30 | 6 | 83.27 (14.52) |
| Columbus | 9 | 7 | 3 | 86.43 (13.18) |
| Sokkerwei | 16 | 17 | 3-7 | 84.29 (9.29) |
| Shinanodai | 13 | 18 | 6 | 83.72 (11.87) |
| Total Average | 14.00 (3.92) | 18.00(9.42) | 5 | 84.43 (1.39) |

As shown in Table 5, the mean environmental attitude scores for the four schools were quite similar: 83.27, 86.43, 84.29, 83.72, respectively for Kingsmead, Columbus, Sokkerwei, and Shinanodai. A negative correlation emerges between the number of green design features and average environmental score: Kingsmead with the highest number of features (18) had the lowest average environmental score (83.27) whereas Columbus, with the fewest number of features (9) had the highest average environmental score (86.43). To assess whether environmental attitudes at the four schools differed significantly from one another, analysis of variance (ANOVA) tests were completed. Findings indicate no statistically significant difference between schools ($F(3,68)=.124$, $p=.945$).

In terms of environmental attitude subscales, no difference between schools was found for beliefs ($F(3,63)=1.37$ $p=.26$), behavior ($F(3,64)=1.07$, $p=.37$) or affect ($F(3,60)=.538$, $p=.66$). Means were also compared with respect to the content areas: conservation, recycling, animal rights, nature appreciation, and pollution. ANOVAs indicated no differences with respect to conservation ($F(3,62)=1.3$, $p=.29$, recycling ($F(3,66)=1.54$, $p=.21$), $p=.28$), nature appreciation ($F(3,61)=2.52$, $p=.07$), or pollution ($F(3,61)=.45$, $p=.72$). There was statistical significance in the variance of animal rights ($F(3,65)=5.11$, $p=.03$). Further statistical analysis with a Tukey test showed that Shinanodai (Japan) had consistently lower scores than both Dutch schools Sokkerwei and Columbus.

# Discussion

In this section, the findings regarding each of the three specific aims will be discussed.

## Contributions of this Study

**Aim 1: (a) What factors aid eco-school development, and (b) in what kind of social contexts this occurs?**

From this study, we may conclude that more progressive areas, meaning more federal and municipal incentives available for green school initiatives, result in more green schools. There also must be a necessity for a new school, such as a population increase, or severe dilapidation of the existing facility. The willingness to invest in sensible, environmentally friendly designs is affected by the intentions of the architect, the level of activism of the principal, and any other highly influential community members, such as a parent. All of these factors tie into a serious devotion to long-term, big-picture type of environmentalism, which we have defined in this report as "deep-green thinking." One if not all of these contributors must believe that the school is not only a beacon of sustainability, but also prevent the project from falling victim to *greenwashing*. Therefore green schools are not enough for real community-wide changes that these activists seek- the curriculum component is the critical part of the transformation to eco-schools. Green buildings do not produce greener students, but facilitate a greener curriculum. Full building automation and lack of system awareness is essentially a monetary benefit for the administration and an educational loss for students (e.g. Thomas L. Wells in Toronto, mentioned in Literature Review).

**Aim 2: What are contemporary exemplars of eco-school architecture and activities?**

The study compiles international examples of eco-school development to provide insight into some of the obstacles and catalysts of green development in other countries. This document also includes an enumeration of common green school building strategies, ways to increase occupant awareness of these systems, and a summary of modes to cultivate whole-systems thinking. By recounting the stories of new eco-school projects, architects, municipal leaders, parents, and school board members alike will have more information to actuate others in their community.

From the case studies, we can conclude that eco-schools are most constructive when they consist of an integrative environmental curriculum, green school features with student-accessible displays, and provide opportunities for discovery. The curriculum must focus on environmental issues across the disciplines and must be reflected in school policies. The summary of environmental activities outlines some successful programs at eco-schools, most notably, outdoor involvement. Students work outside may gain an understanding of their local environmental constraints and affordances, and may benefit physically and mentally by spending more time in nature. Specifically, school gardens with produce that is used in the cafeteria were most common, then monitoring energy consumption and generation panels, and finally engaging in field trips around the local natural areas.

**Aim 3: Can eco-schools influence a child's way of thinking in different ways than traditional schools, in terms of environmental attitudes?**

None of the national reports (Kats, 2006; Mogensen, et. al., 2005; NRCNA, 2006) on environmental education (EE) address the importance of accessible architecture in the framework of EE, but rather on the approaches to teaching the current ecological crisis. While green schools can be a tool for environmental education, the building as a classroom instrument in lesson plans has not been studied for any specific results. There have been some reports of the trends and theories of innovative new ways to teach EE through buildings, however actual data on environmental attitudes of occupants has not been collected. This study is one of few that have examined the possible positive developmental effects from the built environment.

