THE TEACHING GREEN SCHOOL BUILDING: EXPLORING THE CONTRIBUTIONS OF SCHOOL DESIGN TO INFORMAL ENVIRONMENTAL EDUCATION

By

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Architecture and Natural Resources and Environment)
in The University of Michigan
2013

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to women

who help other women

write

Acknowledgements

My gratitude spreads near and far to the many people who helped to make this work possible. I would first like to acknowledge my dissertation committee – Jean Wineman, Raymond De Young, Bob Marans, and Michaela Zint. You have each contributed to my professional development in unique ways. Jean, your advice has always been timely and practical, even when it took me years to understand the wisdom behind it. From the beginning, you have helped me to set realistic goals, informing my ambitions with your experience. Ray, your attention to my work and your mentorship throughout my doctoral path have been invaluable. I daresay your courses, and particularly the Localization Seminar, have modified the direction of my personal and professional trajectory – and for that I am deeply grateful. Bob, I have appreciated your knowledgeable guidance since my first years in the program. In particular, working on the UM pilot project with you and Jean constituted my first substantial introduction to survey research, and I have been on this dangerous path of quantifying social information ever since. Michaela, your enthusiasm for this work has helped to fuel my progress and your expertise in environmental education has been singularly informative.

Further recognition is due to the Graham Environmental Sustainability Institute at the University of Michigan. My fellowship with Graham provided both financial support for an involved data collection process and an intellectual community of scholars who informed the development of this work in critical moments.

This project would not have been possible without the enthusiasm and support from leadership and faculty at each of my case study schools. Heads of Schools, despite their daily demands as administrators, responded to the cold contact from a graduate student in Michigan and offered me a warm welcome into each of their schools. I next owe a deep debt of gratitude to the middle school teachers with whom I worked at each school. Your expertise in sustainability, wryly preteens, and the scientific process were invaluable in conducting this research on the ground. I am in awe of your patience and passion. I would additionally like to thank the students who participated in this study. First, to the students who took the survey, I realize that some of you were more drawn by the Oreo cookie than by the thought of contributing to a body of architectural knowledge. Regardless of your motivations, you brought back parental consent forms and worked through a survey that helped me understand what you think and know about green buildings. And to the students in the photography projects -- your enthusiasm, candidness, and viewpoints added a truly unique dimension to this work.

Throughout this process, I have been humbled by the presence of stellar colleagues at the University of Michigan in both the Taubman College of Architecture & Urban Planning and the School of Natural Resources & Environment. In particular, I would like to thank Jason Duvall for being my unofficial peer mentor and graciously offering time and advice on all matters teaching and dissertating. I am also profoundly grateful for the women in my writing group: Liz Vandermark, M'Lis Bartlett, and Sara Hadavi. It has been an outrageous honor to be part of this small support community we have formed. This dissertation is dedicated to you. Leslie McGarvey, you are one of those special women in this process, and you have been my most enthusiastic cheerleader.

I am grateful to my parents, Tony and Jenny Smith, who have formed the bedrock on which I am building my dreams. It is their support that has made risk-taking – of the sort needed to leave a good paying job for graduate school -- possible.

And to James. I'm not sure how I found you in the middle of this process, but we came into contact the week before I left to collect data on the East Coast. I will never forget the moment driving South on Highway 23 that I passed under the sign toward Sylvania and whimsically asked myself if my future husband was somewhere beyond those trees. I never imagined that day that the thought would become reality, but how lucky I am that it did.

Table of Contents

List of Tables

List of Figures

List of Appendices

List of Acronyms

ANOVA: analysis of variance

EE: environmental education

EL: environmental literacy

ERB: environmentally responsible behavior

ES: environmental sensitivity

GB: green building

GBK: green building knowledge

GBL: green building literacy

GBLS: Green Building Literacy Survey

LEED: Leadership in Energy and Environmental Design (green building rating system)

MSELS: Middle School Environmental Literacy Survey

OLS: ordinary least squares regression

TGB: Teaching Green Building

Abstract

The Teaching Green Building (TGB) is emerging as a way to engage building occupants in environmental themes through the architectural design of buildings. These buildings aspire to high levels of environmental performance and invite occupants to participate in the environmental story of the building and its day-to-day operations. While examples of TGB's exist in the U.S. and beyond, they remain largely unexplored by empirical researchers. This research investigates the TGB from the occupant perspective to explore the ways in which architecture contributes to informal environmental education. The three primary goals of this work are to: (1) offer an interdisciplinary theoretical framework that links architecture with environmental education, (2) propose the concept of green building literacy as a goal for TGB's, and (3) report the results of mixed-method empirical research that examines green building literacy in the context of five U.S. middle schools. The empirical work engaged 399 middle school students in both TGB's and non-green school buildings. The methodologies included survey research, which targeted green building literacy categories, and a photography project, which offered a view of the school campus through the eyes of middle school students. Results suggest that the built environment of schools makes a significant difference for the enhancement of green building knowledge and environmental stewardship behavior. The effect of a TGB was greater for students not already exposed to environmentalism at home or in their broader communities. However, a new or renovated building may not be a requirement for advancing green building literacy. The findings suggest the effectiveness of small, organic interventions, such as modest modification to the schoolyard. These smaller interventions seem especially effective where the school philosophy promotes a child-centered, experiential approach to learning. Student home environments are also an important factor for knowledge and behavior. Green building literacy is thus influenced by a complex array of personal, sociocultural, and physical environment factors. Based on the findings both theoretical and empirical, this work concludes with insights for the practice of creating and operating buildings designed to teach.

Chapter 1
Introduction[1]

In the United States (U.S.), buildings contribute to nearly 50% of total carbon dioxide emissions released into the atmosphere annually, use nearly 70% of all electricity produced annually, and flush 5 billion gallons of potable water through toilets daily (United States Green Building Council, 2009; Yudelson, 2008). That is to say: addressing resource and material flows through buildings is an essential part of moving toward an environmentally sustainable future, but the challenge is not only technical. Green buildings[2] emerge within and are integrated into existing social systems, and it is these systems that arguably drive the innovation and success of each new green building. However, green building projects often fail to engage the broader public in the building design process. Thus, building users may be unable to recognize how a green building is different from a conventional building unless user interactions with the building can address this need. Although the number of green buildings continues to increase worldwide (Katz, 2012), knowledge of how to use these buildings for educational purposes remains stagnant. An emergent question, then, is: *why should* and *how can* we use green buildings to involve the public in the ongoing experiment of building green?

Fortunately, green buildings can be designed – and in unique places *are* being designed – explicitly with environmental education in mind. The phenomenon is best seen today in school buildings. In the realm of school architecture, the concept of combining

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1 Cole, L.B. The Teaching Green Building as Medium for Environmental Education. *The Michigan Journal of Sustainability* **in review**.

2 Though there are many ways to define "green building," the term is used in this study to describe a building that has been certified by a green building rating system, such as the Leadership in Energy and Environmental Design [LEED] rating system. This choice allows for a justifiable selection of case study buildings recruited for the empirical work later in this study.

architecture and environmental education results in a school building that is variously referred to as a "teaching tool" or "3-dimensional textbook" for environmental issues (Nair & Fielding, 2005; Taylor, 1993; United States Green Building Council, 2008). In the absence of a succinct name, the term "Teaching Green Building" is used here to refer to buildings with environmental education intent. Teaching Green Building projects contain curricula, both hidden and explicit, and tell a profound story about how humans relate to the natural environment (Orr, 2004). These buildings can push our conceptualization of green buildings beyond a viewpoint centered on green technologies, further proposing that green buildings can be vehicles to visualize sustainability (Seibold-Bultmann, 2007), draft new behavioral norms, and suggest increasingly thoughtful ways of using the earth's resources in our day-to-day lives. With the advent of buildings that attempt to enhance environmental education, social science research programs can begin to study how these buildings work to increase public engagement and educational opportunities.

Before elaborating on the prospects for environmentally educational architecture, it is worth considering *why* such buildings are a desirable pursuit given the potential cost of implementation. To approach this question, consider two limitations to green building education: 1) few in-roads currently exist for the public to engage with green building issues, and 2) even where green buildings exist, users are not often engaged in the environmental story of the building they use day-to-day. The Teaching Green Building offers one compelling response to both of these challenges.

Problem 1: Green building education is only for experts

We are all life-long consumers of buildings – inhabiting them, owning them, building and maintaining them. Green building education can help citizens broadly understand the importance of buildings in their local ecosystems; education programs can also help people to make informed decisions about their own built environments, such as their homes and offices. Unfortunately, few of us are privy to even basic lessons about architecture or design, let alone green design. While green building education opportunities abound for professionals (United States Green Building Council, 2012), there are few formal or hands-on opportunities for the public to learn about green building practices. Fortunate citizens live in places with public green buildings that have outreach programs or enjoy proximity to businesses and non-profits that support green building do-it-yourself projects. For youth, there is a small but notable movement to provide green building education, where we are beginning to see green building lesson plans that can be used by teachers at the K-12 level (Green Education Foundation, 2012). As early as 1974, scholars such as the director of the Ohio University architecture program, have lamented the disconnect between schooling and architecture. He notes:

> *Students in schools are shut away from the world to be taught about it. Their experience of the real world of building, construction, and technology is limited. Practical experience is reserved for those who will become tradesmen, and our brightest students are counseled away from manual training. Physics, mathematics, and technology are taught as abstract ideas-like school, unconnected to the real world (F. Wilson, 1974, p. 682).*

In sum, access to green building education for many citizens is limited to non-existent. Even more perplexing, however, is the phenomenon that individuals who use green buildings daily are rarely offered information about the performance of the green building design they inhabit.

Given future uncertainties regarding climate stability, energy availability, and a host of concerns relating to natural resources, there may come a time when building owners and users can no longer ignore the financial and environmental costs of their buildings (Kunstler, 2005; McKibben, 2011). Thus, to argue for broad, public green building education is to argue for the importance of empowering individuals and communities to increase the resilience of their built environment in the face of environmental change. Citizen action could manifest in many ways, from the level of home improvements to participation in community projects and local governance. As the building square footage of green projects increases, so does the population of green building users and visitors. The Teaching Green Building, while not a panacea for broad public education, is one potential way to extend green building education beyond professional boundaries.

Problem 2: Green building design fails to engage

To increase the knowledge green building users gain from green buildings, we need to consider the pedagogy of architecture and ask how a building engages a visitor, both mentally and physically. This question allows us to move beyond thinking of the green building as an object and consider the building as a venue for dynamic social and cultural activities, shifting the viewpoint on green buildings from one that is dominantly technological to one that is increasingly social and cultural in nature (Guy & Farmer, 2001). This conceptual shift constitutes new territory for a green building movement that has, in both practice and research, largely focused on the technical performance of green buildings. The technological bias manifests in the LEED system for new construction projects, where only 16 out of 69 credits explicitly state intent to improve outcomes for human beings (Athens, 2009). Stenberg (2006) further notes the trend in the media surrounding green buildings, where "[t]he trade magazines' bias towards technical measures and their proclivity toward traditional definitions regarding environmental impacts may lock practitioners into a technocratic logic." Numerous scholars have challenged the limited viewpoint of green buildings as assemblages of technological innovation, noting that there is no one true notion of a green building, but a variety of lenses through which we can understand sustainable architecture (Guy & Farmer, 2001; Stenberg, 2006). These viewpoints can expand beyond technology to include social and cultural questions.

Engaging building users in the performance of the green building is not a straightforward issue. In fact, from the outside, it may appear that building users are more likely to contribute to problems rather than solutions. We, as building users, can be clumsy, forgetful, unknowledgeable, and busy. We leave windows open and lights on; we turn up thermostats and miss the trash can. Any facility manager could confirm this set of realities as problematic. However, we commonly ignore the role that a supportive environment, one designed to support stewardship inside buildings, can play. This is to say, a behavioral problem inside a green building may be more of a design problem than it is a people problem. Thus, instead of jumping to the conclusion that building occupants do not care or want to help, we can first examine ways the environment supports, or fails to support, stewardship activity. Clearly designed recycling stations, informational signage throughout the building, and generally increasing the convenience of environmentally friendly behaviors are all examples of ways that design can support action. Beyond encouraging environmentally responsible behaviors, a supportive environment is one that attempts to inform and involve people, helping building users gain green building literacy through engagement with the building. Involving people in the building's environmental performance could be one strategy to achieve higher green performance when technology has reached its limits (Lorenzen, 2012). The approach further acknowledges that building users are an integral part of what it means for a building to be green.

Between the two problems outlined – the lack of public green building education and the failure to engage green building occupants in their own buildings – there is an opportunity to reconsider the design of green buildings to increasingly engage and educate users. The Teaching Green Building, an experiment that is today most likely found on school campuses, is one response to these multiple challenges.

Teaching Green Buildings on School Campuses

The Adam Joseph Lewis Environmental Center at Oberlin College is among the first prominent examples of the Teaching Green Building in practice (Orr, 2006). There are numerous features in this campus building that attempt to engage the building visitor in overt and subtle ways (Figure 1-1). The most explicit endeavors include informational signs that describe the building's design and a touchscreen monitor that displays real-time building energy performance information. Other features solicit visitor attention based on size or novelty, such as native plantings within an otherwise conventional university landscape or the sizeable greenhouse that hosts tropical plants in the water recycling system. The more subtle communications within the building are those that comprise aesthetic experiences designed to connect the visitor to nature. One of the most striking sensations is the sound of water heard upon walking into the building. A pleasing arrangement of stones in the corner of the lobby hosts a small fountain, whose contents echo throughout public spaces in the building. Yet more intriguing is this fountain's connection to a solar panel in the front of the building. The fountain gushes water on a sunny day and slows to a trickle under cloud cover. This trickle is one way the structure is connected to the immediate environment and offers an understated cue to the building occupants that the weather may be changing. In one move, this art-piece fountain advertises alternative energy and provides white noise, an auditory aesthetic, restorative benefits, and information about current weather conditions. Together, with the many other visible green features, it signals that this campus building is not like others.

Figure 1-1. The Adam Joseph Lewis Environmental Center at Oberlin College

Left: Building exterior; Center: touchscreen monitor displaying real-time building energy performance; Right; weather-connected fountain (photos by author).

Buildings, like the Environmental Center at Oberlin College, are beginning to marry the technical story of the building with the human story, thus creating new ways for users to think about the performance of green buildings. Imagine if, beyond counting gallons and kilowatts saved, we could add measures such as the amount of ecological knowledge gained or the number of people empowered to improve their local environments. The Teaching Green Building is the first iteration of green architecture with such aspirations.

Since the Environmental Center at Oberlin College was built, numerous campus and K-12 school buildings have pursued the Teaching Green Building concept. As of 2009, the Leadership in Energy and Environmental Design (LEED) green building rating system offers a credit for designers who employ a green school building as a teaching tool (United States Green Building Council, 2008), offering further incentive for architects and educators to consider the approach. Well-known exemplars of Teaching Green Buildings at the K-12 level include The Bertschi School in Washington (2007, LEED Gold Certification; 2011, Living Building Challenge Certification), The Willow School in New Jersey (2003 LEED Gold Certification; 2007, LEED Platinum Certification), and the Sidwell Friends School in Washington, D.C. (2006, LEED Platinum Certification). With the up-take of the concept by a major green building rating system and the number of built examples increasing, the trend to use buildings educationally appears to be on the rise.

Improving Green Building Literacy by improving Green Buildings

As the Teaching Green Building concept is put into practice, there is still much to understand about the opportunities people have in the buildings they use. Tenets in the field of environmental education can inform the starting point for measuring success in a Teaching Green Building. A notion of green building literacy can be constructed based on decades of research on environmental literacy, which sets goals for environmental education (Orr, 1992; UNESCO, 1976, 1977). Green building literacy, like environmental literacy, is more than factual knowledge: it involves awareness, attitudes, skills, and participation. It encompasses a broad range of factors that describe a citizen who is sensitive, knowledgeable, and ready to take positive action on environmental problems, and particularly those related to green buildings. A green building literate building user is better able to meaningfully contribute to the performance of the green building itself. Ultimately, a positive contribution to the building's performance means that the user's knowledge is more than abstract or symbolic; it yields outcomes of environmental significance. For example, a person with a basic level of green building literacy may know how to operate windows to optimize the building's ventilation system or be more willing to adjust behaviors that affect water use in the building. User understanding may even scale to the level of the city or region, where building users increasingly understand how the building itself participates in local ecology. Perhaps the ultimate outcome of green building literacy is translation across buildings, where citizens become advocates for change in their own built environments. Together, the concepts of the "Teaching Green Building" and "green building literacy" identify exciting new directions for green building practice and research. This movement has beginnings in school architecture, where compelling real-world examples can be found.

A New Research Agenda to Evaluate Teaching Green Building Success

While exemplar Teaching Green Building projects are being realized in practice, research about environmental education in these buildings remains sparse. One reason for this could be the newness of the trend in architectural practice; another is that green building literacy is a challenging outcome to measure. It has many dimensions and is difficult to isolate because of the many socio-cultural influences on sustainability learning, such as influential role models and presence of environmentalism in the media. Multi-dimensionality of the outcome (of green building literacy) and confounding influences further complicate the ability to *prove* that building design influences educational outcomes, especially compared to more traditional educational research that focuses on formal learning processes such as the impact of a specific curriculum. For this reason, research methods used in informal environmental education and museum studies present promising models, as their tendency toward mixed-methods better allows the research process to reflect the messiness of the setting. Such research, based on rigorous assessment of user experiences, can inform the design and construction of Teaching Green Buildings to maximize the impact the building has on the users' green building literacy.

Given the significant environmental impact of buildings on resource use and climate change, their increasing prevalence in modern life, and the lack of public green building education, the Teaching Green Building is a goal worth pursuing. Most building users are likely unengaged with the buildings they use, although emerging sustainability issues show the need for increased levels of green building literacy. With green building as one of the fastest growing industries in the U.S. (Plumer, 2012), each new square foot is an opportunity to connect architecture to environmental education. It is important to take these opportunities, and use social research to guide the design of green buildings to maximize the impact of these new green buildings on the environment and the user.

Organization of the Dissertation

The work presented here will offer an in-depth view of the theoretical basis for the Teaching Green Building, and then report on an emprical study conducted in five U.S. schools, three of which are Teaching Green Buildings.

Chapter 2 begins with an examination of theoretical linkages between architecture and environmental education, seeking to define "how" a green building can function as an educational tool. The chapter covers methods of signage and 'factual information' approaches typically used in Teaching Green Buildings. However, the theorization goes beyond static features to consider important social dynamics inside green buildings, and the ways in which architecture impacts these dynamics. The ideas are syntesized in the Teaching Green Building Model for Learning diagram that is unpacked piece-by-piece in Chapter 2.

The following chapter, Chapter 3, undertakes the "why" question in Teaching Green Buildings to propose a set of plausible outcomes for Teaching Green Buildings. If these buildings are meant to be environmentally educational, then foundational literature in the field of environmental education can offer a starting point for proposing educational outcomes. Chapter 3 adapts the Marcinkowski (2010) "Major Features of Environmental Literacy" framework to propose major features of an outcome here called green building literacy. A better defintion of green building literacy outcomes can aid the design and evaluation of Teaching Green Buildings.

The next chapters, Chapters 4-7, present the empirical research that is at the heart of this study. Chapter 4 describes the mixed-method approach that involved survey research and a photography project. Chapter 5 then moves into a detailed decription of the schools that participated in this study. Each school is described in terms of culture, physical environment, and environmental education programming. Differences and commonalities between settings are then summarized.

Green building literacy outcomes are analyzed in two ways in this dissertation. The first approach, reported in Chapter 6, includes all five school settings. The main goal of this chapter is to examine predictors for the two green building literacy outcomes of 1) Green building knowledge, and 2) Environmentally responsible behaviors at school. The second approach narrows the lens to two West Coast schools – one Teaching Green Building and one non-green buiding – to investigate differences in green building literacy measures over time and settings. Both analyses are exploratory in nature, and together, the results in these empirical chapters illuminate educational outcomes linked to Teaching Green School Buildings.