The hypothesis was that a higher number of green school features would be associated with a higher overall environmental attitude score. However, this was not the case in the analysis of the data from these four schools. The correlation was negative: a higher number of green school features was associated with a lower environmental attitude score. Factors that may have influenced this relationship include mediators such as student accessibility of building systems, number, placement, and integration of display features, and intensity of environmental focus of curriculum, which were not measured. However, we may be able to presume that the differences in average environmental attitude score were not statistically significant across schools or countries because the study only surveyed 4 schools, and all of which were eco-schools. In comparison with a study across 12 US schools and 274 children participating in a water festival,  the pre-test mean was 71.4 (9.1) and the post-test was 75.1 (10.6), compared to the total mean of the present eco-school study, 84.43 (1.39) (Kim, Zehman, & Kostareva, 2007). Despite many variables in the international eco-school study, (gender, age, country, school, population density, curricula, socio-economic status, and number of green features at school) environmental attitudes were high and similar across schools. Further clarification regarding research design, threats to validity, and applicability are discussed below in *Limitations of the Study* and *Future Research.*

## Relevance to Previous Studies

### Aim 1: Development & Social Contexts of Eco-Schools

From the government officials' perspective, this study has shown that one of the main obstacles in new eco-school construction is perceived cost. In previous studies (Kats, 2006; USGBC, 2008) however, cost/benefit analyses have shown that a higher cost is a myth. Operating costs are so much lower that the payback is within ten years, and the future savings can be reallocated to directly benefit students, which is documented by Van Leeuwen (2008) as the heart of the Sokkerwei concept. A Tokyo University professor, German Eco-school coordinator, and the mayor of San Francisco have refuted the argument that green schools cost more (Yashiro, 2008; Lorenz, 2008; Newsom, 2009). An Australian principal continues the sentiment that monetary issues should not be a barrier to green design: he has worked with the PTA to fundraise for greener features and is finding low-tech ways to retrofit his school in a grassroots way. He adds, "curriculum [change] costs nothing- the time for teachers planning is included in the budget" (Best, 2008). The whole process of greening the school becomes an activity which the students and teachers can participate in. This co-evolution of building and curriculum is discussed later in *Conclusions and Implications.*

Deteriorating health remains as one of the leading reasons for new school construction, provoking immediate action. This claim is supported by the ergonomists' case for greening schools- by framing the environmental quality as a health risk (worse than prisons), they were able to retrofit many schools with new ventilation systems, which employ natural strategies to save energy (Boerstra & Van Dijken, 2008). In this case, “greening” and “making healthier” appear to be synonymous.

“An elevated sense of responsibility is really what EE is all about” (May, 2007). Results of this study support this statement in *Ecoschool Trends and Divergences.* In an interview with a British principal, Stewart (2008) reported that some parents in PTA meetings have said that their children come home and make suggestions for home modification and family behaviors. Additionally, an Australian principal described some students who bargain with their parents, or reallocate the money saved on energy bills due to the green changes they made at home. While this is unmeasured anecdotal data, it is nevertheless evidence of some children feeling that they have the knowledge and capacity to apply learned concepts from school to affect change in other contexts.

In the United States a green school is usually connected to a wealthy community, high profile architects, media coverage, and a private school system, though this is rapidly changing with new legislation and federal incentives from the new administration.[16] However all the schools studied except one (Fuji Youchien, Japan) were public, and two of them are almost ten years old. This implies that the development of eco-schools abroad is not tied to the income of the community or the popular green building trend, but rather attributed to one progressive leader in a community, with financial support from the federal and municipal governments.

**Aim 2: Contemporary Exemplars**

These five eco-school case studies support Hein’s (1998) statement that hands-on learning is important for intellectual development because the study suggests that without interactive displays, the fully automated building works in the background and does not directly influence students. Like museum exhibits, eco-schools with child-accessible features, (e.g. color coding pipes at Kingsmead) suggested increased student understanding, demonstrated by the student-led building tours (Kingsmead and Sokkerwei). Furthermore, Lorenz (2008) was quoted, “if you spend two to four years collecting garbage, you would never litter,” implying that if you actively participate in the solutions to environmental problems, you will be less likely to cause them.

[16] According to Earth Day Network (2009) US funding priorities for environmental education includes school energy sustainability grants and access to local foods and school gardens- $780 million in FY 2010.

A master's thesis on the types of museum exhibits that increase attraction, interest, knowledge, and interpretation found that "model-frame exhibits, or objects with extended components which involve multi-sensory media, using low technology, …had higher attraction and interest levels" (Noe, 1994). This study on exhibit design can be supported by the eco-school study in that attraction and interest are key components to children's involvement in lessons and therefore their understanding. Furthermore, displays and explanations of green features can be categorized into different exhibit types, as well as low-tech (passive) or high-tech (active). Noe (1994) goes on to say that "exhibit design should not blindly assume that high technology is always the best," which relates back to architects' reservations about flashy active systems for display.