The conclusion in Chapter 8 summarizes findings and contributions to knowledge. The chapter will conclude with insights for practitioners based on these empirical research results.

Chapter 2
The Teaching Green Building: A Framework for Linking Architecture and Environmental Education[3]

In the last decade, tremendous financial and intellectual resources have been invested in the greening of school buildings. In the United States, between 2008 and 2010, spending on green school construction increased by approximately $7 billion (Hiskes, 2011). Since 2004, the United Kingdom mandated that all new school construction must comply with the BREEAM (Building Research Establishment Environmental Assessment Method), the UK's leading green building assessment method (Lockie, Butterss, Adams, Daniels, & Thorne, 2008). Further, nearly 30% of all schools in Australia now belong to Australian Sustainable Schools Initiative (AuSSI), an effort that emphasizes both curriculum development and improvement to school grounds (Australian Sustainable Schools Initiative, 2012). These examples suggest there is an increasing worldwide trend to build greener schools.

While the trend is promising, much of this new construction continues to be built within a high technology paradigm that largely ignores socio-cultural aspects of building green. For school buildings, research has focused on air quality, daylighting, and energy performance (National Academies Press, 2006; United States Green Building Council, 2008). While research on green technologies is expanding, social and psychological dimensions of green buildings have received much less attention in the literature. One particularly compelling social dimension for green schools is the prospect for green buildings to *teach about* and *support the teaching of* environmental issues addressed in the building's design. This concept of environmentally educational architecture is

[3] Cole, L.B. The Teaching Green School Building: A Framework for Linking Architecture and Environmental Education. *Environmental Education Research* **in review**.

especially compelling for schools that have a mission to educate their students, and often their broader communities, about the sustainable attributes of their school building.

Designers of green educational facilities are beginning to design green building education into the architecture, resulting in a unique type of green building that is here called the “Teaching Green (School) Building.” Many administrators and architects hope such buildings will positively contribute to an overall culture of sustainability that is cultivated by parallel efforts in policy, communications, and curricula (Higgs & McMillan, 2006). The overall result can be an immersive environment for sustainability, crafted by diverse experts in social, psychological, cultural, and technical fields. “Whole-school sustainability” is a term used to describe comprehensive approaches to campus sustainability, where the building design is but one among many considerations (Barr, 2011; Henderson & Tilbury, 2004; Koester, Eflin, & Vann, 2006). This body of scholarship uncovers complex interrelationships between school governance, culture, curriculum, physical environment, adult role models, and the orientations of individual students. Factors such as these work with and against each other toward the end goal of whole-school sustainability.

The school building is arguably the largest and most visible physical artifact of school sustainability, and one that changes less often relative to other aspects of the school environment such as curriculum or the sourcing of green office supplies. When new construction or renovation projects are underway, design choices made by architects and their clients affect the school community for many years to come. A well-designed building can support institutional goals, formal curriculum, and engaged teachers, and additionally symbolize the school’s commitment to sustainability in a unique way.

The work presented here is situated between the disciplines of architecture and environmental education. It attempts to navigate these layers of a school’s social system with a focus on the often overlooked, and largely unstudied, contribution of the physical environment to environmental education. The work will be of interest to designers of educational architecture, educators, and other advocates for changing the built environment of their schools. Driving questions include: How can green school buildings engage students, staff, and visitors in the environmental stories a building is telling? How can school architecture both *support* and *constitute* a curriculum for environmental education? What physical design approaches hold promise for advancing informal environmental education through the built environment? The result of this literature review is a framework, including a series of design patterns, constructed from research across the disciplines of environmental education, museum studies, conservation psychology, and architecture that, taken together, suggest that green buildings can play a role in environmental education.

Moving toward a framework that links architecture and environmental education, the following sections (1) offer examples of Teaching Green Buildings in practice, (2) lay out current conceptualizations of these buildings in existing literature, and (3) examine theoretical perspectives from multiple disciplines that connect the physical environment with prospects for learning and doing. These theoretical perspectives are woven into a framework that offers practicable design patterns for use in Teaching Green School Buildings.

The Teaching Green Building in Practice

Designing buildings as environmental teaching tools, in practice, often consists of the placement of informational signage across the building. While this strategy is a promising first step, the framework presented in this article aims to expand our current conceptualization of Teaching Green Buildings as more than canvases for signage: they can also be venues for reaction, interaction, and proaction surrounding environmental themes. Fortunately, there are current built examples that illustrate the architectural possibilities for environmental pedagogy that go well beyond signs on the wall (Figure 2-1).

Disparate efforts to use green school buildings pedagogically can be discovered across North America, and there are likely to be similar efforts in Europe and Asia, though exemplars are difficult to find through conventional means. Efforts are emergent and decentralized, and no public, central network of such buildings exists. In the United States, examples of Teaching Green Buildings can be identified at both the University and K-12 levels. As discussed in Chapter 1, The Adam Joseph Lewis Environmental Center at Oberlin College, built in the late 1990s, and extensively written about, is one of the first examples encountered when researching this topic in the United States (Orr, 2006). Other well-known exemplars at the K-12 level include The Bertschi School in Washington, The Willow School in New Jersey, and the Sidwell Friends School in Washington, D.C.

Figure 2-1. Examples of Teaching Green Building features

Top left: Light designed to communicate building energy performance; Top Right: Orchard, garden, and solar panel; Bottom Left: Green house and wind turbine; Bottom Right: Touchscreen with real-time building energy information.

These schools include building features such as interactive kiosks, informational signage, living machines that recycle water, orchards, vegetable gardens, alternative energy systems, recycled-content materials, and native landscaping. From these examples, it is clear that the Teaching Green Building not only includes the building itself, but also the surrounding landscape. Buildings designed holistically, indoors and out, to teach sustainability often attempt to reinforce environmental messages throughout the building and the campus.

The Teaching Green Building in the Literature

As a concept, the "school building as teaching tool" has been featured in a bevy of recent publications from various disciplines. There are architects simultaneously writing about sustainability and spaces of learning (Day, 2007; Taylor & Enggass, 2009), and others directly addressing the concept as "Sustainable Elements and Building as 3-D Textbook" (Nair & Fielding, 2005). Environmentalist David Orr has written prolifically about the "pedagogy of architecture" (Orr, 2002, 2004), and put the principles into action at Oberlin College, then writing a book about the process of designing a high-performance sustainable campus building (Orr, 2006). More recently, a graphic handbook entitled "The Third Teacher" was published (O'Donnell Wicklund Pigozzi Peterson Architects Inc, V. S. Furniture, & Bruce Mau Design, 2010). The book title was inspired by the mid-century Reggio Emilia approach that treats the surrounding environment as "the third teacher" in a child's education. The third teacher literature thus cites the physical environment, in the constellation of teachers and peers, as a third influential factor in learning (Edwards, Gandini, & Forman, 1997). In the realm of green building rating systems, Leadership in Energy and Environmental Design (LEED) for Schools offers a credit for construction projects that employ the "school as a teaching tool" (United States Green Building Council, 2008).

The concept of the Teaching Green Building clearly has traction across disciplines, and is of increasing interest for both scholars and practitioners. What is astonishing amidst this flourishing of inspirational literature, however, is that the potential outcomes for environmental education in Teaching Green Buildings are neither strongly theorized nor evidence-based. At the frontier of empirical studies is a thesis completed by Susan Barr

(2011) that examines school facility, culture, and curriculum through the perspective of educators, administrators, and architects in Teaching Green Buildings. Situated in elementary-level Teaching Green Buildings, this study revealed underlying structural commonalities between schools, including constructivist philosophies, shared values amongst faculty, and facility opportunities (Barr, 2011). Empirical research on the Teaching Green Building is in a nascent stage of development, and there is yet a need to understand how these buildings might work pedagogically from the viewpoint of the learner.

While the Teaching Green Building is not explicitly addressed in the Environmental Education (EE) literature on place-based learning, the concept fits well within this broader discourse about the importance of 'place' in teaching about environmental issues. The notion of place has been used by educators as a framework for understanding human-environment connection (e.g., Gruenewald, 2003; Kudryavtsev, Stedman, and Krasny, 2011; Somerville and Green, 2011), or at times the *disconnection* between people and nature as a barrier to the goals of environmental education (e.g., Louv 2008; Sobel 2008). Much has been written about children in particular, and the importance of time spent in nature to the development of environmental sensitivity and the likelihood of caring for the environment later in life (e.g., Bögeholz 2006; Chawla 1998, 1999). Though the emphasis on place within EE literature has typically been on the human-nature connection, sense of place is a multi-dimensional construct, with facets physical, psychological, sociocultural, and political, and has been described as "the complex cognitive, affective, and evaluative relationships people develop with social and ecological communities through a variety of mechanisms" (Ardoin 2006, 118). Landscape and building architecture comprise one set of mechanisms that are arguably the most visible within the broader system of factors that define "place" on a school campus.

The in-depth exploration of the Teaching Green School Building thus charts new intellectual territory for place-based EE efforts. As noted, place-based and experiential learning have long been areas of focus in EE research (Braus, 2009; Duffin, Murphy, & Johnson, 2008; Gruenewald, 2003; Sobel, 2004, 2008). Much of this research has focused on the importance of getting *away* from the school building to learn about the environment, such as taking students on field trips to natural settings. Alternatively, the framework offered here targets the school building as "place" and stage for experiences that can help students build environmental literacy. Further, research about everyday, on-campus environmental experiences can add to our knowledge about the effects of prolonged exposure to EE interventions. Existing literature about short term (e.g. one day) exposure shows that such programs are greatly challenged in terms of promoting lasting environmental behavior change (Leeming, Dwyer, Porter, & Cobern, 1993; Zelezny, 1999; Zint, 2012). The provisional framework offered in this paper suggests that distinct advantages of Teaching Green Buildings, and those combined with a whole-school approach to sustainability, offer opportunities for students to both learn about and embody environmental stewardship in their daily lives at school.

A Framework for Linking Architecture and Environmental Education

Given the boom in green school construction, and the small but growing number of schools interested in connecting their built environment to pedagogy, professionals across fields will benefit from a stronger theorization of, and eventually a stronger supporting evidence base for, the Teaching Green Building.

The Teaching Green Building Model for Learning (Figure 2-2), introduced in this chapter, integrates concepts from multiple disciplines woven into a theoretical framework. The goal of the model is to draw out the mechanisms through which a building supports teaching and learning. The diagram uses theory from environmental education, museum studies, and architecture to form the axes of the framework, and the framework is then populated by design patterns further supported by theory in conservation psychology. The resulting model suggests an array of choices in green school building design that can support or encourage learning about, and action regarding, environmental issues. The diagram thus identifies the categories of interventions that can be designed, built, and tested in Teaching Green Buildings.

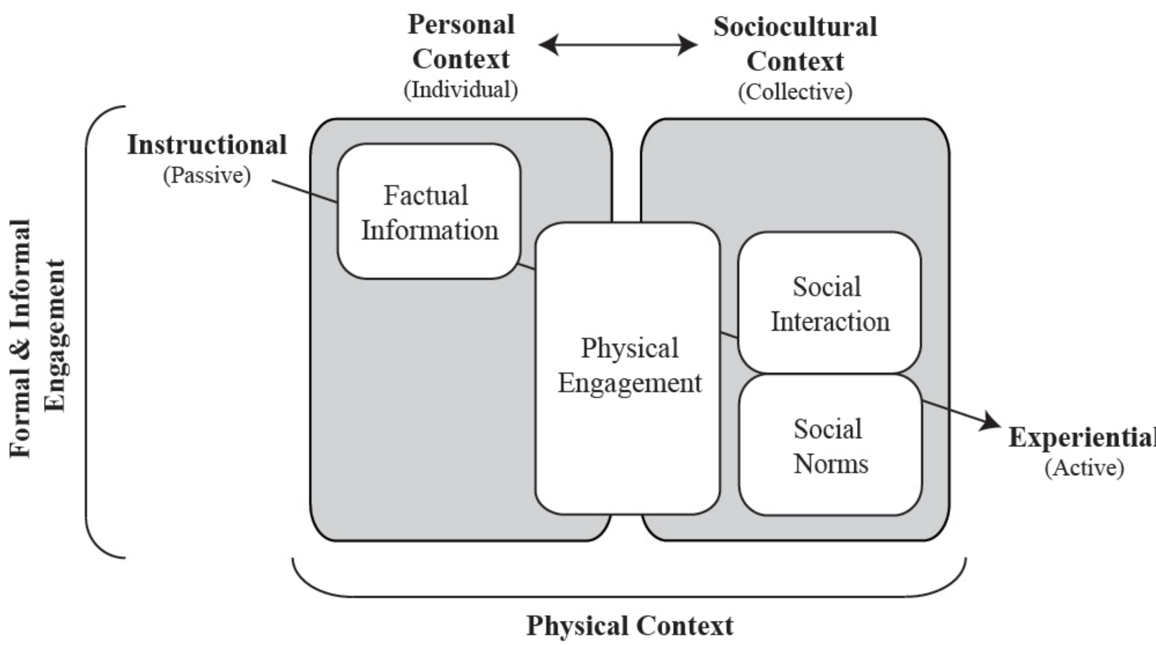


Figure 2-2. The Teaching Green Building model for learning

Engagement with the green school building, as conceived in the framework and elaborated in the following sections, is a multi-dimensional concept. The diagonal axis of the framework, lays out passive to active dimensions of engagement, from one-way instruction to experiential learning that happens through active participation with the building. The horizontal axis employs the Contextual Model of Learning (Falk, Dierking, & Foutz, 2007) (discussed in more detail in Figure 2-3 below), and involves the nature of a student's engagement with the school building's architecture, where that engagement is on a spectrum from person-environment interaction (personal context) to person-person interaction (sociocultural context), all supported by the physical environment (physical context). The result is a web of possibilities for student engagement with environmental issues in and around the school building. One implication of these distinctions is that, while some interventions are direct interactions between the visitor and the building, other interventions require mediation by other people in the building.

Before exploring the central pieces of, or the design patterns within, the framework, major axes of the Figure 2-2 diagram will be addressed. These axes are comprised of three useful spectrums that illuminate the nature of student engagement and bear on learning outcomes: 1) formal to informal engagement, 2) passive to active engagement, and 3) individual to collective engagement. These distinctions are neither clear-cut nor mutually exclusive, but likely manifest in various combinations throughout the design and use of a Teaching Green Building.

Formal to Informal Engagement

The Teaching Green Building is both a tool to be used by teachers formally in lesson plans and the backdrop, or stage, for all that happens between class periods. Additionally, non-formal learning activities, such as gardening clubs or green teams, require spatial considerations and architectural programming. Buildings can thus be designed to support a spectrum of formal to non-formal and informal learning.

A critical consideration for a school with a Teaching Green Building is the alignment between the building's features and the school's curriculum. Ideally, the Teaching Green Building offers ways for students to be meaningfully involved in the care of features or the monitoring of the feature's performance, as can be seen with maintenance of school gardens, testing water quality in water recycling systems, and the monitoring of solar panel energy production. While science programs provide an easy home for these types of curricula, some schools have explored additional ways to celebrate the greenness of their school environments through arts and humanities lessons. Examples of the latter include sketching the school campus, crafting place narratives, or writing histories of the school grounds.

Even without green architecture, schools in non-green school buildings can conduct green building education through programs such as the Green Education Foundation's "Green Building Program," which delivers lesson plans on topics such as building materials, water-efficient technologies, and energy audits conducted by students (Green Education Foundation, 2012). Many such curricular efforts take advantage of the physical environment, regardless of greenness. While having a green school building alone can increase anecdotal teachable moments, a more integrated curriculum with green building education would be expected to deepen student understanding of their green school building's attributes. The study of effective green building curricula is fertile ground for future empirical research.

Teaching Green Buildings can additionally offer informal learning opportunities, or moments of learning that happen in between class periods and over time. Examples of architectural interventions that engage students informally include signage in the hallways, energy feedback monitors that provide real-time energy information, and play structures made from reused or recycled materials. While these features can be integrated into the curriculum, they are also ever-present reminders of sustainability that students can engage with outside the formality of the classroom. How and whether students engage with these features is yet another question for future research. In essence, these features have a shared challenge with science museums, where displays are intended to engage students in voluntary learning and rely to a great extent on adult intervention and/or the natural curiosity of the child. The study of the Teaching Green Building can thus be informed by literature on informal learning environments, which are sometimes referred to as "free-choice learning environments," and are places that are structured to support self-paced and volitional learning by a self-motivated learner (Ardoin, 2009; Bell, Lewenstein, Shouse, & Feder, 2009; Falk, Dierking, & Adams, 2006). Museums, zoos, and parks are settings commonly studied, although Bell et al. (2009) refers broadly to "venues and configurations" which support informal learning, suggesting that the definition can encompass a variety of settings (28). School buildings with pedagogical intent can be added to a growing list of informal learning settings in which learning, in matters of science and beyond, might occur.

Like museums, institutional green buildings, such as schools, are venues for complex cognitive and social processes. A major difference, however, is that the informal learning settings that have been the focus of empirical study, such as museums and zoos, are places that are not inhabited day-to-day by the learners in question. Further, the motivations for coming to the Teaching Green School Building are not primarily to learn from the architecture, but to learn from teachers and participate in the school community. Thus, learning from the architecture is an understated, and perhaps unexpected, aspect of the educational experience, and caution is warranted when comparing the school building to a museum setting.

Passive to Active Engagement

A second distinction to consider is the degree to which building features solicit passive versus active student engagement. A common approach to teaching occupants about the green building is to layer signage over the finished product and hope that visitors will notice and read it. Another common, and more active, approach is to offer guided or self-guided tours of the green building. Such signage and tours may be especially important for new students in unique buildings, as there may be aspects of the building that require knowledge on the part of the user to maintain the environmental performance of the building (*e.g.*, how and when to operate windows to optimize heating and cooling systems). Schools employing hands-on lesson plans that use green building features solicit a type of engagement that is increasingly active, and potentially occurring over a period of time. Thus, Teaching Green School Buildings host a spectrum of engagement that ranges from fleeting and passive to prolonged and active.

Literature in the area of conservation psychology examines the effectiveness of using antecedent communications, such as informational signage and prompts, in the promotion of stewardship behaviors, and particularly in the realm of energy conservation (Ester & Winett, 1981-1982; Katzev, 1987). This literature shows that visible information and static prompts at least partially explain increases in environmentally responsible behaviors in a given setting, though these antecedent strategies often work best when coupled with others strategies like incentives, disincentives, and even mechanisms for applying social pressure. While signage and prompts, in certain research settings, have been shown to affect knowledge and behavior, the behavioral and learning outcomes of placing signage in the context of Teaching Green Buildings require further study.

Although static signage can be greatly informative, it is also a didactic, unidirectional approach to conveying information. At first glance, it would seem that this is a building's primary mechanism for teaching. However, increasing thought can be given to ways in which the built environment invites more active kinds of engagement. An understanding of active, or experiential, learning can be gleaned from numerous scholarly perspectives. To begin, constructivist perspectives in education place emphasis on how an individual interacts with the social and physical world to construct knowledge (Bell et al., 2009; Marshall, 1992). A branch of constructivist learning theory has promoted "situated learning," which emphasizes learning that is highly contextualized and applied in the local setting (Brown, Collins, & Duguid, 1989). This notion of situated learning aligns nicely with the practice of using Teaching Green Buildings to teach about the environment in an active, hands-on way. It is also worth noting that educational approaches such as Montessori and Reggio Emilia commonly integrate elements of participatory projects that involve hands-on learning (Edwards et al., 1997; Moore & Cosco, 2007). Additionally, discourse in environmental education has explored the benefits of shifting the conception of the learner from passive to active (Payne, 2006; Rickinson, 2001). Finally, the Reasonable Person Model, based in environmental psychology literature, proposes that involvement in meaningful actions is a basic component of psychological well-being (Kaplan & Kaplan, 2009). While the concept of active, hands-on learning is well-trodden ground for educators, it is a less developed idea in the realm of school architecture. In fact, green building technologists have long been preoccupied with ways to *override* building user behaviors via automated thermostats, lighting and window controls. This is not to say these are undesirable building features, it is only to point out that physical engagement potentially requires a shifted mind-set of the architect toward the building user.