In two of the more philosophically rooted eco-schools, it was coincidental that both of the buildings were round. This architectural form, implying cyclical continuity, may be a reflection of the whole-systems-thinking values taught at the school. The eco-schools studied have more of a holistic approach: not only do they include nature in their mission statements regarding respect and responsibility, but also non-discrimination based on ability.  Four of the five schools were single level and could accommodate persons in wheelchairs. Though not directly stated, the architect of Sokkerwei, and the principal of Fuji Youchien had inclusive, collectivistic agendas (which included nature) for the students at these schools. "The form is more social, with common space and easy access from internal to external spaces" (Overtoom, 2008). Kato (2008) described the creativity in cyclical play- children like doing things over and over again, discovering new ways to make it fun, so they made it possible for students to explore the playscape and create their own activities, using simple outdoor settings such as racetrack roof or using the slide. This supports studies of children's unstructured play in nature affecting students' development positively, and perhaps in more pro-environmental ways (Wells & Lekies, 2006; Moore & Wong, 1997; Staempfli, 2009).

None of the schools studied had architectural features, intentions, or activities that would constitute regenerative design, which according to McDonough (2006), is the step beyond sustainability. This implies that though these schools are progressive, they are not completely innovative or experimental, but rather that sustainable practices are becoming more conventional and standardized.[17] Green schools could become eco-schools which could become sustainable schools which could become regenerative schools. Green schools are those that are energy efficient and save money; eco-schools are green schools but add the integration of environmental curriculum (using the building), sustainable schools are those that have no environmental impact whatsoever (fully integrated with natural systems so it is energy neutral/carbon neutral) and a regenerative schools restore the environment (Stein, et al, 2005; McDonough, 2006). This study does not intend to position eco-schools as the panacea for the environmental crisis. In fact, natural systems are sustainable, but buildings and people have the opportunity to *replenish* the earth. There is still work to be done.

**Aim 3: Relationship between Green Features & Environmental Attitudes**

"Knowledge of the causes and solutions for environmental problems appears to be more difficult for children to comprehend" (Evans, 2007). The Musser & Malkus (1994) scale used in this study included questions that did not ask whether students knew the causes, but alluded to some solutions. The scale only required that students were able to define different environmental terms and identify the effects of some common children's behaviors. In previous studies of factors that influence adult environmental attitudes (e.g. education level, political affiliation, and religion), rarely do they include features of the built environment.

In Newton, Wilks, & Hes's (2009) study of school buildings as "3D textbooks," sustainable buildings are categorized as a "type of modern space that supports modern pedagogy." Their ongoing study intends to identify what architectural features can support a developing integrative curriculum with the use of an intervention (the transition from old conventional buildings to new "smart green[18]" school buildings). While this is the most similar study to the present eco-school investigation, it does not focus on the outcome of students, but rather on teacher's ability to enhance the curriculum and manage the spaces to suit an environmental curriculum. However, the present study supports Newton, et.al.'s (2009) research in that buildings are being designed and used to

[17] For example, the International Green Flag Award and USGBC's LEED for Schools.
[18] The term "smart" was not defined in the article, and thus further and unnecessarily complicates the already jargon-filled realm of eco-schools. The researcher believes that it could imply evidence-based designs, or schools designs developed from prior research, such as post-occupancy evaluations.

teach (Aim 1 & 2), and furthermore, that buildings can facilitate behavioral change (Aim 3). Though the results of this research found a negative correlation between green building features and environmental attitudes, it does not negate the fact that a carefully designed built environment has an effect on occupants' attitudes, beliefs, and behavior. This notion of intentional, behavior-specific spaces opposes Mogensen & Mayer's (2005) view that favors cultivating critical thinkers, instead of providing biased spaces, which is sometimes the architects' intent. It remains unclear how much an architect can (or should attempt to) influence occupants beyond their normal lifestyle, a dilemma that many architects interviewed have struggled with (Kristensen, 2008; Coynes-Jensen, 2008).

## Limitations of the Study

It is important to recognize the various limitations of this study so that they may be improved upon in the future.

### Alternative Explanations: Threats to Internal Validity

One limitation to the study, especially concerning Aim 1, is that with the exception of the school principals, the other contributors had different positions in society, different roles in the development of eco-schools, and different methods of interviews. Many other factors could have influenced the information gathered from each of the interviewees including their experience with a specific school, the progressiveness of the area in which they live and work, whether they have children of their own, or the number of years of experience in their current position.

Additionally, the questions were the same for each type of person (architects and design professionals, principals, and government officials), but because of the dynamic nature of conversation, not all the questions could be asked in the same order. Many of the interviews led from one topic to another depending on the area that was most interesting or relevant to the interviewee, or what was next on the building tour. Some schools may have more information in certain areas, such as school activities, because of the presence and observation of the students themselves. Only at Shinanodai Shogakko were the students not present during the interview with the school principal.

Regarding Aim 2, the school selections were not controlled for population density (urban, suburban or rural area). Each of these green school buildings is different because of the varying architects' intentions, which are suited to each of the specific sites and economic conditions. Additionally, each of the green features had varying amounts of display or accessibility to the occupants, which was included as another green feature, but could potentially be the mediator of the relationship between green features and environmental attitudes of students. If there is no intervention or access for the occupant to understand the architectural feature, there may not be a direct effect, only a residual effect of perhaps the media attention of the green school. This coverage could have some effect on the image of success of the school, not accurately describing normal school days. The schools did not have the same number or type of environmental activities, policies, or outdoor learning opportunities, which would dramatically affect students' environmental attitudes, and could be an area for further research.

Selection bias. Regarding Aim 3, the surveyed groups of students differ in many ways other than the type of school building they learn in. Sample size and age were not consistent across schools. The age and maturity of the student, and gender were not controlled for. The 6th grade was the target class, but due to availability on the tour date, not all classes had time for the 20 minute survey. For example at the Daltonbassischool Columbus, the principal scheduled the survey during recess, and some students opted out of participating. It was also difficult for students to remember to keep track of their Parental Consent forms, which were required for minors before participation. At Columbus, there were only 7 participants, whereas at Kingsmead, there were 30. Because three of four groups were from different countries, ethnic differences, geographic familiarity, and prevalence of green design in their respective communities could have influenced students' environmental attitudes. Parental environmental attitudes, awareness, or promotion of green beliefs and behaviors, unstructured time spent outdoors, and proximity to natural play areas could have affected the study.

Random Assignment. This was a non-experimental design because random assignment of students to eco-schools and non-eco-schools was not possible. This was due to time restrictions of the study, municipal policies in place, and no access to data that would allow tracking of students' background and progression through different schools in the district. There were also no control groups from traditional (non-eco) schools from within the same region of each of the eco-school.[19] This leads to uncertainty of the direction of the relationship: whether students become more environmental because of their school, or whether pro-environment minded students from ecologically conscious families are attracted to eco-schools (only a correlation).

**Generalizability: Threats to External Validity**

The generalizability or external validity of this study is questionable. Due to the modest, non-representative sample, the results of this study may not be generalizable to other eco-schools in the countries studied or to other countries not included in the study. Moreover, because most of the schools studied were in a rural or suburban location, and most of the children were average age of approximately 12, these findings may not generalize to other age groups or urban locations.

These schools examined in response to Aim 2 were not chosen because they are the best schools in their respective countries, but because of their availability for visiting, consent for data collection, media coverage, and literature available. They are not meant to be models for future eco-schools but rather snapshot of what components of eco-schools are common today. Because only one school was studied in England, and two in both the Netherlands and Japan, we cannot generalize within or across countries, or rank their success in cultivating environmental stewardship.

Legal Jargon & Cultural Differences. Across all schools, the researcher found that the documents required by the Institutional Review Board, which includes Parental Consent, Child Assent, Principal Consent, Professional Consent, Performance Release, and Permission of Entry forms were overwhelming for all parties. Especially between the principal and the parents, two out of the four schools at which surveys were administered, additional reassurance to downplay the seriousness of the forms was needed. Both Kingsmead and Shinanodai school principals attached their own personal letter to each one of the parental consent forms assuring the parent that this was specifically and American protocol that protects both parties from legal action. The principals believed that the letter was necessary because the legal jargon of the documents seemed so severe that it caused concern rather than assurance. Especially in countries where voluntary

[19] Kingsmead Primary School principal personally knew the principal from the nearby traditional school and made attempts to collect surveys from the 6th graders there as well. Though 30 surveys and proper IRB documentation were printed with instructions, no surveys were returned.

participation is not a cultural norm, participants may have believed that this survey was a test of their knowledge rather than a voluntary report of their behaviors, belief, and affect.

Random Selection. Students were not randomly selected for surveying. The researcher targeted students in the 6th grades of available eco-schools in the three countries. However due to availability and timing of the visit, one of the classes was a 3rd grade class (De Sokkerwei, Netherlands). Furthermore, due to email miscommunication of the survey instructions, gender data was not collected.

Setting. Because the students were surveyed in the classroom environment, they may only have environmental behaviors when they are around their peers, in the context of pro-environment activities, or with the green cues of their school building.

**Measurement Issues: Construct Validity**

Regarding Aim 1, it is difficult to ascertain whether the high hopes and prospects of the principals at each school are correlated with students' long-term environmental responsibility, or whether students who are already actively pro-environmental are more receptive the philosophies and opportunities the eco-school can afford.