Individual to Collective Engagement

A third key consideration relative to engagement is the degree to which individual learning is mediated by personal factors and the social setting. This is a potent set of questions now common in educational research, which traditionally relied on behaviorist notions of the student as a blank slate, but has shifted toward an educational paradigm that increasingly embraces a broad set of social and environmental factors that affect learning (Falk et al., 2006). These factors are no less important in the consideration of place-based, contextual learning. Within the scholarship on museum learning, the Contextual Model for Learning presents three factors, including the personal context, sociocultural context and the physical context, each of which have been shown to influence free-choice learning experiences (Falk & Dierking, 2000; Falk et al., 2007; Falk & Storksdieck, 2005) (Figure 2-3).

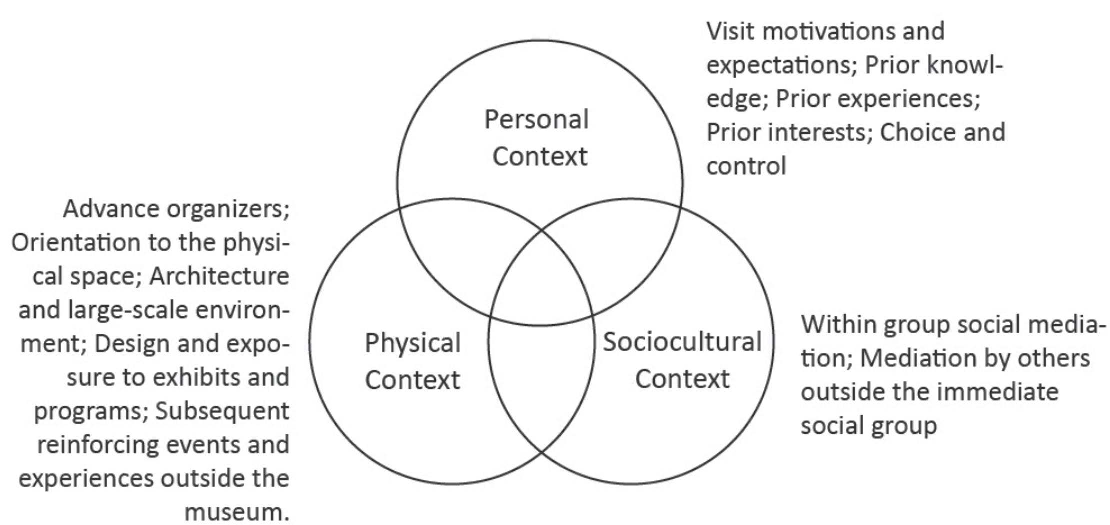


Figure 2-3. The contextual model for learning in museums

Relevant to the "Personal Context," Falk et al. (2006) aptly note: "[l]earners start from different cognitive frameworks and build on learning experiences to create unique, highly individualized schemas. Operating from a constructivist perspective requires accommodating to the diverse and individualized nature of learning" (325). A Teaching Green Building that is effective for the greatest number of people thus needs to meet individual learners who are at different starting points in their understanding of environmental and architectural issues. Beyond variation in knowledge, individual learners come into the building with potentially very different attitudes, goals, motivations, and so on. A multi-pronged approach to engagement, such as working across numerous patterns within the Figure 2-2 framework, may increase participation across a diverse group of building users.

It is perhaps not surprising that personal factors, such as prior knowledge and experience, affect learner motivation; but the model additionally highlights the importance of social factors in the informal learning experience. Thus, the model goes beyond an understanding of the personal context, incorporating sociocultural perspectives on learning that have roots in the literature on social constructivism (Bell et al. 2009, 30). [Though, the notion of social learning enjoys a rich research tradition, dating back to such influential work as Lev Vygotsky's on sociocultural approaches to learning (Vygotsky & Cole, 1978) and Albert Bandura's formulations of social learning theory (Bandura, 1969).] In terms of social learning, and of primary interest to green building design, is the question of how a person arrives at environmental education outcomes through observation of, and interaction with, other people. In the museum context, researchers have put much focus on visiting a museum alone versus within a group (or children within their families), with results that suggest positive, though different, learning results of each individual and social engagement. For example, visiting a museum alone can allow for reflection without distraction while the presence of other people can increase understanding via information sharing (Packer & Ballantyne, 2005). Other research has shown that, particularly for individuals high in interpersonal orientation, the presence of other people can increase motivation to learn (Isaac, Sansone, & Smith, 1999).

Finally, and importantly, The Contextual Model of Learning addresses the "Physical Context," where literature on behavior settings (Barker, 1968) and situated cognition (Brown et al., 1989) is integrated to argue for the importance of physical design features in the process of learning (Falk & Dierking, 2000, pp. 53-67). Where Falk and colleagues approach the physical context predominantly from perspectives in education and psychology, it will be suggested in the following section that many theories on the built environment can contribute to our understanding of the physical context of Teaching Green Buildings.

Taken together, the elements of the Contextual Model for Learning draw a picture of the informal learning environment as one that includes a rich array of explicit informational content, social processes and features of the physical environment, all of which are experienced by individuals with diverse personal orientations. Research in museums has shown that all of these factors differentially contribute to outcomes for individual learning (Falk & Storksdieck, 2005, p. 747). The empirical research base of the model, together with the explicit mention of the built environment, offers a useful starting point for scholars interested in the pedagogy of architecture in places beyond museums. These three domains (Figure 2-3) constitute the horizontal axis of the Teaching Green Building Model of Learning (Figure 2-2).

Embodied Learning in Green Buildings

The three spectrums of engagement – formal to informal, social to collective, and passive to active – are all at work in a Teaching Green building, and all contribute to a multi-pronged approach to green building education. Payne (2006), in identifying trends in environmental education curricula, summarized well the integration of these varied dimensions:

…learning should be a positive, experientially placed process of individual and collective inquiry. Situated investigations of one's own and others' (embodied) environmental experiences are required to reveal how we practically live and construct our problematic environmental relations with various (local) places and (global) spaces (Payne, 2006, p. 28).

Payne's use of the term "embodied" eloquently points to the nature of the four-dimensional experience of architecture through time and space. It resonates with constructivist learning perspectives, and helps us understand building occupants as "embodied learners" from a vantage point on learning that views "mind, body, and environment as inextricably-embedded systems" that continuously interrelate (Horn & Wilburn, 2005, p. 749). The next section unpacks the design patterns that occupy the Figure 2 framework, and demonstrate numerous ways in which building design can support learning across multiple dimensions of engagement. A close examination of the design patterns reveals that the notion of embodied learning, in various ways, permeates the domains of the Teaching Green Building Model for Learning. Understood in this way, the cumulative outcome of experiencing a Teaching Green Building with diverse elements could be the chance for students at school to embody sustainable living throughout their daily lives.

Four Design Patterns for the Teaching Green Building

Within the Figure 2-2 framework, and building on the three spectrums of engagement, the concepts that occupy the framework are factual information, physical engagement, social interaction, and social norms. Together these concepts constitute a provisional set of design patterns for a green building that aspires to teach about environmental issues. In the tradition of using design patterns to communicate practicable design ideas, each concept is supported by literature in one or more discipline, and is not a specific solution, but a general strategy for supporting or encouraging engagement with environmental issues in the school building (Alexander, Ishikawa, & Silverstein, 1977; Nair & Fielding, 2005). The result of this approach is a toolbox of workable patterns that can be woven into the architectural language of Teaching Green Building designs.

Though each pattern is supported by research across disciplines, pedagogical architecture is a fairly recent phenomenon in practice, and to the author's knowledge none of these concepts have been empirically tested in the specific context of the Teaching Green Building.

Factual Information

A straightforward way for buildings to "teach" is through the layering of information (verbal or image-based) over architectural features. Common ways of delivering such information include signs, touch-screens, brochures, websites, and so on. Information can pertain to static features (*e.g.,* recycling bins) and can offer both content and process knowledge (*e.g.,* why and how to recycle). Information can also refer to real-time performance in the building (*e.g.,* pounds of material recycled in the building this week). Beyond offering facts, visible information can also serve as behavioral prompts that remind building users to conduct environmentally responsible behaviors, such as turning off lights, printing double-sided, and shutting down computers.

Physical Engagement

Places for physical engagement with the building's environmental features could be any location where a person is encouraged to functionally use, or even informally play, with a building feature. Vegetable gardens, demonstration kitchens, chicken coops, compost piles, living machines, energy system monitoring, and ponds for water quality testing have been used to promote hands-on learning in Teaching Green Buildings.

In a broader sense, the concept of physical engagement could also refer to *any* location where the building occupant makes a decision about resource use in the building, which means that hands-on engagement is not always consciously made "active engagement," but could include habituated behaviors, such as turning off the lights. A designer or educator interested in physical engagement might ask two related questions: 1) how do building occupants actively learn about the green building features in a hands-on way, and 2) in what ways can a person embody sustainability and meaningfully participate in the environmental performance of this building? Hands-on green building features are a natural fit in school buildings where such features can integrate with formal environmental education curricula.

As suggested by its positioning within the framework diagram (Figure 2-2), "Physical Engagement" can span numerous spectrums from personal to social engagement and from learning to doing. If a building's features can foster engagement that is variously personal, social, intellectual and physical, physical engagement is arguably the most important, and most exciting, domain for Teaching Green Building design. It is hands-on features – such as gardens, compost systems, and energy monitors – that are most likely to solicit conscious engagement for prolonged periods of time, especially compared to features such as signage where engagement is sporadic and fleeting. The concept of physical engagement additionally bridges to Payne's notion of "embodied" environmental experiences (Payne, 2006) as those that engage numerous senses in route to increasingly conscious, minds-on learning.

Social Interaction

The Reggio Emilia approach is an educational approach known for its spatial sensibilities. It encourages educators to view "space as a 'container' that favors social interaction, exploration, and learning" (Edwards et al., 1997, p. 164). This philosophy offers an inspired way to imagine Teaching Green School Buildings as venues of interaction, exploration, and learning tailored to the goals of environmental education. On a basic, pragmatic level, Teaching Green Buildings can be programmed to support social functions that enhance the sustainability culture of the school, including such nonformal activities as green team meetings and gardening or energy clubs. Architects and school administrators can work together to ensure that there are physical spaces in which student groups can self-organize for on-going environmental action both inside and out of the school building.

There is another, more subtle way in which buildings can enhance social networks, and that is by providing a building layout that encourages unplanned interactions among the people who use the building. Architectural theory in the area of space syntax, discussed below, illustrates how building configuration supports these kinds of casual interactions (Peponis & Wineman, 2002). A reasonable hypothesis, based on space syntax theory, would be that unplanned interactions around teaching green features increase the likelihood that these features are part of everyday conversation.

Social Norms

The individual is not a lone figure in the context of the school building, but a person who participates in the social patterns, and both influences and is influenced by the social norms, or the behaviors that are considered normal, in that given place. Looking across disciplines, there is a convincing argument for making the social norms in a building manifest. First, deeply rooted in a constructivist perspective on learning is the notion that the social culture constitutes an entire channel of information absorbed by an individual learner. The Contextual Model for Learning referred to this as the "Sociocultural Context" (Falk et al., 2007) (Figure 2-3). In addition, research in conservation psychology has shown the influence of social norms on our decisions to behave in environmentally friendly ways (Cialdini, 2003; Nolan, Schultz, Cialdini, Goldstein, & Griskevicius, 2008). Overlaying these notions in the Teaching Green Building prompts consideration of how the built environment provides social information, and how that information has broader influence. To promote the norm of environmental stewardship, buildings can attempt to make social norms, such as the norm to recycle, increasingly visible. This strategy can be achieved through practical tactics, such as making recycling sites highly visible, or even creative approaches, such as building an artistic display that offers feedback on a group's recycling performance. In this way, buildings can offer nuanced layers of information regarding social norms to the building users, increasing the likelihood that building users perceive environmentalism as the norm and participate in stewardship activities.

The Physical Context: Building Design Considerations

Perspectives from environmental education, museum studies, and conservation psychology, such as those presented above, are useful building blocks for constructing a theory of the Teaching Green Building. One perspective that remains understated is the consideration of how the physical elements of the building support the goals of the building. On a basic level, a building needs to support taking environmentally responsible actions by affording opportunities. Even a Teaching Green Building with all of the right features, however, can suffer from a poor building layout, such as a maze-like building with no central spaces, which then substantially undermines the effectiveness of its teaching green features. The physical environment further impacts student cognitive functioning by enhancing comfort through pleasing environmental conditions, which includes considerations such as lighting, temperature, and controlling noise levels. Another well-proven benefit in terms of cognitive functioning is the provision of opportunities for mental restoration. Restorative features at the school building can include plants, ample daylight, and nearby walking trails in natural areas. Finally, symbolic design choices, such as forms and materiality, tell a nuanced story that can variously work for and against the overall environmental messaging. These are four major considerations of how the built environment can affect learning outcomes: 1) supportive environment, 2) well-configured environment, 3) comfortable environment, and 4) meaningful environment. It is worth addressing each of these architectural questions in turn.

Supportive Environment

We know that many forces are acting on a person’s learning processes and behavioral decisions; however, not all of these forces are personal or social, but directly related to the physical environment a person inhabits. In terms of existing behavior change models, the physical environment has been operationalized under constructs such as “situational factors” (Hines, Hungerford, & Tomera, 1987) or “perceived behavioral control” (Azjen, 1991). These factors are included in models because research has shown over time that structural factors, such as opportunities provided in the physical environment, can be the ultimate determinant of behavior change (*e.g.*, no recycling bins in the building would greatly reduce the likelihood that a person recycles in the building, regardless of one's values or intentions.) Interestingly, measures such as perceived behavioral control are a hybrid of what a person *can do* and what a person *perceives they can do*. It is, thus, not purely a measure of the physical environment, but also one of how a person perceives the environment.

The concept of affordances, first introduced by J.J. Gibson, relates to this discussion (Gibson, 1977, 1979). As conceptualized by Gibson, affordances are at the intersection of human perception and the opportunities for action[4]. Others who have built on Gibson's work have further developed the perspective that affordances are not a property of the physical environment alone, but sit in the space between the environment and the person (Chemero, 2003; Stoffregen, 2003). A full discussion of this complex topic will not be covered here. The basic question posed to those interested in the design of the physical environment of a Teaching Green Building is: how does this environment support learning and environmentally responsible behaviors? And then: do building occupants perceive these opportunities? Understanding the importance of affordances in the built environment is one building block for conceptualizing the total impact of the built environment on learning and behavior change.

Comfortable Environment

Indoor Environmental Quality (IEQ) is a topic of special interest to green building experts. This concept includes variables common to all building types, such as temperature, air circulation, and lighting levels. Green building designers additionally emphasize daylight, views through windows, and reducing environmental toxins as significant contributors to IEQ (United States Green Building Council, 2008). Important empirical research has been emerging over the last decades, confirming the link

[4] Note: Gibson was primarily concerned with human perception and action (behavior), and did not study the outcome of "learning" that is integral to the current study.

between IEQ and occupant health and productivity, with a special branch of literature dedicated to schools in particular due to the high susceptibility of youth to environmental toxins (National Academies Press, 2006). Summative reviews of this literature reveal that there is conclusive evidence for the effects of air quality, temperature and noise levels on learning, where learning is typically measured via student attainment, engagement and physical well-being (Higgins, 2005; Mendell & Heath, 2005).

Highly related to the topic of physical comfort is that of mental restoration. A view through the window, fresh air, and nearby nature are all examples of mentally restorative elements in buildings. Research has shown that the presence of such features can aid building occupant ability to restore attentional capacity, thereby improving mental state factors such as effectiveness, ability to focus and absorb new information. Decades of research has confirmed these outcomes in a variety of environments, such as homes (Kaplan, 2001; Tennessen & Cimprich, 1995), offices (Kaplan, 1993), public housing (Levine Coley, Sullivan, & Kuo, 1997), and of particular relevance to the current work, schools (Matsuoka, 2008).

Well-configured Environment

Where the Contextual Model for Learning offers a somewhat vague conception of the physical context (Figure 2-3), there is a sub-area of architectural research called space syntax that is devoted to the study of spatial configuration. Architectural researchers in this area have sought to understand how the configuration of buildings makes a difference in the social patterns, and thus social life, inside a building (Bill Hillier, 1996; Bill Hillier & Hanson, 1984; Peponis & Wineman, 2002). Their research has endeavored to quantify spatial properties such as layout and sightlines, and relate these metrics to use patterns and social outcomes.

Of particular interest here is the interior spatial configuration of school buildings, and the ways that configuration can support the social and educational goals, and namely the goal of promoting environmental education. It is helpful to first think about what the spatial configuration, or layout, of a school is physically able to do. Two major impacts of spatial configuration are visibility and movement, which can be described as two different types of access:

- **Visual access** is about the objects, scenes and other people that can be seen from particular locations in layout. Visual access is about what can people see as they move through the building.
- **Movement-based access** is about movement between areas in the layout. This metric measures the *ability* to move between areas, regardless of the quality of the path. Beyond ability to move across the building, a designer should also consider distances that need to be covered between key areas of the building.

Various research programs over time have examined these kinds of spatial factors and linked them to outcomes for organizational and institutional success. For example, research has explored the effects of office layout on communication and productivity (Brill, Margulis, Konar, Buffalo Organization for Social Technological Innovation Inc, & Westinghouse Furniture Systems, 1984; Peponis et al., 2007) and social networks and innovation (Penn, 1999; Wineman, Kabo, & Davis, 2008). Other work has studied the relationship between space and pedagogy, suggesting that space facilitates interdepartmental communication in higher education buildings (Peatross & Peponis, 1995).

Based on several decades of empirical studies, such as those noted above, there are two central theoretical concepts that are well supported in Space Syntax theory: 1) spatial configuration relates to patterns of movement and visibility, and 2) spaces that engender higher levels of movement increase the likelihood that people in the space will be aware of and interact with each other (B. Hillier, Burdett, Peponis, & Penn, 1987; Peponis & Wineman, 2002). In other words, by looking at a building layout, we can predict where the most movement is likely to occur. Secondly, chances for encounter with and awareness of other people arise as a result of increased movement. This phenomenon is referred to as “virtual community” because it describes the probability that people come together as a result of spatial configuration (Peponis & Wineman, 2002).

Research in this area can offer helpful insights for the designer of a Teaching Green School Building. Both visual and movement-based accessibility are factors that will influence whether or how often students come into contact with green building elements, such as signage and displays. These spatial factors of visibility and movement also can affect the extent to which the school building layout enhances social community. Further, given this interest in movement and sightlines, it is interesting to consider perceptions of boundaries between distinct areas in the school building (Zimring & Peatross, 1997), because these perceptions likely drive the movement choices made by building users. As an illustration, consider the way different grade levels occupy distinct areas of the school building. For example, a fifth grader may not feel comfortable walking through the middle school to take out the recycling for her classroom. These psychological senses of boundaries may be particularly acute for youth and worth considering when placing teaching green features in the building layout. Further, a designer will want to consider how far people need to travel to arrive at teaching green features. For example, a single, distant recycling area is less likely to be used compared to numerous, close-by recycling bins.

In summary, research in Space Syntax has shown that interior configuration matters for a variety of social outcomes. Use patterns that enhance contact with the teaching features and help maintain a visible culture of sustainability could be outcomes due in part to the successful architectural configuration of a Teaching Green Building.

Meaningful Environment

Seibold-Bultman (2007) writes about the need for tangible manifestations of sustainability, or images and objects that bring abstract ideas into focus. These visualizations of sustainability are not simply educational, but can be designed to fascinate and inspire. They can "embody virtue" and evoke a creative reaction on the part of the viewer. Understood in this way, each new green building constructed is part of an on-going experiment to visualize sustainability (Seibold-Bultmann, 2007).