Additionally, architects of each school only provided digital media (professional photographs, brochures, and some simple architectural diagrams) for use in this study. Therefore identification of green features (independent variable) was limited to what was mentioned on the tour (by principal and students) or what was described in the literature. There may have been additional features, such as thicker walls, insulating values, or specific glazing types that could have been missed because there was no access to the original construction documents.

Effects of the Researcher. Because of the researcher's present age and undergraduate standing, interviews of these professionals may have been specific to a student-teacher relationship in the context of Aim 1. Another researcher, such as someone with working background or comparable age to those interviewed, may have garnered different kinds of information because of their relatability, such as economic viability data, school-age population, or further contacts. With regard to Aim 3, it did not occur to the researcher at the time of the selection of a measure that the survey would need to be read aloud to the students. The researcher was only able to read the questions to the students at Kingsmead Primary School because it was administered in English, whereas the others were read in either Dutch or Japanese. There were no instructions for the reading of the survey, and the tone of voice of the teacher, who has a close, on-going relationship with the participants, may have unconsciously implied the greener choice. Also, because of the presence of the foreign visitor, students may have felt it necessary to impress or seek the “correct” answer, like a test, rather than choose the option that they relate to (Evaluation Apprehension). Had there been other methods to measure environmental attitudes, some of these threats to validity may have been eliminated (mono-method bias). Teacher interviews and parent surveys would have been additional means of measuring a child’s environmental belief, behavior, and affect had there been sufficient time and resources.

Bias of the Report. Of the schools in this study, Kingsmead was the most thoroughly studied, had the highest number of green features, and returned the most surveys. After the survey, representatives from the student eco-council gave their own tour of the building, explaining their favorite parts. This was a special circumstance where the principal had prepared time and a special introduction for the research. Both the architect and school principal were able to meet on site to give a tour and engage in a five-hour discussion. This rare opportunity to talk to two key players in the eco-school’s development resulted in the most direct transmission of information: the researcher was able to observe and analyze the expressions, gestures, and tone of voice to gauge importance and salience. The principal was also able to connect the researcher with the school board member who saw the eco-school project from start to finish. With all of these special circumstances at Kingsmead Primary School, the results may be a bit biased in that the other schools are compared to this exemplar.

Language Translation. Language was not an issue in any of the countries except Japan, where an additional translator was necessary because of the limited knowledge of Japanese by the researcher. However in the Netherlands, one of the architects misused the English words *insulation, insolation,* and *isolation.* The researcher reviewed the notes in context and corrected the mistakes in the transcript of the interview. Additionally, there were language concerns with the Musser & Malkus (1994) survey questions, especially in Japan. Though the survey items were translated by natives of Japan, conceptual issues did not arise until the principal suggested alternatives. For instance, the deforestation of tropical rainforests is an issue that sixth graders had difficulty understanding because there are no rainforests in the Gifu prefecture of Japan where the school is located, they are not taught to be concerned with such “obscure and foreign” issues, and their only source of this type of information would be a television program. Similarly, the concept of “carpooling” is not a common mode of transportation, to school or otherwise. Schools are built so that the majority of students walk to school, and a few ride a school bus. In the Netherlands, the word for “dam” also means checkers, and one student asked jokingly how they were playing in the river.

Self-Report. The survey asks students to “choose which group they identify with” rather than choosing which group they believe is right. There were only two options and the participant was forced to choose one or the other, disregarding neutral responses. Even if the survey explicitly asked the student which group matches their behavior, it would be difficult to determine whether the student is accurately reporting their behavior without another measure, such as an observation of the child by a parent.

Independent Variable Construct Clarity. “Green school features” is not easily quantifiable because many green strategies fall into multiple categories. For example, daylighting, maximizing orientation, and passive solar heating cannot be separated as three different features because one south-facing façade with low-emissions glazing would achieve all of these things. Furthermore, a feature such as zoned radiant-floor heating promotes stack effect, a form of natural ventilation if automated clerestories are in place, and a form of optimized occupant control. However this feature alone would only be considered energy-efficient and without an explanatory display or visible section, may not serve any other purpose to the occupants other than thermal comfort, which is not a green feature, but a building code.

## Future Research

Future research studies might both extend the findings of the current study and address some of the limitations of this work. In particular, limitations concerning internal validity, external validity, and construct validity should be considered. To address weaknesses with respect to internal validity and to more clearly understand the causal influence of green building features on environmental attitudes, future studies might employ a quasi-experimental or experimental design. Students might be randomly assigned to green schools versus traditional schools and their environmental attitude would be measured before and after their enrollment. Or, researchers might take advantage of interventions or natural experiments, when schools "go green" through curricular and design renovation. In this scenario children's attitudes would be measured before and after the intervention. Additionally, with baseline data of traditional schools in these three countries, one could compare the energy-savings of these eco-schools, compared to conventional schools and add the data to other cost/benefit studies such as Kats (2006).

Another strategy for future studies to strengthen internal validity is to use a much larger sample of schools and to include a variety of potential independent variables in the study. These variables can then either be included in the analyses as predictors or controlled. For example, these might include the SES of both the region and the student's family, population density, urban or rural location, the architect's intention, as well as more details regarding the building features such as different levels of accessible displays. The eco-schools examined in this study were actually quite similar and future studies could look at schools that vary more from one another.

External validity issues can be addressed in several ways. First, a larger, more representative sample of schools in the study countries could be included. Second, the study could be expanded to include schools in the United States. Sokkerwei is an exceptional school designed over ten years ago. So why are green schools just starting to catch on in the United States? What areas in the United States are more likely to have eco- schools and why?

Issues of construct validity can also be addressed in future research, such as using additional measurements of children's environmental attitudes and behaviors along with children's own responses. Other measures could include observation by parents or teachers, or objective measures of behaviors such as shower length, recycling behaviors, etc. The 10-item Likert style New Ecological Paradigm Scale for Children, which was added to the survey late in the study, would be a shorter and more manageable measurement for future studies with larger samples (Manoli, Johnson, & Dunlap, 2007).

Another research strategy would be to conduct a post-occupancy evaluation like at Sidwell Friends School in Washington DC, which was designed by KeiranTimberlake

Architects. This ongoing study by Stephen Kellert from Yale School of Forestry and Environmental Science looks at the health, motivation, and academic performance of the occupants. It is valuable because Kellert aims to show that "children who have greater contact with nature in the school environment [will] show superior physical, emotional, and intellectual performance and well-being" (Kellert, 2007 quoted in Whitney, 2007). While greater environmental stewardship or pro-environmental behaviors are not dependent variables in Kellert's study, it is important to study the other positive developmental effects of eco-schools.

In addition, future research might include longitudinal studies that track students from their enrollment in an eco-school system, through their graduation and beyond. Relatively few studies (e.g., Wells & Lekies, 2006) have attempted to examine long term effects of childhood experiences on environmental attitudes and behaviors. Ideally, it would be valuable to understand whether eco-schools have not only a short term influence, but also an enduring effect that stays with individuals through their lifecourse.

Another compelling avenue for research is to consider what other building types or settings might teach or inspire green behaviors, such as museums, grocery stores, or malls. If eco-schools do instill environmental values in children can an eco-office building do the same for adults? If eco-residences were the only type of housing available, would a person unwilling or unaware of environmental issues be affected by their living situation?

Is there an approach to environmental education that can qualify/accredit students who graduate from an eco-school? Much like a driving test for a license or a First Aid certification, could people become certified to know/assist people in greening their behavior? For instance, in higher education, it could model a technical college, where a governing body could guarantee that the person is prepared to address any profession from the standpoint of sustainability.

## Conclusions and Implications

This study has made three important contributions to our understanding of eco-school development and success. First, this is the only study that has looked at the relationship between green school buildings and environmental awareness. Second, the study identifies key factors in starting an eco-school. Third, it elucidates the roles of mainly architects and school principals' collaboration in establishing an effective eco-school.

**Curriculum Integration in Green Schools**

From this study, we can conclude that an environmental curriculum and school policies are critical components of an effective eco-school. A green building cannot stand alone, even with high technology and sufficient funding for the active systems. The primary goal of this study is to elucidate the difference between *building* green and *being* green, and how the two can co-evolve in the school setting.

Today, buildings are only supposed to last 50 years with good maintenance. This is the same as planned obsolescence of products. What if new buildings were designed to last forever, exist in symbiosis with humans or even regenerate themselves? As mentioned above, many schools are starting with what they have, by looking around the existing building. To what extent can the building shape the curriculum? In one instance, middle school students from a seminar at the Powershift 2009 conference were trained as energy auditors.[20] Children as young as ten years old are auditing their own classrooms for ways to save money and reduce environmental impact. Afterwards, they might be able to decide where to allocate the money they have saved- increasing their school involvement and classroom control, which has been shown to increase academic achievement (Schelhas-Miller, 2009).

Obvious and visible active systems compete for time and money with background intrinsic passive systems, so how do architects raise awareness using both? How do designers stress reducing the demand *first* then attempt to meet the smaller demand with renewable sources? For instance, Sokkerwei compensates their energy consumption by buying off-site wind power. There was no evidence of conservation behavior instruction or reducing demand through occupant or policy changes, only the glorification of the building and more media attention for energy neutrality (through offsets). How do we recognize and instill deep-green thinking in buildings? We must ask: does this design, curriculum, philosophy, or societal consequence go deeper than a solar panel?