Insofar as spatial configuration can be quantified, tidy frameworks created and used, and environmental performance measured, there is no checklist for obtaining a sum of parts that is meaningful and aesthetically coherent. Among the tools in the architect's toolbox is the ability to craft environments that create an overall aesthetic through considerations such as material, form, scale, and color. More than trivial decisions, these aesthetic choices convey, whether with intention or not, core underlying philosophies about sustainability.

Consider two exemplar Teaching Green School Buildings, each LEED certified[5] K-8 schools and each designed with the intent to engage students in the greenness of the building, though with very different overall aesthetics (Figure 2-4). Both of these buildings were included in the empirical study to follow, and are described in more depth in Chapter 5. The Ethics School (School 3 in this study) has a campus comprised of numerous small-scale buildings divided by stone pathways and native plantings. Nearly all visible materials are natural, dominated by stone and wood, and the colors are consistent with those one would find in nature. By contrast, the Arts School (School 1 in this study) has a larger scale building with exposed mechanical systems, bright colors, and a mixture of metals, wood, and smartly manufactured eco-surfaces. Despite shared values about the pursuit of green design, it is clear that the two campuses read quite differently to the visitor. One on hand, the School 3 buildings communicate a proximity to nature, and a certain humbleness, while the School 1 structure is aspirational and the technological excellence visible. Each response aligns with slightly different paradigms of sustainable design, and therefore suggests different core philosophies held by each school. [See Guy and Farmer (2001) for a robust discussion of divergent philosophies in

5 Leadership in Energy and Environmental Design (LEED), advanced by the United States Green Building Council, is a major green building rating system in the United States.

sustainable architecture]. The schools' environmental philosophies are further underlined by factors institutional, cultural, and curricular.

Figure 2-4. Two different meaningful environments

The Arts School (School 1) is pictured in the images on the left and the Ethics School (School 3) is pictured in the images on the right.

The question of symbolic design choices in the Teaching Green Building would benefit from a more thorough discussion of architectural semiotics, a sub-area within architectural theory that addresses ways in which architectural design uses symbolism and communicates meaning (Leach, 1997; Preziosi, 1979; Venturi & Scott Brown, 2004). While the work here does not include an in-depth analysis of semiotics, it points to yet another area of literature that can inform the design of Teaching Green Buildings.

The Impact of the Physical Environment: A Summary

It is proposed here that aspects of the environment impact learning and behavior change. Table 2-1 summarizes these propositions. These propositions constitute researchable questions for the setting of the Teaching Green Building.

Table 2-1. Impacts of the physical environment on learning and behavior change

Physical Context Factor	Impacts for learning	Impacts for behavior change
Supportive Environment	A supportive environment provides learning content that is perceptible to occupants	A supportive environment provides opportunities to adopt environmentally responsible behaviors.
Comfortable Environment	A comfortable environment enhances cognitive function (by decreasing distractions and increasing opportunities for mental restoration) and thereby supports learning and behavior change.	
Well-configured Environment	A well-configured environment increases the likelihood that a person will engage with learning content presented by the building.	A well-configured environment increases the likelihood that a person will identify behavioral opportunities (affordances) and see other people in the building conducting environmentally responsible behaviors (social norms).
Meaningful Environment	A meaningful environment provides symbolic cues that can reinforce learning content.	A meaningful environment can evoke an affective response that contributes to one's desire to participate in the environmental performance of the green building.

Whole-school Sustainability

The elements of the Teaching Green Building Model for Learning (Figure 2-2), taken together, reveal that the physical structure of the building has both unique contributions and limits as a teacher, and that buildings designed to teach can benefit greatly from complementary social and organizational dynamics. Green schools working at various levels to promote sustainability are thus nurturing a "sense of place" that conveys sustainability through much more than the physical environment alone. In fact, scholars have begun to explore theories of place that integrate many channels of communication and explore the connection between place attachment and environmental stewardship. Most recently, Kudryavtsev et al. (2012) proposed that both *experiential* (*e.g*., hands-on features) and *instructional* (*e.g*., curriculum) components, used separately and in combination, can foster a sense of place that supports the goals of environmental education. They state: "The combined approach takes advantage of nurturing place meanings both through direct place experiences and through instruction, negotiation, and interpretation" (Kudryavtsev, Stedman, & Krasny, 2011, p. 240). The approach of weaving together experiential and instructional elements fits nicely with the Higgs & McMillan (2006) proposition to model sustainability through school facilities and operations, school governance, school culture, and individual role models. These two frameworks suggest that environmental education goals can be supported on many levels: from the institution to individuals. Though the dominant focus of this paper has been on the contributions of architecture to environmental education, the realms outlined by Higgs & McMillan (2006), particularly regarding governance, culture, and role models, deserve further attention due to their important contributions to a successful Teaching Green School Building.

To begin, institutional-level decisions can set the tone and expectations for sustainability in the school building. Institutional policies and campaigns that support the goals of the Teaching Green Building can include anti-littering, pro-recycling, paper reduction guidelines, and the procurement of environmentally friendly office supplies and cleaning products. Together these policies demonstrate institutional commitment and act as tangible reinforcements of a school-wide culture of sustainability.

There are numerous aspects of school culture that can impact the effectiveness of pedagogical architecture. Higgs & McMillan (2006) summarized the essence and importance of school culture:

> *The strong influence that culture has on people's actions, thoughts, and feelings makes it a powerful teaching tool. Culture is a pattern of shared assumptions, values, beliefs, and norms of behavior that is considered valid and is taught to new members of a group…School culture is manifested through the school's rituals, traditions, buildings, programs, instructional methods, and extracurricular activities (Higgs & McMillan, 2006, p. 47).*

Perhaps some of the most important cultural considerations are those of space and time. Imagine, for example, a Teaching Green Building with informally engaging features, but in a school environment where students are limited in terms of free time and ability to investigate the environment in self-directed ways. That is to say, a fast-paced school culture with strict rules about where students can be and go could be incompatible with the goals of informal environmental education through architecture. In contrast, schools that endeavour to create a safe environment for exploration and play, and give students the time and space to do so, are more likely to experience desired outcomes with informally engaging Teaching Green Building features.

Additionally, the types of rituals and traditions that are part of a school's culture can be supported by a Teaching Green Building. For example, schools that have morning gatherings, harvest celebrations, or host community-wide sustainability festivals are beginning to weave sustainability deeply into the fabric of their school's culture. The architectural space plays an important role in the types of cultural events a school can host. The nature of student-faculty relationships is another important factor in considering the ways in which the school environment, broadly, models sustainability for students. In their work on modeling sustainability, Higgs & McMillan (2006) found that "tight relationships between students and teachers appeared to have a strong influence on the effectiveness of individual role modeling" (44), which was then connected to the ability for teachers to help promote sustainability efforts through their own environmentally responsible behaviors. The idea of teachers modeling sustainability in the school environment is highly connected to the pattern of "social norms" discussed above – and further acknowledges teachers as special actors whose actions have the ability to either harm or reinforce school-wide sustainability messaging.

Finally, on the individual level, it is unclear how the features of a Teaching Green Building will succeed in engaging students with diverse personal backgrounds. Literature from museum studies suggests that personal motivations, expectations, and prior knowledge all shape the experience of the free-choice learner (Falk et al., 2007). As in museums, all of these factors likely impact individual experiences inside Teaching Green Buildings. This is yet another area for future research.

Chapter Summary

If the trend to build greener school buildings continues upward, there is likely to be increasing interest in ways that green building design and environmental pedagogy intersect. Despite a well-established literature base on technical aspects of green buildings, the topic of environmental education in green buildings remains largely unexplored in the literature. The work here attempts to establish a theoretical case for Teaching Green Buildings as potentially effective teaching tools. In addition, a propositional framework, the Teaching Green Building Model for Learning, is offered, demonstrating ways that architectural environments can both teach and support the process of teaching about environmental issues – and they can do so through strategies well beyond the provision of informational signage. The model lays out a framework inspired by three spectrums of engagement – formal-informal, individual-collective, and active-passive – and then offers four design patterns that bridge to architectural choices. The model additionally proposes that overall architectural decisions and a compatible institutional environment make a difference in the success of a Teaching Green Building.

There is yet a need to better understand how specific design features connect to much-desired environmental education outcomes such as environmental awareness, knowledge, and behavior change. A stronger conception of the Teaching Green School Building, aided by frameworks such as the one proposed in this paper, can inform future empirical research and support the design and evaluation of architecture that intends to be environmentally educational.

Chapter 3
Theorizing Green Building Literacy

Meaningful evaluation of the Teaching Green Building will depend on the ability to articulate educational and behavioral outcomes that we would expect to be influenced or supported by architectural design. There is no unified agreement about what precisely is meant by the phrases "School as 3-D Textbook" (Nair & Fielding, 2005; Taylor, 1993) or "School Building as Teaching Tool" (United States Green Building Council, 2008) – and likewise, there are no agreed-upon goals for these buildings. The previous chapter offered a framework that defines the mechanisms at work in a Teaching Green Building. The goal of the current chapter is to elaborate on the range of educational outcomes that define green building literacy as the desired set of outcomes for Teaching Green Buildings. This work looks to stated goals in the field of environmental education for guidance. Thus, the work here attempts to meet in the middle of two key disciplines that have not traditionally interacted: architecture and environmental education.

The combination of these disciplines is not so straightforward. Consider, for instance, the logic chain needed to move from the physical school environment to educational and behavioral outcomes. The physical building is but one influence in a complex social environment involving teachers, peers, institutional factors, and formal and informal curricula (Higgs & McMillan, 2006). Decades of work in environmental education, and related fields, has shown that the progression from education to informed action is more complicated than initially conceptualized by a field historically based on informational interventions (Hines et al., 1987; Hungerford & Volk, 1990; Kollmuss & Agyeman, 2002). It is now commonly acknowledged that pro-environmental behavior is multi-determined, likely involving a complex array of variables such as attitude, skill set, self-efficacy, and others (De Young, 2000; Geller, 2002; Kaplan, 2000). It is therefore reasonable to suspect that using green buildings as teaching tools would be fraught with similar complexities. In other words, to assume that the typical intervention of informational signage in buildings alone increases knowledge or changes behavior is to disregard decades of research in environmental education that cautions otherwise.

There are two halves to this chapter. The first half seeks to define the outcomes of green building literacy, and utilizes foundational theory in environmental education to aid the development of a framework. This provisional conceptualization of green building literacy can aid the process of goal-setting for, and evaluation of, the Teaching Green Building. The second half of the chapter examines the specific green building literacy outcomes of *green building knowledge* and *environmentally responsible behaviors at school* (referred to in this study as School behaviors) in more depth. This portion of the chapter creates the framework for the empirical analyses in Chapters 6 and 7.

Major Features of Green Building Literacy

Many types of literacies are integral to this research. For example, textual and technological literacies are both potentially important for reading and using the various features of a Teaching Green Building (*e.g.,* building signage and interactive kiosks about energy performance). Developing student abilities to navigate language and technology are common goals in contemporary education. These types of literacies are already well engrained into school missions. Environmental and architectural literacies, however, are less common in the educational landscape. Green building literacy sits at the intersection of architectural and environmental literacies (Figure 3-1).

Nathan B. Winters asserts that “years of research indicate that the lay public has not grown much beyond the fourth-grade level in visual literacy” (Winters, 2005, p. 1). If this is indeed the case, then the plight to educate *through* architecture is a challenging one. But the issue of visual literacy is not a new one. Numerous scholars writing in the 1970’s expressed concern that students were not being taught awareness of the physical environment [See Volume 82, Issue 4 of *The School Review* for one collection of such articles]. The pervading sentiment is summed up: "Developing...awareness is not simply a matter of studying facts and figures but rather of stripping the blinders from one's eyes and finding an active mode of perceiving the environment" (Sommer, 1971, p. 49). This kind of awareness was about more than being able to attach words to form; it was also about "awareness to one's immediate physical surroundings in a problem-solving fashion" (David, 1974, p. 693). Whether termed design awareness (Sommer, 1971) or environmental literacy (David, 1974), or the expanded notion of visual literacy (Dondis, 1973), the basic call was for an increased awareness and understanding of the designed environment, and in a way that fostered activism toward making environmental change. The term architectural literacy is used in this chapter to describe a person's orientation to – awareness of and knowledge about – the built architectural environment including human-made landscapes and buildings.

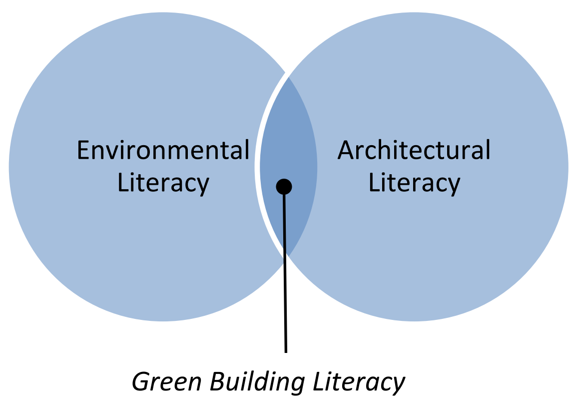


Figure 3-1. Positioning green building literacy

Environmental literacy[6] describes the ability of citizens to relate human and non-human systems as part of an interconnected fabric (Orr, 1992). Fairly clear-cut goals for environmental literacy can be found in the field of environmental education, which has

[6] It should be noted that the author has chosen to use the term "environmental literacy" and not "ecological literacy" since the former is broader in scope and incorporates the many dimensions social and technological that are pertinent to green building themes.

offered documents such as the Tbilisi Declaration of 1977 (UNESCO, 1977) which set the foundational objectives for environmental education as: awareness, knowledge, attitudes, skills and participation. These objectives build on each other – from recognition of the issues to desire and ability to make a difference to actually participating in environmentally responsible behaviors. Additionally, two different types of knowledge, both content and procedural knowledge, are highlighted in this framework.

Adapting a Framework from Environmental Education

Learning is not an outcome typically associated with architecture. Architectural theory for green building literacy thus benefits from foundational work in education. To merge environmental literacy and architectural literacy into a set of outcomes for green building literacy, a framework from environmental education can be adapted to focus on green building themes.

The "Major Features of Environmental Literacy" framework (Marcinkowski, 2010) builds off previous environmental education efforts (UNESCO, 1977), and is a useful starting point for considering what students take away from Teaching Green Buildings. While this table was designed specifically for curricular activities, it is perhaps illuminating to ask how the building, as a more silent type of curriculum, could contribute to these domains. The table below uses the same categories from the Marcinkowski framework, but adapts each cell to focus more specifically on green building themes (Table 3-1).

The columns are about the nature of the learning content, whether it is broad learning about nature or learning specifically about problems or solutions to environmental problems. The rows are organized by green building literacy outcomes: knowledge, skills, affective dispositions, and behavior. Note that knowledge and skills are combined in the sections to follow, as skills are conceptualized as procedural knowledge.

Table 3-1. Major Features of Green Building Literacy

(Marcinkowski, 2010)

	Nature	Environmental Problems & Issues	Solutions & Sustainability
Knowledge	Knowledge of the relationship between the built environment and eco-systems.	Knowledge of green building problems and issues	Knowledge of past and potential solutions to problems, issue resolution and social change strategies, and service/action strategies available to citizens
Skills	Field/lab skills used in study of nature – and particularly nature that intersects with the built environment (such as gardens, storm water runoff, and so on.)	Field/lab skills used in monitoring and analyzing/interpreting data on green building problems (threats/impacts), Skills used in identifying, analyzing, investigating, and evaluating green building issues (conflicts)	Skills involved in identifying, analyzing, investigating, and evaluating past and alternative/proposed solutions, Skills involved in planning, implementing, and evaluating service/action projects.
Affective Dispositions	Environmental sensitivity, Attitudes and values associated with nature	Environmental concern, or attitudes and values associated with problems and issues related to green buildings (*e.g.*, pollution, technology, economics)	Personal responsibility, Efficacy/Locus of Control, Willingness to Serve/Act
Behavior	Participating in various forms of nature-based outdoor recreation and education	Participation in various green building problems and issues at the community, county, state, and national levels.	Participation in responsible environmental behavior, individually and collectively, at various levels.

The school building could potentially serve as an intervention in all categories of the table, helping to foster outcomes on each dimension of knowledge, skills, affective dispositions and behavior. While some of these outcomes – particularly affect and behavior – could result directly from building design, the majority of outcomes call for the use of formal or non-formal curriculum. A framework such as this is not only helpful as an evaluative tool, it is also useful at the start of the design process of the Teaching Green Building, including the design of complementary curriculum. Green building literacy outcomes could again be reviewed when conducting post-occupancy evaluation of the building and curriculum. The following sections examine each of the Table 3-1 dimensions of green building knowledge (including skills), affect, and behavior.

Green Building Knowledge

The conceptualization and measurement of green building knowledge is one major undertaking in this study[7]. There are numerous dimensions of knowledge embedded in Table 3-1. The first category of knowledge covers understanding that is factual and conceptual in nature, while the category of skills refers to understanding that is more procedural.

To better understand the multiple dimensions of knowledge, the Taxonomy Table from the Krathwohl (2002) adaptation to Bloom's Taxonomy (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956) provides a useful starting point (Table 3-2). This table posits a six-step cognitive process dimension (i.e. remember, understand, apply, analyze, evaluate, create) and draws it across four different kinds of knowledge (i.e. factual, conceptual, procedural, metacognitive). The overarching goal of this framework was to standardize the way in which educators talk about delivering education. For example, a particular course or unit could be placed somewhere on this table, which helps to make clear its objectives, activities and assessments. To demonstrate the table in use, Table 3-2 depicts a fictional lesson plan on composting. Imagine a lesson that involves classroom learning about the scientific process of composting, involving recall of special terms (factual knowledge) and an understanding of the overall process of how food moves from the table to a final product as compost (conceptual knowledge). The lesson further involves collecting and weighing food scraps from lunch (application), recording the data (analyze), and then maintaining the compost bins. The final product is a chart of the

7 The concept of green building knowledge will be elaborated in depth here. How it has been operationalized in this study is described in Chapter 4 on methodology.

data collected throughout the project and a report that demonstrates understanding of the process (create). The point is that lesson plans – involving green building features and beyond – can be designed to engage multiple cognitive processes and engender different kinds of knowledge.

Table 3-2. The Taxonomy Table

The Knowledge Dimension	The Cognitive Process Dimension					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	X					
Conceptual Knowledge	X	X	X			
Procedural Knowledge				X		X
Metacognitive Knowledge						

(Krathwohl, 2002)

A key take away of the Taxonomy Table is the notion that multiple kinds of knowledge can be expected as outcomes – and that *use* of the knowledge varies as well, from reproductive (memorizing) to generative (creative) capabilities. The sections below address the dimensions in turn to suggest that there is not just one facet, but numerous facets, to green building knowledge.

Factual and Conceptual Knowledge

The scope of green building knowledge that can be conveyed architecturally is potentially quite vast. Green buildings can aspire to teach environmental literacy broadly by helping occupants to engage with a wide set of environmental issues, such as stream ecology, wildlife observation, and agriculture. It is also anticipated that Teaching Green Buildings educate more specifically about environmental issues that intersect with the design, construction and use of buildings. To this end, educators and architects could look to categories of green building rating systems as a starting point (United States Green Building Council, 2008). These rating systems are often divided into the following broad categories:

- **Sustainable Sites:** This category includes issues that deal with the surrounding context of the building, such as stormwater management, landscaping, transit to and from the building, and the effect of the building on light pollution and heat island effect.

- **Energy and Atmosphere:** This is a sizeable content area that addresses energy reduction, efficiency, and the carbon footprint that results from the building operations.
- **Water**: Issues here include the conservation of water through building fixtures such as toilets and sinks.
- **Materials and Resources:** Many important questions exist in the area of building materials. For example, do building materials contain recycled content, come from far distances or prior uses?
- **Indoor Environmental Quality** (Daylight and air quality): Green buildings also promote healthy indoor environments that are free of air and water-borne toxins and provide pleasant day lit atmospheres for building users.

These categories are applied broadly to green buildings of all types. It is prudent to further consider the special nature of the school building and the activities that happen in and around the building. Analyzing green school award programs offers insights on additional topics in green building curriculum. One analysis across such award programs resulted in a group of themes that included the five categories above from LEED, and then added the two additional themes (Pastorius & Marcinkowski, 2013).

- **Local and Healthy Food Choices**: This category explores the ways in which the green building support growing and consuming food choices that are healthy for both people and the environment. Units in this topic area would include those such as gardening, cooking, composting, and procuring local food.
- **Outdoor Experiences**: Green buildings can promote human health and at the same time promote low-energy practices. Nearby nature trails, for example, can enhance both physiological and psychological health with an activity that does not require electrical energy.

Taken together, these categories outline the basic elements of a green building, or foundational building blocks for a more sophisticated understanding of green buildings. What is yet needed is to communicate the interrelationships between building elements, and the ways in which these built features interact with the local ecology – the air, water, plant and animal life that surround the building. This latter type of knowledge is more conceptual in nature. It may include, for example, making the connection between turning off a light and the building energy that comes from a nearby coal power plant, which is then connected to air quality issues. Thus, while factual information within the categories described above can be taught and tested, a more advanced curriculum is needed to help students to connect factual knowledge into a systems-level understanding of green building issues.

Procedural Knowledge

Procedural knowledge relative to green buildings involves a fairly expansive array of skill sets. Table 3-1 offers a useful way to understand a broad set of skills that entail exploring, analyzing, and problem-solving at the intersection of building design and environmental issues.

An illustration of teaching green building skills can be found in the College Preparatory School (School 2) featured in this study (Chapter 5). In this school, a middle school science teacher uses the built environment of the school to help students develop green building skills related to water issues in urban settings. Her seventh grade students work together in small research teams to sample and analyze the water in a stream that runs through school property. By chance, this stream is downhill from a parking lot and thus collects runoff from the paved surface above. Among the many lessons learned in this unit, there is the potent realization that toxic particulate matter from the parking lot can be found in the stream water. This lesson leaves students not only with the knowledge that cars can impact water quality (conceptual knowledge), but the skills to test water quality and connect findings to practices in the real world (procedural knowledge).

Metacognitive Knowledge

Metacognitive knowledge describes the knowledge students have about their own cognition and learning processes. Its importance has primarily been discussed in realms of formal education, where students need to develop strategies for classroom learning (Krathwohl, 2002; Pintrich, 2002). For example, one type of metacognitive knowledge involves an understanding that multiple choice and essay tests each require different kinds of preparation. Another broad category of metacognitive knowledge involves self-knowledge, or a student's understanding of the way in which he or she learns best. Metacognitive knowledge is not the kind of knowledge that is typically evaluated, but "is important in terms of how it is used by students to facilitate their own learning" (Pintrich, 2002, p. 224).

Where the application for formal learning is somewhat clear, the connection between metacognitive knowledge and *informal learning,* and particularly informal learning in green buildings, presents an interesting question. If metacognition is, in essence, the ability to reflect on one's own learning experiences, then the question emerges: do students recognize their ability to learn from a green building? And further, does meta-cognition pertaining to informal learning enhance the learning that happens? This is a potentially interesting research question for the design and study of green building curriculum.

Affective Dispositions

Within the Marcinkowski (2010) "Major Features of Environmental Literacy" table (Table 3-1), affective dispositions include a person's environmental sensitivity, environmental concern, self-efficacy, feelings of personal responsibility, and willingness to take action. Note that these constructs are not purely affective, but also have cognitive dimensions. For example, feelings of responsibility may have a close mental link with the knowledge of an issue. Despite these potential overlaps with knowledge, this dissertation will maintain the Marcinkowski terminology of “affective dispositions” to describe factors that are attitudinal in nature.

Affective dispositions, such as those listed above, have been included in numerous theoretical models of behavior change (Azjen, 1991; Bamberg & Möser, 2007; Hines et al., 1987; Hungerford & Volk, 1990; Kaplan, 1991; Schwartz, 1977; Stern, 2000). These variables have been included in behavior change models based on decades of supporting empirical research, and their prevalence across the literature suggests that personal attitudes and feelings play an important role in the adoption of environmentally friendly practices.

Can green buildings impact general affective dispositions about the environment? If so, then the connection is certain to be convoluted and difficult to measure. Perhaps a more productive line of questioning is to ask: how can a building support the development of positive feelings toward the environment? Asked this way, we can begin to think about the important antecedents to environmental sensitivity (such as time alone in nature, and proximity to nature) and inquire how the built environment facilitates these needs.

Thus, one way to approach the question is to investigate students’ general attitudes about the environment, broadly speaking. Another angle to consider is the feelings that people have *about green buildings specifically* from their experiences inside such buildings.

The current study does not conduct an in-depth investigation of feelings relative to green building. Rather, it will explore more general affective dispositions toward nature and environmental issues. Environmental sensitivity and behavioral intention (willingness to act) have been shown over time to be two especially strong predictors of environmentally responsible behaviors (Azjen, 1991; Bamberg & Möser, 2007; Hines et al., 1987; Hungerford & Volk, 1990). For this reason, these are the two constructs that were included in the Green Building Literacy Survey (described in detail in Chapter 4).

Affective dispositions, and particularly the variable of environmental sensitivity (ES), are incorporated into the empirical work that follows due to their importance as predictor variables; however, they are not treated as dependent variables in the current research. There are several reasons for this. First, ES is notoriously difficult to influence with a single intervention. As Marcinkowski (2001) notes:

> *Environmental sensitivity is perhaps the most difficult of the significant predictor variables to address through formal education practices, since this would involve exposing learners to pristine natural environments on a direct basis over time, as well as on an indirect basis through role models, films, books, and the like. (Marcinkowski, 2001).*

Thus, ES is a variable influenced over time and experiences with nature, significant role models, and other external influences (Chawla, 1998; Tanner, 1980). It is also a variable highly influenced by factors in a student's life a home, such as influence from family members, and is thus results from many factors outside of the control of architects and educators in the school environment.

Environmentally Responsible Behaviors

The ultimate goal of environmental education is to bring about change not only in people's minds but in tangible benefits to our natural and built environment. Attempts to increase positive attitudes, awareness, knowledge, and skill sets would be largely for not if positive environmental behavior change were not the ultimate outcome.

The Marcinkowski (2010) conceptualization of participation, or behavior, is multi-faceted, including actions taken individually and collectively on levels local, national, and global (See Table 3-1). These many forms of action are applicable to the topic of green building literacy. Drawing out the many different actions helps us to envision impact that potentially extends beyond the singular green building. For example, consider the many ways a student could take action on energy issues. At the level of the building, a student can help turn off lights and shut down computers. The same student could work with peers in an environmental club to advocate for energy efficiency on their school campus. Further reach beyond the school building might include trying behaviors at home or writing local legislators about energy issues in public buildings.

Through these examples, we can begin to imagine how student knowledge, attitudes, and skill sets combine to pave the way for a wide range of environmentally responsible behaviors. In some cases, participating in a stewardship activity may be straightforward (*e.g.*, turning off the lights). However, complex behavioral decisions may require an advanced level of knowledge to achieve what Stern (2000) terms “environmentally significant behavior.” In his work, Stern distinguishes between *environmental intent* and actual *environmental impact*, a distinction that highlights the potential discrepancy between perceived and actual benefits of one’s behaviors. The disconnect between intent and actual impact may manifest in many arenas, from throwing the wrong type of plastic in the recycling bin to driving an electric car plugged into a coal-powered energy grid. In these cases, the intent is positive but the outcome is questionable. In terms of pedagogy and environmentally responsible behaviors, it is possibly more important to teach the process of *thinking through* a behavioral choice rather than promoting a specific behavior given that contexts and technologies are in constant flux.

The previous sections outlined high-level outcomes for green building literacy based on conceptualizations of environmental literacy and insights from the field of education. The major features discussed were knowledge (factual, conceptual, procedural, and metacognitive), affective dispositions, and environmentally responsible behaviors. Of these three major green building literacy outcomes, the two outcomes of knowledge and behavior will be the focus of the empirical work in this study.

Promoting Knowledge & Behavior

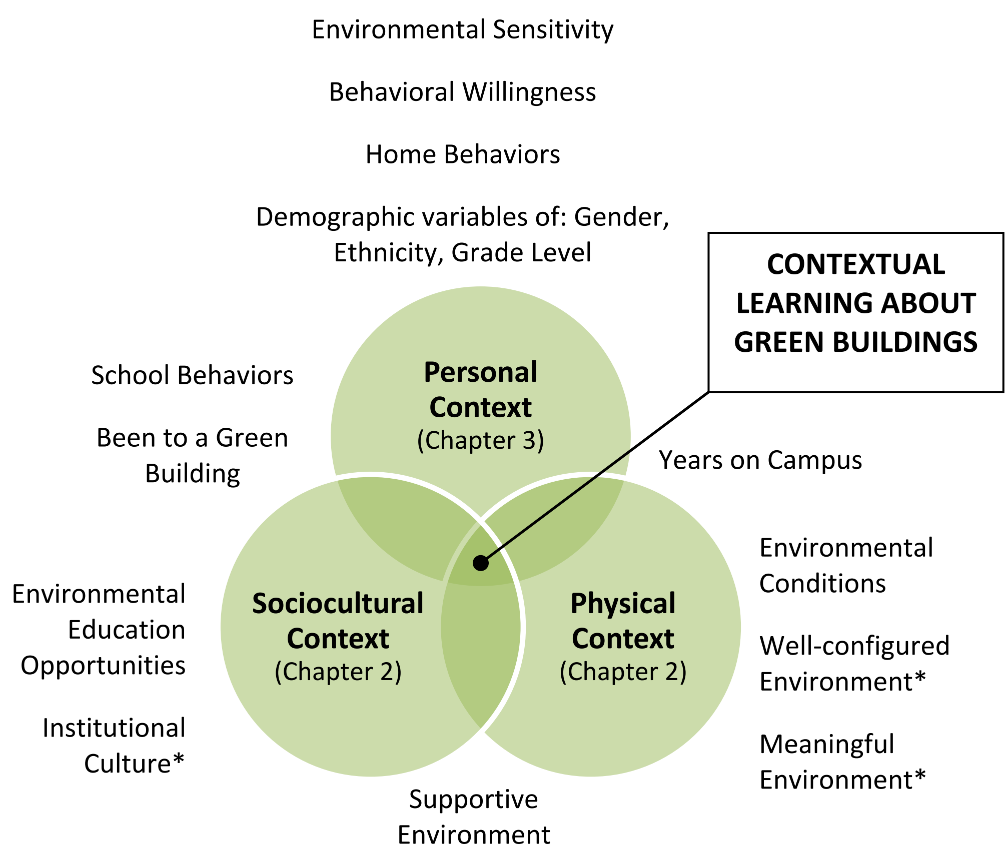
The primary foci of the empirical work to follow include green building knowledge and behaviors, and the ways these outcomes vary across settings and time in each non-green and green school building. The sections below discuss each of these major outcomes in turn and the factors that are hypothesized to influence each outcome. The sections below provide the linkages between theory and the empirical research design. Chapter 4 outlines the research instruments and measures in detail. Note that the predictor variables for each outcome are virtually the same. However, much research on behavior change allows for a more detailed propositional diagram regarding variable relationships, while the model for predicting green building knowledge is more nebulous due to the lack of research on this outcome.

Promoting Green Building Knowledge: A Contextual Model for Learning in Green Buildings

A primary goal of the current research is to investigate what students know about green buildings, and the factors that explain the variance in student levels of green building knowledge. This section ties together information introduced in this chapter and in Chapter 2 to propose a model for learning in green buildings.

The dependent variable of green building knowledge could be conceptualized in numerous ways using frameworks described in the first half of this chapter. But we are not only interested in the facets of green building knowledge, we are also curious about the factors that impact a student's level of green building knowledge. The "Teaching Green Building Model for Learning" (Figure 2-2) presented in Chapter 2 can be of use in this task. The Figure 2-2 framework combined the Falk et al. (2007) Contextual Model for Learning (Figure 2-3) with design patterns largely derived from conservation psychology and environmental education. The framework further included a robust discussion of the physical context (pp.29-37) that suggested numerous ways that the physical environment may impact learning outcomes (*e.g.*, by offering a restorative environment, comfortable environment, etc.). To operationalize these ideas for this study, the independent variables proposed to influence green building knowledge are arranged in a Venn diagram (Figure 3-2).

The major organizing principle of the Figure 3-2 diagram is the Falk et al. model, which presented three major domains of influence on informal learning experiences in museum settings, including personal, sociocultural, and physical contexts. As suggested in Chapter 2, this model is adaptable to the question of learning in green buildings, and particularly in a scenario where formal curricula are lacking and learning is assumed to occur through informal interactions with the physical environment and other people. This is the case in numerous Teaching Green School Buildings where the formal curriculum has not caught up with the physical environment of the school, and this is indeed the case with the Teaching Green Buildings that were part of the current study (see Chapter 5).



These factors were theorized, but not measured in the empirical work to follow.

Figure 3-2. A contextual model for learning about green buildings

Layered over the three Figure 3-2 domains are the numerous factors that fall into each domain and would be expected to impact informal learning outcomes, or contextual learning about green building issues. The factors in the sociocultural and physical contexts were discussed at length in Chapter 2, a chapter which sought to outline the field of external influences that are both sociocultural and physical in nature. The personal context factors were then elaborated in the first part of this chapter in the “Major Features of Green Building Literacy” section, which proposed a range of personal-level variables that pertain to environmentalism. The variables included in the diagram are not all-inclusive, but are presented here as a group of promising predictor variables based on the interdisciplinary literature reviews in Chapter 2 and the first half of this chapter.

Figure 3-2 organizes variables into three categories, but the categorization is simplified here and intentionally shown on a Venn diagram. These variables do not cleanly fall into the three major domains. Some variables sit between conceptual categories. Home behaviors, for example, is a personal-level factor that illuminates the behavioral choices students might bring into the school building from home. At the same time, home behaviors may be influenced by parental or sibling role models, and are therefore potentially motivated by external sociocultural factors. Another example is the notion of supportive environment, where the physical environment and the institutional culture fuse to encourage the adoption of environmentally responsible behaviors.

Notice that, as conceptualized here, the variables in the physical and sociocultural context are all specific to the school setting. Factors under the personal context are those that the student brings into the school building, though some of these factors certainly overlap with social and physical environments. For example, ethnic background contains sociocultural aspects and having been to a green building outside the school intersects with the physical environment. Both of these factors are included under personal context, however, because they are influences coming from outside the school setting.

Additionally, the complexity of relationships between variables in Figure 3-2 is not diagramed here. There are well-demonstrated relationships, for example, between affective dispositions (such as behavioral willingness) and environmentally responsible behaviors (Azjen, 1991; Hines et al., 1987). How these variables interact to predict green building knowledge, however, is unknown. The Figure 3-2 diagram is thus offered as a starting point for a research agenda in its early stages of development.

Promoting Environmentally Responsible Behaviors at School

The question of student environmentally responsible behaviors at school[8] is the second major outcome of interest in this work. Where predicting informal learning about green buildings is a more exploratory aim of the study, the study of environmentally responsible behaviors sits on firmer empirical ground due to advances over the last decades in conservation psychology, social psychology, and environmental education.

While numerous models of behavior change can be identified across disciplines, the use of one model over another depends on the context, core assumptions, and the behavior(s) in question. Azjen's Theory of Planned Behavior, for example, works under the assumption that behavior change occurs when there is a benefit to the individual that outweighs the costs (Azjen, 1991). This model can explain the choice to save money by driving less, for instance, but may not well explain altruistic behaviors where there is little to no tangible benefits to the individual, such as the decision to donate time and money to a cause. The latter types of behaviors are better predicated by normative models such as the Norm Activation Model (Schwartz, 1977).

There are many different viewpoints from which behaviors in the school environment could be examined. Per the Theory of Planned Behavior, the costs and benefits of student behaviors – such as time investment versus teacher praise -- could be measured to investigate the mixture of internal motivations and external influences acting on student choices. Alternatively, norm-based models could be used to measure student feelings of efficacy and responsibility toward solving environmental problems at school.

[8] Note that there is a spectrum of green-building related behaviors in which students could participate, such as joining environmental clubs or writing a congressperson (discussed on p.53). In this study, school behaviors refer to a simple set of environmentally responsible actions a student can take inside the school building, such as turning off lights and picking up litter (see Chapter 4).

As discussed earlier in the chapter, there are many different influences on behavioral decisions. Rare is it the case that a behavior is adopted and maintained by a person for one reason alone.

A primary objective of the current chapter is to investigate the role of the physical environment in environmental education, and more specifically in green building literacy, which includes behaviors conducted in green buildings (Table 3-1). Thus, a desirable behavior change model for investigating relationships between the physical environment and behaviors at school would be a model that incorporates contextual factors.

The Hines et al. model for environmental education is one predictive model of behavior change that targets environmentally responsible behaviors and includes a set of variables entitled situational factors (Figure 3-3) (Hines et al., 1987). The basic proposition of this model, which is based on a meta-analyses of studies up through 1987, is that cognitive and psycho-social variables determine a person's intention to act (behavioral intention), which then increases the likelihood that the person will conduct the environmentally responsible behavior in question. The model goes beyond the person-level factors to additionally propose that situational factors have a direct influence on behavior. The situational factors alluded to were not emergent from the meta-analysis, however, and remain fairly ill-defined by the authors. A follow-up meta-analysis 20 years later integrated a more robust description of situational factors including social norms and perceived behavioral control (Bamberg & Möser, 2007), though the influence of the built environment is yet absent.

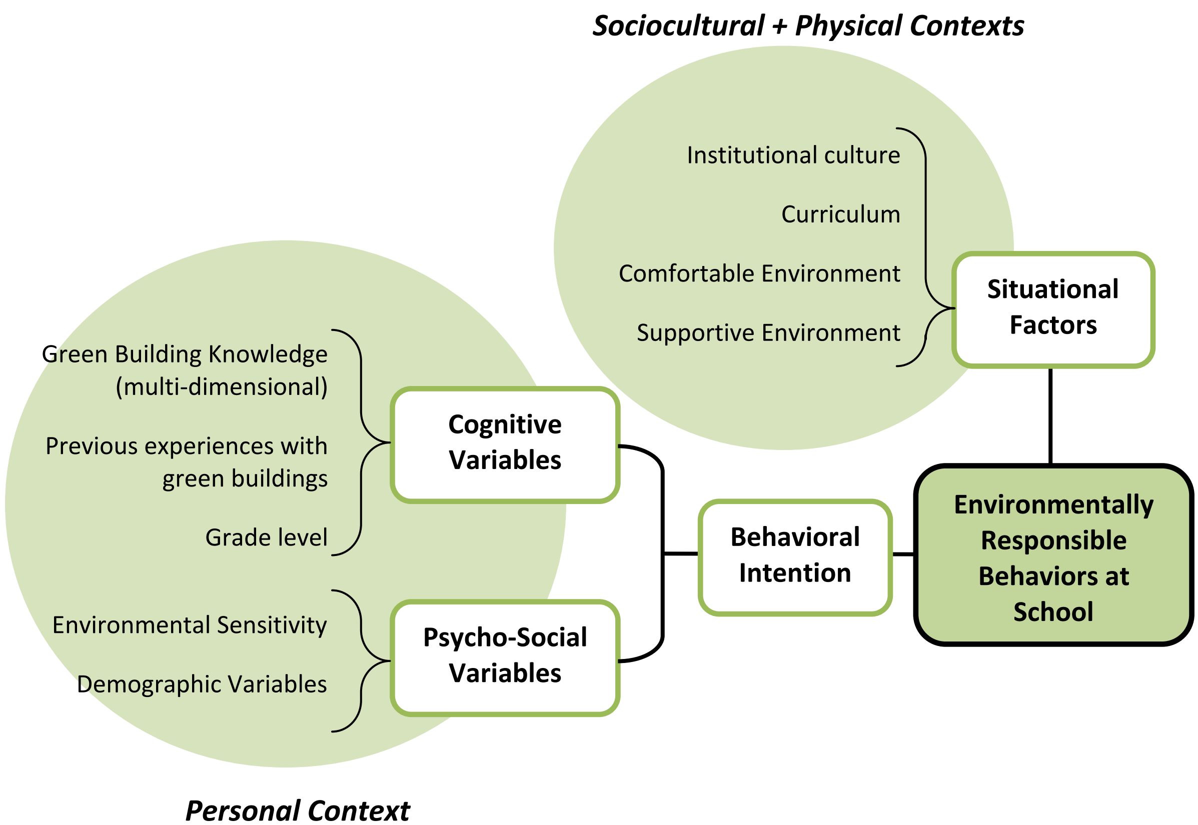


Figure 3-3. The Hines et al. (1987) model for predicting ERB, adapted for school behaviors

The factors of interest in the current study have been layered into the Figure 3-3 diagram. The three domains of the contextual model for learning (personal, sociocultural, and physical contexts) are also overlaid here, and align nicely with the categories within the Hines et al. model. Situational factors in the Hines model could be conceptually divided into sociocultural and physical context factors – and this is the area of primary interest in this study. Where previous research in environmental education and museum studies has been slightly vague in terms of the physical environment, the current study investigates a multitude of physical environment factors for their relationship to environmentally responsible behaviors in the school setting. This is a complicated set of factors that covers a great range of external influences on student behaviors. Some of these external influences may be direct, such as rules and policies that mandate behavior or whether a building physically supports recycling by offering recycling bins. Other external influences are more subtle in nature, and can include the behaviors modeled by teachers and peers or whether the environment supports mental health by reducing environmental distractions and providing opportunities for mental restoration. While the latter factors are challenging to connect directly to behavior, they are potentially part of a system of factors acting on a student's behavioral decisions in the school environment.