[20]Young Energy Auditors (YEA) Project. *How to Green your K-12 School*. Powershift Conference, Washington D.C. February 28, 2009.

In a global economy it follows that every person becomes a consumer and provider for someone they may never meet. How do we bring involvement, and therefore concern back to the local level? Schools are only one setting for this paradigm shift- a reversal of the self-distancing and deferral of responsibility that economic globalization has brought from decades past. Understanding the local environment-taking a closer look at the assets available in the home area- could help people become more resourceful, creative, and less dependent on instant gratification for well-being. By asking children and to think critically, posing questions like "What is my connection to it and what is *my* role in *its* future," rather than blindly accepting the systems we have in place today, we can cultivate citizens who take responsibility for their consumption habits and understand their effects on the environment.

**To Build New Schools Versus Renovating Existing Schools**

Interviews with both ergonomists and government officials led to a discussion of the decision to build a new school. Environmentally, it will usually cost more to construct new (demand more resources) rather than renovate. Financially however, reusing materials within the constraints of an existing building is much more costly than designing new. If the population is stable and the old building is structurally sound, when do we advise to retrofit, and when do we advise new construction? Furthermore, can curriculum modifications necessarily follow building updates?

In the United States, retrofitting and renovation of classrooms will outnumber new construction 4 to 1 (McGraw Hill Construction, 2004). Many states[21] have been working green school standards into building codes. The No Child Left Inside Act mandates recess and bans school bus idling. This mass green building movement also means there is an enormous opportunity to not only modernize our spaces, and improve our policies, but revise our pedagogy.

Take into consideration the path to an eco-school system from the status quo:

| | |
|---|---|
| START: | Traditional bldg + no green programs |
| IMPLEMENT ACTIVITY: | Traditional bldg + green programs |
| RESULT: | Environmentally focused school with poor facilities |

[21] Illinois, Florida, Massachusetts, Minnesota, New Mexico, Texas and Virginia. For more information on the green school movement in the United States, visit www.buildgreenschools.org or www.earthday.net/greenschools

| | |
|---|---|
| START: | Traditional bldg + no green programs |
| CONSTRUCT SCHOOL: | Green building + no green programs |
| RESULT: | Automated facility with little occupant awareness |
| | |
| ECO-SCHOOL: | Implement both green bldg + green programs |
| REQUIRES: | Facility and faculty upgrades + co-evolution of both |
| RESULT: | Environmentally-conscious, engaged citizens of Earth |

It is evident that this system requires great investments in better buildings and the right people for the intended result. So how can we equip teachers (of different generations) with the tools they need to educate the children? Facilities that provide more learning opportunities may be one of many methods. Are there physical elements in the environment that are modalities for children to feel agency? What parts of the building structure can express the fact that citizenship comes with responsibility? Can the built environment help children unlearn extreme individuality (that Americans are so well known for)? A holistic pedagogy, which incorporates the building, the environment, and the occupants as contributors towards a collective aim, can be a powerful instrument for greater societal change. Following Kohlberg's (1971) theory of moral development, it may start off with younger children as a reward or punishment system, then a conventional system where students fear disappointing others, and finally, a grounding in and commitment to a higher principle, maybe one of interconnectedness, rights of all organisms, or the delicate balance of life on earth. The *reasoning* behind behavior must be developed. This demands time for *reflection*, which will make meaningful experiences that could influence thinking. Taking a step beyond reflection, a student of this new pedagogy would have opportunities for action: to teach others what they know, learning to communicate effectively. *Sustainability* implies intergenerational conversation forward and backward in time. In this way, from taking the time to develop their own code of ethics and practicing interaction with others, the new generation will grow into engaging and interrelated dialogue. Through this new teaching philosophy, facilitated by improved architecture, we can cultivate critical thinkers well-versed in the issues that concern modern society (e.g. the ecological crisis), slowly combating fear (of nature, of other people) and apathy in young people.

**Final Thoughts**

Speaking with government officials, school board members, architects, principals, teachers, and students I have learned that to get the green revolution going, you need a lot of people in the same mindset in many different fields. A green school activist needs a collaboration of people who can pull from their resources to get green initiatives off the ground. I was wrong when I thought that an architect alone could change the way people think and act. It is a mistake to make an attempt at such a monumental task of altering children's understanding of the world in one aspect alone- the physical setting. A high-performance green school cannot serve its purpose without the environmentally committed faculty inside the walls, which serve as living, breathing models for a sustainable lifestyle. The structure and systems can serve as the backdrop, reinforcing the principles that are taught. A school building can facilitate that awareness, can be used as a tool and a model for the underlying systems that bring the earth to life, but it cannot stand alone. Construction of green buildings in the public sector will surely take off because of the monetary savings. But the point of this study is to put the children first. I focus on the qualitative change in thinking, rather than the quantitative changes in health, behavior, or performance. It is in the best interest for 'Generation G' to not only be healthy, more alert, and interested in learning, but at the same time, to cultivate an interconnectedness with the natural world, which empowers the child. He/she must leave school believing that he/she has the power to energize other people like the sun has the power to charge the building. (Imagine a diagram of inserting hand into a panel that lights up with the warmth of your body.) In self-sustaining systems, closed loop cycles, the outcomes are tracked, resources and wastes are accounted for. A sense of responsibility for this delicate system, taken on at a young age, is important in shaping a world citizen, a person of the human race, of equal obligation to planetary preservation. At eco-schools, they learn to harbor a deep respect for this intergenerational interspecies connectivity, resulting in more holistic, purposeful, and sensible professionals.