Chapter Summary

Within the practice of designing Teaching Green Buildings (TGB's), we need to move beyond vague notions of learning. Literature in environmental education and broader educational theory offer adaptable frameworks for conceptualizing the range of environmental education outcomes possible in TGB's. These tools can be used to both design and evaluate architecture with pedagogical intent.

This chapter examined four major dimensions of environmental literacy (knowledge and skills, affective dispositions, and behavior), and applied each domain to learning about green buildings (Table 3-1). The overlap points toward an initial theorization of green building literacy as a sub-theme within broader prospects for environmental literacy. The work here adds to environmental education frameworks by drawing forward factors in the physical environment.

The chapter concludes by offering propositional models for predicting two primary outcomes of interest: 1) green building knowledge, and 2) environmentally responsible behaviors at school. These frameworks will be investigated in more depth in the analyses and discussions in the chapters that follow.

Chapter 4
Methods

This chapter offers an overview of the methods used for this study. It begins by outlining the research setting and participants involved in the study, and then describes the two major data collection methods: 1) the survey instrument design and administration in five schools and 2) the running of a student photo documentation project in four of the five schools. Data analysis procedures will be discussed for each approach. Additional supporting evidence for each school, including interviews with key informants, focus groups with teachers, and building documentation, will also be described.

Research Settings and Participants

School building architectural intent was the major determining factor of buildings selected for this study. Desirable research sites were not simply LEED certified school buildings, but they were green buildings that additionally aspired, through design, to teach students about the buildings' environmental features. In this study, such buildings are called Teaching Green Buildings (TGB's). TGB's are not only difficult to find, but unlikely to be in the same geographic region. It is for this reason that geographic location could not be held constant in this study. Three TGB's were identified through a process of web searching and making contact with organizations such as the U.S. Green Building Council. When a school granted permission for the researcher to conduct the project, examples of local non-green school buildings were sought for comparison. Comparison schools for the Midwest and West Coast schools were identified, however, no comparison sites were obtained for the East coast middle school.

TGB's can be found at all levels of the educational system from elementary schools to high schools to college campuses. The student grade level, and the ultimate choice to conduct the research in middle schools, was not a determining factor at the beginning of this project. However, after two strong exemplars of a TGB were identified at the K-8 level, and permission to conduct the study was granted by each school, all other schools were chosen for having 6-8th graders present on campus.

Table 4-1 offers information about participating schools in this study. These five schools are all located on suburban campuses that adjoin wooded areas, they all have curricular freedom compared to schools in public school systems, and they have numerous commonalities in terms of demographics. There are, however, many differences among schools that bear noting. Chapter 5 on School Settings elaborates in-depth on the make-up of schools in this study, including information about school buildings, driving philosophies, and programs and curricula of pertinence to this study.

The timing of the West Coast Teaching Green Building (School 1) construction presented the unique opportunity to work with students before and after their move into the new construction building. Thus, there are two basic data sets in this study: 1) a comparison of School 1 over time, and 2) the comparison of data collected from all five schools in the same academic year.

Table 4-1. Basic information about participating schools

School	**U.S. Region**	**Building Type**	**Time period constructed** (renovated)	**Grades**	**School Type**	**# of students in middle school**	**Tuition**
1	West Coast	TGB	2011	K-8	Public Charter	150	$0
2	Midwest	TGB	1968 (2011)	6-12	Private	220	$18K
3	East Coast	TGB	2003;2007	0-8	Private	44	$24K
4	West Coast	Non-green	1970's	K-8	Public Charter	65	$0
5	Midwest	Non-green	1960's	0-8	Private	75	$12.8

"TGB" refers to a LEED certified Teaching Green Building; "Non-green" refers to a school building that is not certified by LEED or any other green building standard. Grade level 0 = Pre-Kindergarten.

Research Questions

The investigation of green building literacy, with its many domains, is core to this study. The major features of green building literacy were unpacked in Chapter 3 (Table 3-1). Given that little precedent research exists on the topic of green building literacy, the research was designed to broadly measure numerous themes. The research questions for the chapters ahead reflect the exploratory nature of this study.

Chapter 6 includes data from all five schools in the study, and focuses on survey data from the Green Building Literacy Survey (GBLS). The research questions posed in this chapter are:

1. In terms of green building literacy and educational context factors, are there statistically significant differences observed between: a) school settings, and b) grade levels?
2. What factors explain variance in levels of: a) student green building knowledge, and b) student environmentally responsible behaviors at school?

Chapter 7 examines the specific setting of School 1, where data was collected over time and also with a local comparison school (School 4).

1. Are there statistically significant differences in green building literacy measures and educational context factors in School 1 before and after the move into a new Teaching Green Building?
2. Are there statistically significant differences in green building literacy between the School 1 and its comparison school, School 4?

Mixed Method Data Collection

Mixed methods of survey research and the student photography project were deployed across school settings. Table 4-2 summarizes the data collection activities that were possible in each setting[9]. Note that issues concerning budget, timing, and personnel availability prevented a uniform administration of research methods across the schools.

The first round of data collection occurred in May 2011 with School 1 prior to their move into a new construction Teaching Green Building. Data collection across all five schools, including School 1 post-move, occurred in the 2011-12 school year. School 4 was a late addition to the project, and the information about this setting is thinner compared to other schools.

Table 4-2. Summary of data collection activities in each school setting

School	Building Type	Survey	Photography Project	Admin/ Teacher Engagement	Teacher Focus Group	Architect Interview
1	TGB	X	X	X	X	X
2	TGB (Renovation)	X	X	X		
3	TGB	X	X	X	X	X
4	Non-Green	X		X		
5	Non-Green	X	X	X		

The Middle School Green Building Literacy Survey

This section will discuss the development of the survey instrument, the major constructs it measured, how it was administered, and how it was prepared for analysis.

Instrument Development

Using existing frameworks in environmental education research and green building practice, the "Green Building Literacy Survey" (GBLS) was developed for middle school students (Appendix A). The primary goal of the survey instrument was to measure a range of factors that would comprise or impact green building literacy (See Chapter 3 for a detailed discussion of green building literacy). The GBLS was developed by the authors and tailored to middle school students using two primary tools: an existing

[9] Institutional Review Board (IRB) approval was obtained for all data collection activities in April 2011, with amendments as new study site were obtained (IRB Study ID: HUM00049701).

survey instrument designed for middle school students and the LEED framework[10] for categorizing green building issues (United States Green Building Council, 2008). The study author is a LEED accredited professional, and three outside LEED accredited professionals, all architects, were consulted independently in the development of the green building knowledge questions. Prior to launching the survey in the five case study schools, the instrument was tested in two ways: 1) An early-stage "talk aloud" pilot with an 11 year-old male, and 2) two iterations with two different groups of ten 5th graders at a public school that was not part of the main study. These pilots illuminated problem words and questions, and were especially helpful for those parts of the survey instrument that were newly drafted (i.e. questions not based on previous instruments).

The structure for the survey instrument was based on the Middle School Environmental Literacy Survey (MSELS) (Bluhm, Hungerford, McBeth, & Volk, 1995). This instrument was developed over time, involving multiple research institutions and a panel of diverse stakeholders, to measure the Environmental Literacy of middle school students in the United States, and was part of the National Environmental Literacy Assessment project. The MSELS was designed to measure Environmental Literacy (EL) broadly, and using a current agreed upon conceptualization of what EL is (McBeth, Hungerford, Marcinkowski, Volk, & Meyers, 2008). The survey instrument thus measured constructs as diverse as ecological knowledge, environmentally responsible behaviors, environmental sensitivity, the ability to identify and analyze environmental issues, and knowledge of action strategies (McBeth et al., 2008, p. 15).

The current study investigates green building literacy, which could be considered a sub-theme within EL. The MSELS survey instrument was thus adapted for this study to add constructs of interest.

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[10] The framework used was the Leadership in Energy and Environmental Design (LEED) system developed by the United States Green Building Council (USGBC) specifically for schools in 2009.

The sections adapted from the MSELS were typically modified in one of several ways. First, the MSELS is a computer-scored exam, while the GBLS was administered using pencil and paper, thus the GBLS was able to feature more write-in questions. Second, the GBLS carefully edited out survey items to reduce the overall length of the survey instrument, which then allowed for the addition of questions regarding other constructs of interest (constructs aligned specifically with topic of student experiences in their green and non-green school buildings).

Survey Instrument Measures

This section outlines the banks of questions that were included in the GBLS. These are based on concepts outlined in Chapter 3 on "Theorizing Green Building Literacy." After data collection, these question banks were analyzed for statistical soundness. The results of these analyses are reported in Appendix D.

Green Building Knowledge: A significant portion of the GBLS involved assessment of green building knowledge (Parts I and II of the GBLS). This part of the GBLS will hereafter be referred to as the green building knowledge test. The LEED Rating System for Green Buildings was used as a guiding framework to determine question content.

Figure 4-1 illustrates how the green building questions of the GBLS map onto the LEED for Schools rating system. This figure depicts graded weight of each category, which is the weight of questions relative to the total score possible for the test. Note that sustainable food issues comprise one knowledge category that was covered by the GBLS, but is not part of LEED. Gardening and composting systems are common features of Teaching Green Buildings, and are thus areas where students would be expected to gain competency.

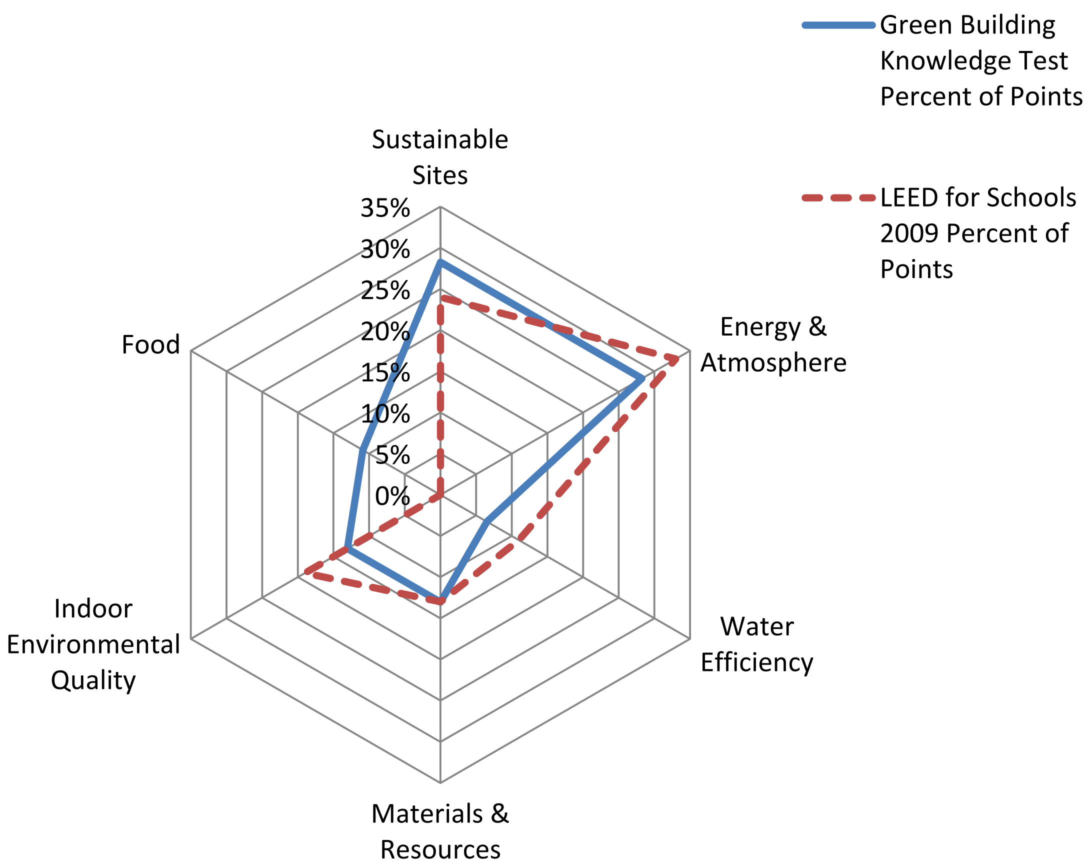

Figure 4-1. Green building knowledge test question content compared to LEED categories

On the green building knowledge test, there were a total of 30 questions, which took the form of write-in, multiple choice, photo identification, and fill-in-the-blank questions. Before students began the main portion of the knowledge test, they were asked to: "Please write a list of environmentally friendly building features with which you are familiar" and were further told "You do not have to fill in all the blanks if you do not know four (4) environmentally friendly building features." This portion of the test allows the researcher to analyze the types of themes that students mention before they have turned the page and read the rest of the knowledge questions. The multiple choice questions covered themes such as composting, native plants, and indoor air quality. The photo identification portion showed photos of a bike rack, a sensor faucet, a solar panel, and a wind turbine, and asked students to name the object and briefly describe its environmental benefit. Finally, the fill-in-the-blank questions gave students question items such as: “A vegetable garden at school can help the *environment* by…” and “Give one reason why *local building materials*, or building materials made close by, could be good for the environment.” The test was graded by the researcher and analyzed for summation into a composite green building knowledge score for each student. The analytical process is described in the second half of Appendix D.

Note that there is some range to the type of knowledge measured in the GBLS green building knowledge test (Parts I and II of the GBLS). Chapter 3 presented the multi-faceted nature of green building knowledge that included factual, conceptual, procedural, and meta-cognitive knowledge types. The types of knowledge for which students were tested in the GBLS include factual and conceptual knowledge about green buildings. For example, the photo identification portion of the test asked student to name the green building feature in the photo (factual knowledge) and then describe how this feature benefits the environment (conceptual knowledge). Likewise, fill-in-the-blank questions asked students to name water saving features (factual knowledge), but also asked students to complete sentences about how daylight impacts building performance (conceptual knowledge). The multiple choice questions covered a range of knowledge types, from picking out the alternative energy source (factual), to considering sources that impact indoor air quality (factual/conceptual), to the ingredients of a successful compost pile (procedural knowledge). In the knowledge test, procedural knowledge is minimally addressed and meta-cognitive knowledge is not addressed. The student photography project, described in the next chapter on methodology, was a means to assess student awareness and knowledge in a more qualitative fashion.

<u>Environmentally Responsible Behaviors</u>: There were 14 questions designed to measure frequency of student environmentally responsible behaviors (ERB’s), where actions were rated on a 5-point scale from “never” to “always.” The questions asked about behaviors at both home and school, such as turning off the lights, recycling, composting,

helping others remember to take action, and talking with parents about environmental problems. Three questions in this section were adapted from the MSELS Section IV. "What You Do About the Environment" (Bluhm et al., 1995). For analysis, these questions were divided into behaviors student conduct at home and those students conduct at school.

Environmental Sensitivity: The survey instrument included nine questions intended to measure a student's environmental sensitivity (ES), or predisposition toward caring about the environment. Much literature in environmental education has shown a consistent relationship between ES and environmentally responsible actions (*e.g.*, Chawla, 1998; Hungerford & Volk, 1990; Marcinkowski, 2001), and thus may be expected to impact the ways in which a student interacts with his or her green school building. All questions were on a 5-point scale from "Not at all" to "A great amount." Two questions asked for a general assessment of ES: one where the students rated themselves and a second question where they rated their families. The remaining questions asked about known indicators of ES, such as whether or not students read about nature, spend time outdoors alone, or have a role model for ES. With the exception of two questions that asked about green buildings, all questions were adapted from the MSELS Section V. "You and Environmental Sensitivity" (Bluhm et al., 1995).

Behavioral Willingness: The intent to take action is a separate construct from, though typically highly correlated with, actual environmentally responsible behaviors (ERB's) (Ajzen & Fishbein, 1977; Azjen, 1991; Hines et al., 1987). In conservation psychology research, questions about willingness or intent have in certain circumstances been considered acceptable substitutes for measuring behaviors, particularly in settings where behaviors are difficult to either conduct or measure. In the current study, willingness to adopt ERB's can be compared across green and non-green schools, where the physical environments in the study offer very different opportunities for actually conducting ERB's. The willingness scale thus detaches student willingness to act from affordances in the actual physical environment, and allows for a comparison of students across schools. It is worth noting that all seven questions on this scale pertained to ERB's that are likely to be conducted in the home environment. Questions were assessed on a 5-point agree/disagree scale ranking willingness to take actions such as reducing water for bathing, saving energy by using less air conditioning, and walking more places to reduce air pollution. All seven items were adapted from the MSELS Section III. "How You Think About the Environment" (Bluhm et al., 1995), including a fluctuation between statements that are both positively and negatively worded, a strategy meant to increase the likelihood that students consider each question and reduce the likelihood that students check boxes down a single column. Interestingly, when these questions were reversed coded to move in the same direction and then input into factor analysis, the positive and negative questions split into two different factors. This ultimately led to the omission of all questions with the negative stem in the final analyses (see Appendix D on the development of survey categories for analysis). It appears that numerous students misunderstood the double negative in the reversed questions.

Supportive Environment: Students were additionally asked to rate their school environment for its supportiveness regarding environmentally responsible behaviors (ERB's). Questions asked students to assess support from each the building, teachers, and peers for helpfulness in taking ERB's. The items were rated on a 5-point scale from "Not at all" to "A great amount," and included statements such as: "There are opportunities to take environmentally responsible action in my SCHOOL BUILDING" and "The SCHOOL BUILDING (MY TEACHERS, MY PEERS) help(s) me learn to take environmentally responsible action while at school." (Based on the survey instrument pilot, select words were capitalized to call student attention to what is being assessed.) These items, in combination, measure the level of support students perceive they are receiving from the school environment, where *environment* is understood broadly as a combination of social and physical environmental factors.

Environmental Conditions: Five survey questions asked students to assess the environmental conditions of their own school building, including an assessment of temperature, lighting, noise, connection to nature, and general satisfaction with the school building. These questions were ranked on a 5-point scale from “Not at all” to “A great amount.” These questions were considered potentially important for understanding the personal comfort dimension of a student’s experiences in a building. Comfort, and particularly discomfort, are hypothesized to affect student affective responses to the building, a response that may in turn affect the ways that a student thinks about and relates to the building.

Environmental Education Opportunities: Four survey questions asked students to assess their exposure to environmental education broadly and green building education specifically, with a separate survey question to rate activities inside and outside the classroom for each. Since the topic of green buildings might be new and unusual to some students taking the survey, capitalized and underlined text was used to call student attention to the concept (e.g., “What is the extent to which you learn about GREEN BUILDINGS from…”). Additionally, for green building questions, students were given the opportunity to write-in a description so that the researcher could assess student understanding of the questions.

Student Background Information: Finally, students were asked a number of background questions. The front page offered an introduction to the study and a definition of “green buildings” and asked students to answer the following questions:

- Name
- Grade Level
- Have you been to a green building before? (not including your own school building)
- How much do you know about green buildings? (5-point scale from “Nothing” to “A Lot”)

The back page of the survey instrument asked students to input:

- Gender
- Birthday
- Grade student began attending the school (Used to calculate number of years on campus)
- Ethnicity

Students were asked for their names so that the researcher could match surveys to parental consent forms and also in anticipation of matching follow-up surveys in future years. The student names are kept in a confidential and secure file separate from the files used in the data analysis process.

Administration of the survey

The researcher worked closely with middle school science teachers in each school to administer all data collection activities. Teachers played an instrumental role in the data collection process, and not only in terms of scheduling class time for the researcher, but often working with the researcher as collaborators in the scientific process. Science teachers were identified because it is their curriculum that is most likely to address school building sustainability, or sustainability topics in general. It was coincidental, and quite beneficial to the project that these individuals have in-depth knowledge of scientific method, and were thus able to assist with threats to validity throughout the data collection process. Examples include seating students to limit student interactions during the survey and refraining from helping students with answers to knowledge questions.

In each school, the survey instrument was administered within one class period. The survey instrument was administered by the researcher in some settings and by educators in other settings. The logistics of when and how to fit the survey within the existing curriculum and balance the survey administration with simultaneous data collection events made it impossible to control for administrator. To reduce variation, the same introduction script was used by all survey administrators.

Depending on the school, the amount of time available for the survey administration ranged from 40-60 minutes. However, students typically needed less time than the length of the period, with 24 minutes as the median and average amount of time students across schools took to complete the survey.

Students were invited, but not required, to participate. Recruitment for the project was conducted by teachers in each school. As incentive to return parental consent forms, the researcher entered participating students in a raffle for a bookstore gift certificate and gave small token gifts (such as cookies and pencils) to all students who submitted the survey.

The students completed the survey instrument with pencil and paper, and the results were subsequently entered digitally into a database by the researcher.

Table 4-3. Survey response rate across schools

School	n	Response Rate
1	92	61%
2	175	80%
3	44	100%
4	32	51%
5	56	75%
Total:	**399**	**73%**

Survey Data Analysis

The researcher input all pencil and paper survey instrument data into a digital Excel spreadsheet that was then prepared for input into SPSS. All data were analyzed using SPSS software, unless noted otherwise. Prior to category development, survey items were analyzed one-by-one in SPSS frequency outputs for potential data input mistakes. A priori categories, described in the “Survey Measures” section above were then used as the starting point for developing final categories for analysis. The in-depth process of category development is described in Appendix D, including items that were omitted based on statistical tests. The green building knowledge test scores were subject to a different set of analyses given that the questions in this section where not scaled questions, but test questions meant to measure students' overall comprehension of green building themes. The procedures used to finalize the knowledge test are described in the second half of Appendix D.

There are eight categories that were confirmed via statistical analysis. These categories again are: Green building knowledge, School behaviors, Home behaviors, Environmental sensitivity, Behavioral willingness, Supportive environment, Environmental conditions, and Environmental education.[11]

There are two different data files. The first contains West Coast school data, including the pre-move and post-move data from the Arts School plus the data for its comparison school, the Technology School. This is the data file used for Chapter 7. The second file contains the data collected during the academic year of 2011-12 for all five schools, thus excluding the pre-move data for School 1. This is the data file used for Chapter 6.

Following data preparation, multiple statistical procedures where used. For the multi-school study in Chapter 6, Ordinary Least Squares (OLS) regression was the primary data analysis technique used. Chapter 7 analyses included descriptive statistics, independent samples and paired sample T-tests. A more detailed explanation of each analysis is provided in the pertinent chapters.

Student Photography and Interviews

The photo documentation project was modeled after an approach called Photovoice, a technique recognized for its ability to involve the participants in research in an active,

[11] Per APA standards, the first word of these categories will hereafter be capitalized when the document refers to the category as the one finalized through factor analysis.

participatory way (Strack, 2004; N. Wilson, Stefan Dasho, Anna C. Martin, Nina Wallerstein, Caroline C. Wang, Mereditch Minkler, 2007). It has been used to assess informal learning (O'Neill, 2005), and help researchers better understand issues such as childhood obesity (Darbyshire, 2005), public health promotion (Wang, 2001), and youth perceptions of their urban environments (N. Wilson, Stefan Dasho, Anna C. Martin, Nina Wallerstein, Caroline C. Wang, Mereditch Minkler, 2007), to name a few examples. It has been described as a method that can increase participant empowerment in the research process by shifting the dominant lens on the issue from the researcher to the participants. Similarly, in the current study, it was a method selected as a way to engage middle school students with their school environment in both visuals and language, and in a way that allows them to drive the conversation from their own point of view. The approach was intended to remove, to the extent possible, teacher and architect expectations from actual student experience, with a focus on how students perceive the environment around them. The method additionally allows students to express themselves through multiple avenues including both imagery and text, and is thus a method well-suited to the middle school age group with a characteristically high variance in language skills.

Photography Data Collection Process

The Photovoice data collection process in this project was multi-stage and conducted with 7th graders in four school settings. The project spanned over 1 week and yielded data that is both image-based and text-based, and included interview data for a subset of students at each school. In three schools,[12] the researcher was able to conduct the project within science class periods, requiring one day for an introduction, one to two days for photography around the school and grounds, and one final day for editing photos and assembling photo boards. Several days after boards were assembled, the

[12] One school could not fit the project in the science curriculum, and the researcher designed an afterschool version of the project for students. This scenario resulted in a much smaller group of students who participated in the photography project at this school compared to other schools.

researcher chose a subset of students for 20-minute one-on-one interviews, typically endeavoring to meet with a mixture of boys and girls, and with a particular interest in talking to students who wrote little to no text with their photos.

In the first meeting with each class, the researcher introduced herself and the project. Beyond giving the project assignment, the project introduction had two major goals: 1) encourage creative expression through photography with a strong focus on the research question, and 2) discuss the phrase "environmental sustainability," which was of central importance to the photo taking assignment. For the first goal, students were shown numerous photos of a reusable water bottle taken by the researcher, each illustrating different camera angles and lighting considerations. For the second goal, the researcher asked students to help her define the phrase, collecting different phrases the students already use, such as "being green" and "saving the planet." The researcher repeated and agreed with all of the definitions shared by students, and then summarized by saying that environmental sustainability is about sustaining the environment that surrounds us.

Creating Photo Boards

After discussing the concept of environmental sustainability, the researcher segued into the introduction of the photography project. Students were instructed to take photographs that answered the following question: "Where do you learn about environmental sustainability around your school campus?" Taped to each disposable camera was a fluorescent piece of paper with the driving question and the project rules to help students remember (Figure 4-2).

Where do I learn about environmental sustainability around my school building?

- TAKE 20 PICTURES OR MORE: AT LEAST 10 PHOTOS MUST BE INDOORS.
- Please work on your own.
- Focus on objects and areas. Ask permission if you photograph a person.
- You can use both positive & negative examples of sustainability.

Figure 4-2. Camera label to remind students of project question and rules

Introducing the question and the rules typically took the whole class period. If time remained, students were given a piece of paper and encouraged to start planning the photographs they want to take tomorrow.

The following day in science class, disposable cameras[13] (each with 27 exposures available) were distributed to students and they were given the whole period to take photos indoors and outdoors, with the rule that at least 10 photos needed to be indoors.[14] Students were highly discouraged from working together, but the tendency for middle schools to group together and walk around with friends was impossible to control. Occasionally, a student desired to go to a part of campus that required adult accompaniment (such as walking to a stream at the edge of the property or toward the front road to photograph the school sign), and the researcher or classroom teacher would assist.

Cameras were collected at the end of the day and taken to the nearest location for film development and "1-hour" processing, where the researcher requested a single set of prints and a photo CD to have digitized copies. Within the next 24-48 hours, the photos would be organized into envelopes for each student and all materials prepared for the final classroom activity of making photo boards.

One of the most important aspects of setting up the photo board creation activity was assigning students to seats distanced from their friends in the class. Before the period, the researcher would work with the classroom teacher to place photo boards and envelopes across the room to create appropriate assigned seating. Before students were directed to find their photos, the science teacher highlighted the importance of today's process, reiterating that this is a scientific process of collecting information, and that we need their complete cooperation and full attention today. Students were then

[13] One school had enough digital cameras for all seventh graders to use digital photography for the project. Disposable cameras were used in all other schools.

[14] This rule emerged from pilot studies where students were so excited to be outdoors that they neglected to take interior photos.

instructed through a multi-step process by the researcher, who used a PowerPoint presentation or a blackboard to keep the instructions in front of students at all times. The steps were as follows:

- **Review Photos:** Open your photo envelopes and look at your photos
- **Edit Photos:** Select the top 12 photos that *best* answer the project question for YOU (the question was on screen or board)
- **Rank Photos:** Rank these photos from 1-12, where #1 is the photo that best answers the question for you. Place the numbered stickers in the top corner of each photo.
- **Locate Photos on a Map:** Now, take the campus map and indicate where each numbered photo was taken using a second set of numbered stickers.
- **Attach Photos to Board:** Now attach your top 12 photos to your poster board, leaving room to write about each one.
- **Add Text:** Write 1-2 sentences about each photo on your board. Your sentences should help me understand what the content of the photo is and why you took it. You can start your sentences with: "This photo teaches me about sustainability because…" or "The environmental lesson I learn here is…"

Figure 4-3. Student photo board example

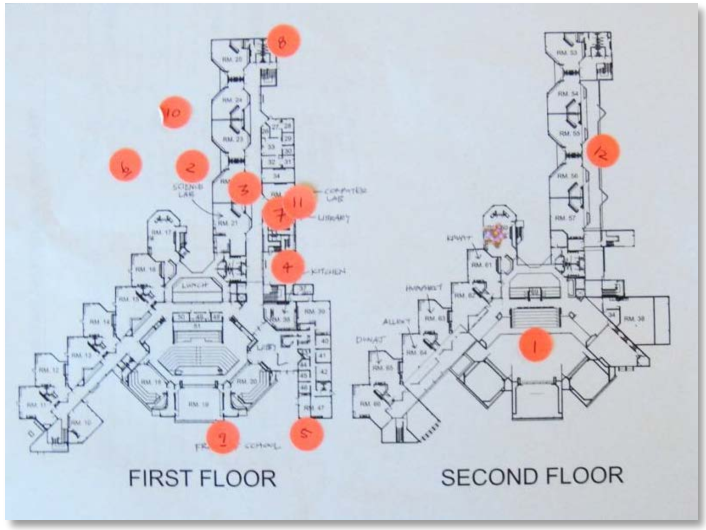

Figure 4-4. Student photo location map

It was a fairly complicated activity with many steps. The researcher and the science teacher walked around the whole period assisting and answering student questions. In each school, there was at least one student who had a difficult time finishing all the steps within the class period (while a small number of other students actually finished early). All students managed to attach photos to the board, where some students wrote prolifically and others included only a few words or none at all. Figure 4-3 shows an example of the finished product.

When students submitted their boards to the researcher, they were asked to fill out a small information sheet asking for student birthday, gender, ethnicity, a 5-point scale question asking student to assess their own understanding of "environmental sustainability," and a question asking which classmate(s) they conversed with while taking photos, if any.

At the end of the project, all students were gifted a reusable water bottle as a token of gratitude. Students who did the project two years in a row at the pre- and post-move school received a water bottle the first year and the second year received a book about the environment and a personalized bookmark with their name and a photo they took during the project.

Student Interviews

Interviews were the next stage of the data collection process. Of the students who took pictures, a subset of students were selected for a one-on-one interview. The process was constrained by student availability in the time period the researcher was scheduled to give interviews, and the interviews were kept to a reasonable number given that the project had already created a significant intrusion on regular instruction. The researcher endeavored to interview the same number of girls and boys, where priority was given to students who had little to no written text on their photo boards. These semi-structured interviews ranged from 15-20 minutes, and were audio recorded. The researcher followed the same outline of questions for every student:

- **Questions about sustainability in the student's life:** [five minutes] This is the chance to learn about sustainability in the student's home life, his/her extracurricular activities, and what classes he/she has taken that focused on environmental issues.
- **A discussion about the student's selected photos.** [10 minutes] This discussion offered the opportunity to hear about the building features or areas in the student's own words: why a particular photo was chosen, how the student engages with the feature/area, what it means to the student, how he/she first learned about the feature/idea, and what other life experiences he/she might have with the content of the photo.
- **Perceptions of the school building**: [two-five minutes] Is the student satisfied with the building overall and does he/she find it an effective place for learning?

Photography Data Analysis

With both digital and printed photos available, the researcher was able to reproduce boards digitally, typing in the text written by students next to each digital photo. Digitization of the boards allowed for import of files into Atlas TI qualitative analysis software, where both photos and text were analyzed. Once imported into the software, the photos were coded for content (*e.g.,* themes were assigned to each photo, such as recycling or wildlife). The photos were also coded as indoor and outdoor. Ideally, there would be more than one independent reviewer of the data, however, in this context the researcher was the primary coder and analyst. The photo content provided by students was generally straightforward, and between the written text and the photo itself, it was not challenging to assign a major theme to each photo. Only 3.6% of photos (22/601) could not be assigned a clear category due to uncertain photo content with vague or missing text.

Additional Supporting Evidence

The student viewpoint was the major focus of the data collection efforts in this study; however, conversations with adults were critical for understanding the overall physical and educational environments that students inhabit. The discoveries from these interviews are woven into the Chapter 5 descriptions of each individual school setting, where the physical environment, school culture, and environmental education efforts are described for each school.

Interviews with Key Informants

Administrators and science teachers in each school were interviewed. For green buildings, where possible, the researcher also attempted to interview building architects to learn more in-depth about the architectural goals of the green building projects. The interviews were semi-structured, with interview scripts tailored to each different profession, and then the protocols were used across all schools with minor variation.

For administrators and science teachers, the major interview topics included:

- Formal environmental education efforts present and future
- Assessment of school's culture of sustainability
- The process of designing, constructing, and using a Teaching Green Building

- Teaching Green Building features you value most
- Informal versus formal learning from the Teaching Green Building

The focus of interviews with building architects focused dominantly on the design intent of each building – the guiding philosophies, major strategies, and desired outcomes. These interviews were also particularly helpful for understanding the relationship that each architect has to the school as a client, and how the vision for each Teaching Green Building was (or is) distributed across stakeholders.

Teacher Focus Groups

Teacher focus groups were arranged, although the high demands teachers face during the academic year made scheduling difficult. The researcher was able to host focus groups in two of the green schools. In the West Coast green school, the researcher visited twice over the course of a year, and met with teachers before and after their move into a new building. Thus, a total of three focus groups were held in the duration of this project, and each provided incredible insight into the viewpoint of teachers who work in Teaching Green Buildings.

Major questions for teachers included:

- Observations about student environmentally friendly behaviors
- Formal environmental education
- Formal and Informal use of their Teaching Green Building

Building Documentation

To describe the physical environment of each school setting, information about the grounds and buildings of each school was collected as possible. At a basic level, the researcher toured and photographed each school building. Where possible, documents were sought and obtained, including: floor plans, written narratives about building design, detailed Green Ribbon School applications, and LEED checklists.

Chapter Summary

This chapter summarized the research design of this study, introducing the study sites and research questions, and then outlining the mixture of methodologies deployed across five U.S. school campuses. The next chapter will describe each school setting in more depth using interview data, focus group insights, and building documentation. Chapters 6 and 7 to follow will uncover results from the survey research and photography documentation projects.

Chapter 5
School Settings

This chapter introduces the five schools included in this study. As discussed in the previous chapter, the primary criterion for choosing school sites was to identify buildings where the architectural intent was to use green architecture educationally. Each of the green schools in the study are LEED [Leadership in Energy and Environmental Design] certified green buildings by the USGBC [United States Green Building Council], and all three are seeking, or have achieved, LEED credit for using their school buildings as teaching tools. In this work, these three buildings are collectively referred to as Teaching Green (School) Buildings. When three schools were identified and each agreed to participate in the study, local comparison schools were sought. This selection method, together with the difficulty of recruiting comparison schools, led to schools with significant differences, and some differences that challenge comparison. Further, the lines between green and non-green school buildings are not clear when institutional culture and curriculum are considered. That is to say, a strong culture of environmentalism can yet persist without the presence of a green building, as is the case with one of the non-green schools in this study. It is thus the primary objectives of this chapter to describe each of the schools, and then synthesize major differences and commonalities among the settings.

While the major goal of this chapter is to offer a foundation for the empirical chapters to come, there is another value in presenting information about these schools. In route to describing each school, there is a story about how Teaching Green Buildings come into existence, and the challenges practitioners face in constructing and using architecture in pedagogy.

Census data was collected for the census tract within which each school building is physically sited (Table 5.1). While somewhat useful for understanding the immediate communities that surround each school, census data is not particularly useful for describing actual school demographics, as all schools in the study have a selective process for student admission and draw families from the immediate neighborhoods to places as far as an hour away by car. This information does, however, show that each school is sited in a neighborhood that is predominantly white in racial demographics, average to very low in population density,[15] and lower to upper middle class in terms of socio-economic status.

Table 5-1. Census tract Information, by school

	West Coast		Midwest		East Coast
	School 1 (public charter)	**School 4** (public charter)	**School 2** (private)	**School 5** (private)	**School 3** (private)
Census Tract Population	5,006	2,923	2,335	1,551	2,355
Population Density (per square mile)*	140.7	7.2	132.8	95.2	9.5
Median Household Income	51,114	41,071	92,750	142,188	130,594
Mean Household Income	60,448	70,757	131,758	181,563	242,053
Percent Unemployed	5.7%	26.3%	2.5%	5.6%	0.0%
Percent College Graduate**	30.1%	32.3%	84.7%	89.8%	66.4%
Percent of population born outside of U.S.	4.2%	1.5%	20.1%	11.6%	8.1%
Percent White	83.0%	87.8%	75.7%	85.2%	94.2%
Second highest racial group (%)	Asian (8.2%)	Mixed Race (9.9%)	Asian (19.5%)	Asian (9.9%)	Asian (3%)

**Population density was calculated by dividing total population by total square miles (including land and water area), where the calcuation was based on formula from: http://dataserv.libs.uga.edu/sdc/sdc2kfaq.html#popdensity*

***Includes Associates, Bachelors, and Graduate Degrees*
All figures are based on the 2007-2011 American Community Survey 5-Year Estimates provided on http://factfinder2.census.gov. The data in this chart describe the immediate communities in which each school is physically sited, but do not necessarily reflect the populations within each school.

The green qualities of each school campus were of primary importance to school selection for this study. Table 5-2 illustrates the environmental features available on each school campus. In this format, the Teaching Green Buildings (Schools 1, 2, and 3),

[15] The population density of the United States overall is 89 people/square mile. (http://en.wikipedia.org/wiki/List_of_sovereign_states_and_dependent_territories_by_population_density) Census tracts in urban areas are typically well over 1,000 people/ square mile, and commonly 30,000-70,000 people/square mile in the country's densest urban areas.

schools explicitly designed to teach students about sustainability through the built environment, can be quickly identified as the columns with a large number of X's. It is important to note, however, that even the non-green buildings (Schools 4 and 5) in this study have some green features. Thus, in efforts to find suitable comparison schools (*e.g.*, on the basis of comparing private schools in the same region with each other), the non-green buildings are *not* canonical examples of campuses devoid of greenness, but examples of campuses with outdated buildings and a small number of environmental features that are added on and typically outdoors (like a school garden or native plantings.) Furthermore, within these non-green school buildings there was no overall vision to use the school building as a teaching tool, as was the case with the green buildings in the study. The comparison schools thus provide the opportunity to explore settings with some but minimal investment in green infrastructure, a scenario that is certainly more typical across American school buildings than new construction Teaching Green Buildings.