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I'm going to describe two groups of kids. In each example, choose which you are most like. If you're a little like the children described, check the small box. If you're a lot like the children described, check the big box. You should only check one box per question.

For example:

Some kids like broccoli — but other kids don't like broccoli.

1 2 | 3 4

You have to choose if you like broccoli, or don't like broccoli, and then how strongly you feel about it (big box = a lot, or small box = a little.)

1. Some kids like to leave the water running when they brush their teeth, — but other kids always turn the water off while brushing their teeth

   1 2 | 3 4

2. Some kids use both sides of the paper when they draw or write, — but other kids use only one side of the paper when they draw or write.

   1 2 | 3 4

3. Some kids think we should throw away things when we're done with them, — but other kids think we should recycle things.

   1 2 | 3 4

4. Some kids think dams on rivers are bad because they hurt plants and animals, — but other kids think dams on rivers are good because they prevent floods.

   1 2 | 3 4

5. Some kids like to bring home plants or bugs they find outside, — but other kids like to look at plants or bugs outside but never bring them home.

   1 2 | 3 4

.

6. Some kids don't like to make bird feeders or bird houses.

Other kids like to make bird feeders or bird houses.

1 2 3 4

7. Some kids think outdoor lights should be turned off at night because they use electricity,

but other kids think outdoor lights should be left on at night because they keep us safer.

1 2 3 4

8. Some kids think people are more important than animals,

but other kids think people and animals are equally important.

1 2 3 4

9. Some kids are concerned about the rain forest,

but other kids aren't concerned about the rain forest.

1 2 3 4

10. Some kids think we should build more landfills to hold our garbage,

other kids think we should find other ways to deal with our garbage.

1 2 3 4

11. Some kids like visiting national parks,

but other kids don't like to go to national parks.

1 2 3 4

12. Some kids don't worry about animals becoming extinct,

but other kids worry about animals becoming extinct.

1 2 3 4

13. Some kids throw things away when they are done with them,

but other kids reuse things or give them to other people to use.

1 2 3 4

14. Some kids think we should use chemicals and fertilizers in our gardens,

but other kids think we shouldn't use chemicals and fertilizers in our gardens.

1 2 3 4

15. Some kids pick up trash and throw it away,

but other kids don't like to pick up smelly trash.

1 2 3 4

16. Some kids don't sort their trash,

but other kids sort their trash and recycle it.

1 2 3 4

17. Some kids like to live where there are lots of plants and animals,

but other kids like to live where there are lots of people.

1 2 3 4

18. Some kids touch or catch wild animals,

but other kids never touch or catch animals they find outside.

1 2 3 4

19. Some kids don't like to carpool because they don't like being crowded in the car,

but other kids like to carpool even if it is a little crowded.

1 2 3 4

20. Some kids are excited about solar energy,

but other kids don't care about solar energy.

1 2 3 4

21. Some kids believe people should be able to live wherever they want

but other kids believe that people should be careful not to destroy animals' homes.

1 2 3 4

| | | | | | |
|---|---|---|---|---|---|
| 22. Some kids worry about air pollution, | 1 | 2 | 3 | 4 | but other kids don't worry about air pollution. |
| 23. Some kids think we should be able to hunt all wild animals, | 1 | 2 | 3 | 4 | but other kids think that animals need protection. |
| 24. Some kids turn off the lights when they leave, | 1 | 2 | 3 | 4 | but other kids leave the lights on. |
| 25. Some kids get their parents to drive them places they want to go, | 1 | 2 | 3 | 4 | but other kids ride their bikes or walk when they can. |
| 26. Some kids take a lot of food in the cafeteria even though they can't eat it all, | 1 | 2 | 3 | 4 | but other kids only take small portions of food at a time, and go back later if they need more. |
| 27. Some kids are excited about wind turbines, | 1 | 2 | 3 | 4 | but some kids don't care about wind turbines. |
| 28. Some kids feel that they don't have to protect the environment, | 1 | 2 | 3 | 4 | but other kids feel like they should protect the environment. |