The two West Coast schools are on the periphery of the same West Coast city and the two Midwest schools are in the same Midwestern city. The schools have additionally been named using words that speak to the core missions that underlie the founding of each school (*e.g.*, "Arts School"). These terms were determined according to the observations on each site and conversations with faculty and administrators at each school. The school titles are not meant to encapsulate the totality of each school's mission, but offer a memorable way for the reader to distinguish the five schools from each other.

Table 5-2. Comparison of green features across schools

		School				
		TGB			Non-GB	
		1	2	3	4	5
Alternative Energy	Wind Turbine	X	X			
	Solar Panel(s)	X	X	X		
	Geo-thermal	X	X			
Transportation	Bus Stop	X	X			X
	Electric Car Plug-in or carpool parking	X		X		
	Bike Rack	X	X	X	X	X
Food	Vegetable Garden	X	X*	X		X
	Compost	X	X	X		X
	Animal Husbandry	X				
Landscape	Ammenities for wildlife	X	X	X		X
	Native landscaping or xeriscaping	X	X	X	X	X
	Nearby woods (accessible)	X	X	X		X
	Nearby stream or pond (accessible)		X	X		
	Greywater or rain water recycling system	X	X	X		
Building	Greenhouse		X			
	Green Roof		X			
	Recycled content building materials	X	X	X		
	Reused building materials	X	X	X		
	Rapidly renewable building materials	X	X	X		
	Water efficient plumbing fixtures	X		X		
	Energy Efficient Light Fixtures	X	X	X		X
	Motion-sensor classroom lighting	X	X	X		
	Daylight in most classrooms	X	X	X		X
	Operable windows in classrooms	X	X	X	X	X

Legend:

GB: Green Building
TGB: Teaching Green Building
ST: Strong program
WK: Program somewhat existent, but weak

X	Feature onsite
X*	Feature off-site
X	Planned, but not present at time of data collecton

Table 5-2. Comparison of green features across schools, continued

		School				
		TGB			Non-GB	
		1	2	3	4	5
Communications	Signage about green features	X	X	X		
	Energy Dashboard Touchscreen	X	X	WK		
	Building tours available for students	ST	WK	ST		
	Formal education about green building features	WK	WK	WK		
Operations	Recycling Program	X	X	X		X
	Healthy Lunch	X		X	X	
	Green cleaning supplies	X	X	X		
	Green office supplies	X		X		

Legend:

GB: Green Building
TGB: Teaching Green Building
ST: Strong program
WK: Program somewhat existent, but weak

X (shaded)	Feature onsite
X* (shaded)	Feature off-site
X (unshaded)	Planned, but not present at time of data collecton

The following sections describe each school that was part of this study, including a description of the following three dimensions:

1) school culture
2) school building
3) environmental education efforts

The information that follows was compiled from onsite interviews, teacher focus groups, researcher observations, and archival research including documents provided by the schools and school websites. Where possible, data from the Green Building Literacy Survey is used to support conclusions.

Teaching Green School Buildings

School 1: Arts School

The founders of this K-8 public charter school sought to create an environment that combines academic excellence with a celebration of the arts, with a belief that the arts can enrich every aspect of the curriculum. Along with conventional academic training in reading, writing, and math, students have an elective option to develop competencies in the visual and performing arts. The architecture of the new school building most overtly expresses and supports this aspect of the mission in the design of the amphitheater space at the heart of the building. This space is a two-story, open air gathering space with a center stage and two side stages that also double as classrooms. The school uses this space for weekly all-school gatherings that feature student performances.

The school building was the product of a multi-year, and now ongoing, collaboration between the charter school and a local foundation exhibiting exceptional generosity. Thus, a striking aspect of this green school project, when looking together at the green building and school mission, is that environmentalism was not a core philosophy in the founding of the school. In the words of a co-founding administrator: "It was a partnership. We needed a home or we were going to be closed down. They [the foundation] wanted an example of sustainability for the county and the community, so together we partnered to do both things at once." Thus, a mutually beneficial partnership was formed, leading to a unique setting where artistic and environmental sensibilities combine.

While much of the groundwork for the new school happened initially between the administration, foundation, and design team, there has been an ongoing need to bring the school's faculty and parent constituencies on board with the new green mission. This is an effort that both the administration and architect say is moving in a gradual and positive direction. The newness of the environmental efforts to some teachers was captured in this statement from a faculty member in the post-move focus group:

Our school is an arts school, and it [environmental education] is not our area of emphasis. But, like you said, we moved into this building, there is an awareness that has begun, and it is just starting... [my students] basically came in not knowing anything. And I don't really know anything. That's not really what we're about, but why not? [emphasis added]

School Building

The Arts School moved into a new construction Teaching Green Building in August 2011. The building was designed from the early stages to be a nearly net-zero building, engineered to, on the whole, use almost as much renewable energy as the building requires for operation. The building was the first school building to achieve LEED platinum certification[16] under the new 2009 LEED for Schools criteria. The design intent to use the building design to teach about green building features was also a decision made in the early stages of the project, and was a mission that arose organically through client-architect conversations. The intended result is a high-performing building that creates opportunities for students to learn about and engage with the various environmental features. Actual metrics on building performance are not yet reported, though the design team is meticulously tracking energy goals to evaluate the design. Early data reveals numbers that turn heads at green building conferences. In an interview with the researcher, the architect noted that the Energy Use Intensity (EUI), which is a basic measure of total energy consumed divided by square footage, is only 13 for the Arts School. This number is almost unbelievably low compared to the average EUI of 169 for U.S. K-12 school buildings. It is even more astonishing when you compare it to other types of buildings in the U.S., such as hotels with an average EUI of 228, and hospitals with an average EUI of 468.[17] Schools, of course, are running for much less time of the day and the year, and should be much lower. Nonetheless, if the Arts School data bears out over time, an EUI of 13 is exceptional.

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[16] Of four possible certification levels, “Platinum” is the highest level of achievement for buildings seeking LEED certification.

[17] All EUI averages reported online by Energy Star: http://www.energystar.gov/index.cfm?fuseaction=buildingcontest.eui

There are numerous teaching green features designed into the building. Some of the most obvious features include a small wind turbine visible upon arrival (a feature more educational than functional), a kiosk in the lobby that tracks building energy performance, a window into the mechanical room, and outdoor classrooms with a nearby school garden and chicken coop. One of the major implicit lessons of the building is its extreme openness to the elements, with most corridors and a sizeable amphitheater largely open to the outside. This openness, in fact, was a major strategy used to achieve a nearly net-zero building [and the incredible EUI value] by severely reducing conditioning needs for 39,000 square feet, or 51% of the building's 77,000 square feet. A number of the middle school students in the photography project were keenly aware that this strategy saved both energy and materials while providing natural light and air. (Data in Chapter 7 will show that 15% of student photos of their campus engaged the theme of daylight, with was the highest frequency within the new themes observed in the post-move condition, see Figure 7-6).

Aesthetically, this building has a high-technology look and feel. Rustic, reused wood walls can be found in places, and an artful clay wall graces the entrance, but the overall materiality is comprised of hard surfaces such as eco-composites, and metal. Ceiling systems with innovative cooling ducts – which are educational in themselves -- are exposed in corridors and lend an industrial feel. The landscape is still immature, signaling the recent construction, with low trees and emergent small plantings, though the design team made a point of keeping some older growth trees by designing the parking lot around them. (Indeed, this is one lesson students learned about in witnessing the construction of their new school, and is another theme that emerged in student photography data.) Despite the immature schoolyard landscape, the view from inside the building is not lacking with surrounding forested areas and distant mountains as a backdrop.

The collaborating foundation provided the land and much of the funding for the construction. Previous to the relationship with the foundation, this public charter school occupied one-half of an outdated school building. Their previous school building was an older structure with non-intuitive circulation and fairly drab interior finishes. The middle school classrooms were in trailers in the parking lot, and the outdoor recreation areas featured a paved courtyard with several trees and a sizeable sports field. In nearly every dimension, the new school building is a stark contrast to the environment that students previously occupied.

Environmental Education Efforts

Explicit environmental education (EE) curriculum did not exist in the Arts School prior to the green building process. Once the collaboration with the foundation was formed, and the construction project underway, the administration slowly started to encourage faculty to integrate EE into their classrooms. The primary method of doing this was the request for teachers to experiment with one lesson or one unit that addressed environmental education in the school year of 2010-11, the year before they moved into the new building. Teachers were asked to report on their lessons at the end of the school year, and these lessons eventually made it into a set of binders. At this time, faculty had toured the under construction new building, but indicated that they had not been formally trained on green building themes. When asked about tailoring lesson plans to the architecture of the new building, the teachers in the pre-move focus conveyed a fairly unified angst about teaching students about a building that they themselves did not yet understand.

The first year in the new school building was a frenzied one for educators. The administrator, when asked about the curriculum in the new school, stated: "when teachers began here [in the new building] they went back to what they are used to, and I don't blame them one bit." The post-move focus group with teachers further illuminated the difficulty teachers experienced moving between buildings and trying to take up new environmental lesson planning all in the same two years. In the words of one teacher in the post-move focus group: “we were hit so hard and so fast that we didn't have time to absorb it all.”

That said, teachers did mention the teachable moments afforded by the building design. One common example includes using the positioning of the windows to talk about air flow and the movements of the sun. The Physical Education teacher further discussed ways in which he used the open-air building design to talk about overall health and bodily adaptation to a high range of temperatures. In sum, after one year in the building, no formal EE curriculum yet existed, though faculty noted that anecdotal teaching moments significantly increased given the green building and its features.

At the time of post-move data collection with the Arts School, the California Environmental Protection Agency (EPA) had just begun to roll out pilot lesson plans under The Education and the Environment Initiative (EEI) (California Environmental Protection Agency). A representative from the California EPA makes visits to the Arts School and demonstrates various units to teachers and students. The school administrator interviewed indicated that this curriculum aligns well with external educational standards, but that the school needs more time to connect it well to their existing curriculum. The EPA program will increasingly be integrated into the curriculum in years to come. When asked about existing formal lesson plans that tie specifically to green architecture, the same administrator lamented that "it just doesn't exist."

School 2: College Preparatory School

School 2 is a private school recognized widely across the region for its academic excellence and ability to prepare students for entrance to prestigious college institutions. It serves grade levels 6-12, and thus the goal of college preparation permeates throughout middle and high school levels. As a prominent private school in the region, it is also considered a school of significant affluence, with parents ranging from college professors to top executives of locally-based corporations. The Head of School notes that tuition is $5-10,000 lower per year than competitor independent day schools in the region, and this is partly due the desire to attract professors' families from the nearby university. The school additionally offers a robust financial aid program, upwards to $1 million a year, to help put tuition in reach for families that need extra support.

Like the Arts School, despite green building infrastructure on campus, environmentalism has not traditionally been explicit in the College Preparatory School's core mission. In fact, even with the presence of the green renovation wing of the school, a staff member in admissions explained that he has never been asked by a single parent about the school's environmental mission or building features. It appears that the green features of the school play a small to nonexistent role in a parent's decision to send their child to this school, at least at the time of this study. Likewise, environmentalism is not likely to be a strong pattern across families that attend this school. The survey data in the study showed that environmentally responsible behaviors at home were significantly less for the College Preparatory School compared to the Waldorf School (School 5) located in the same city. However, this may be partly due to the fact that College Preparatory School is near a major highway, which the Head of School mentioned as a factor in drawing out-of-town families to consider commuting from neighboring communities – communities that may have different environmental sensibilities compared to the college town in which the school is located. The Waldorf School, located in the same college town, will be described below, and it is clear that the general school philosophy aligns well with environmentally sensitive parents.

Students at the College Preparatory school are busy. Their schedules are packed throughout the day with formal gatherings with teachers as well as non-formal meetings tied to clubs, athletics, artistic pursuits, and the list goes on. Middle school students in every school setting in this study are busy young people. This collective flurry of activity is difficult to quantify across schools, however, the researcher experienced a very different quality, and heightened sense of frenetic activity, in the College Preparatory school compared to other schools in the study. The administration of the photography project in this study demonstrated the difference. A packed science curriculum meant that the project could not be conducted within class periods (as it was in other schools), but that the project would need to happen in student's free time after school. Unfortunately, few students in this school have free time after school. The after-school scenario resulted in a low number of students in the photography project at the College Preparatory school, which is the largest school in the study.

This aspect of the school culture is of potential consequence to the pursuit of a Teaching Green Building. With little free time on campus, it is less likely that students will spend time engaging with Teaching Green Building features that are designed to solicit informal engagement (such as signage and energy dashboards.) For a school culture with back-to-back student schedules, the best approach to a Teaching Green Building will be to tie the architecture to formal lesson plans. This is largely the approach taken by the College Preparatory school in their green building renovation project, and it seems well suited to their culture.

School Building

There is no explicit school board-driven initiative for the school to be a leader in sustainability. When the need to conduct building renovations arose, the choice to go green was not an inevitable path. Instead, it was a labored decision by a board of members with mixed opinions. Some board members enthusiastically supported the idea of engaging in green building practices, while others remained deeply concerned about the financing and worthiness of the pursuit. For the Head of School, the concern about the cost of green building has persisted throughout the renovation project and into the cost of operations and maintenance, and this is a person who started his career in outdoor education and is 100% behind the green building concept.

The College Preparatory School has a large building at 140,000 square feet, and the renovation was localized to one wing of the building, and ultimately designed to meet LEED green building guidelines. The wing of the building has been branded and named for the generous donor family who made it possible, a family who has championed green practices in their own major corporation based in the region. From the beginning, the design team was interested in the LEED objective to use the building and grounds as teaching tools for environmental education. The architects and educators worked together to consider ways in which this kind of education could be supported by the building and delivered by educators.

The renovation project introduced an impressive array of green features to the campus, including planned demonstrations of three major types of alternative energy: solar, wind, and geothermal (the solar panels will be added in the future). The school additionally hosts a greenhouse, recycling and food composting programs. A sizeable cistern sits at the northern part of the building to collect rain water. Another special feature of the outdoor landscape is a stream with a wooden boardwalk used by the middle school science teacher in her semester-long unit on water. The building is comparable in greenness to the other green buildings (see Table 5-2). It should be noted, however, that most of the features are not building-wide, but contained within the renovated portion of the building, and the school gardens are off-site. Another important note is that the green wing is occupied by 11th graders, and thus the middle school students who took part in this study do not occupy the green wing daily, but in passing.

Natural light is pervasive throughout the structure. The building is low and long, and offers daylight to most interior spaces. The most fetching spaces of the building are those that face toward the woods with large windows on the east side of the building. Most interior public spaces at the heart of the layout benefit from clerestory windows that allow natural light from above.

One interesting aspect of the school building design is the integration of social forums, which are dotted across the building and serve as social hubs for each grade level. Each one features a carpeted series of steps or seats surrounded by student lockers. These forums allow educators to bring students of a grade level together for gatherings, and they also create a home base for students to be together and interact informally between classes. As the largest school in this study, with approximately 75 students *per* middle school grade level, these forums likely serve an important role in community building across the lines of assigned classrooms.

Renovation projects, while significant undertakings, are often more realistic than new construction projects. This school presents an interesting question that many other schools will be interested to know: what are the impacts of a partial green renovation? Since the green systems are limited in scale compared to the rest of the building systems on campus, and only partially impact the building's overall environmental performance, it is possible that the most significant outcomes will be educational ones.

Environmental Education Efforts

As with successful environmental endeavors in many organizations, a deeper look at the context will reveal a few exceptionally passionate people who are at the heart of the effort. In the case of environmental education at the College Preparatory school, the science teachers are the major driving force. The Head of School cited two people, a married couple, in particular:

> *You know, so much of this is personality driven. [These two teachers] are great examples of that. If we had not hired them 30-40 years ago, who knows where we would be. So, they have been champions just because of who they are… They ran outdoor programs here years ago, and there was a core of kids who were taught to care about the environment before we had words for these things.*

This school does not have a highly coordinated or streamlined approach to environmental education. Though, each middle school science teacher undertakes a major unit related to environmental issues. In sixth grade the students learn about the food system, in seventh grade students learn in depth about water issues, and eighth graders study alternative energy systems. Beyond this, decisions are made at the level of the classroom teacher with loose linear coordination. Without the need to follow strict standards, teachers have the freedom to explore, test, and weave together lesson plans as they see fit.

It is perhaps this level of freedom that supported some of the first formal green building lessons that were organized by the 6th grade social studies teacher. When the green wing of the school was complete, this teacher organized a whole-grade outing for 6th graders to tour a green campus building at the nearby university. The teacher then brought students back to tour their own building, then comparing and contrasting the two green buildings.

The seventh grade science teacher also takes advantage of the school campus in her year-long investigations of water issues with students. This unit teaches water issues at many scales, from the local schoolyard to the watershed to global water issues. By the end of this unit on water, students will have journal entries, sketches, graphs, and scientific reports bound together in booklets. The researcher had the opportunity to observe a class period on a day when students were collecting water samples from the on-campus stream. The period began with an intense set of instructions written across the white board, which took students outdoors to obtain samples and then back into the classroom for laboratory work. Students worked in teams, which the teacher notes is a very intentional part of the educational experience. Her students have been taught that science is a collaborative effort and that they can use each other to ask and answer questions. The workability of these teams of young scientists was apparent the day the researcher observed the class, where the atmosphere was collegial and studious, an impressive feat considering that the room was filled with 20 mixed-gender seventh grade students. Part of the magic is likely due to the hands-on lesson plan that engaged students and allowed them 20 minutes next to an outdoor stream.

School 3: Ethics School

Founded in 2002, the Pre-K through 8th grade Ethics School is both the newest school and the school with the longest standing green buildings in this study. A fascinating aspect of the school, however, is that environmentalism was not part of the initial goals for the founders, but a sensibility that emerged with the need to design and build a school campus. Four pillars that have formed the foundations of their school philosophy from the beginning, according to the founders and the Head of School, are: academic excellence, celebrating the joy of learning, mastery of the English language, and ethical relationships. The emergent realization was that a Teaching Green Building can support and reinforce all aspects of the school's core mission.

In conversation, a co-founder of the school elaborated on a series of influences that pushed the founders to consider the divide between humans and nature, resulting in a belief that this philosophical divide was not only false, but destructive. In the co-founder's words: "So once we realize that, the bell that went off is that if we are going to mentor ethical relationships between [humans], then the natural extension of that is that we need to have that relationship with nature…when you come at sustainability from that standpoint, all of the political parts go away." Environmental stewardship was thus a logical extension of the school's core mission to teach caring relationships.

The "joy of learning" piece of the mission, seemingly abstract, is potentially a cornerstone for informal learning about architecture. One way this mission translates to practice is the recognized importance of down-time for children within the school day. In the words of the Head of School:

> *How do you develop a meaningful relationship with yourself if you don't have time to think? Our kids understand what meta-cognition means...having that kind of time is also needed for connecting with other people, exchanging ideas, laughing, and having a pace that isn't crazed where you only feel stress.*

One of her stated goals was to create a safe place for students to explore. While there are many possible outcomes of student-directed learning and down-time in the school environment, one is that students are more likely to engage informally with the environment they inhabit. Perhaps they stop to read signs, observe changes in campus plants, or notice architectural details. To be sure, none of this is guaranteed, but the chances are increased when students are given the time and freedom to safely explore their environment. If this sounds like a long stretch for K-8 students, this quote from a focus group teacher illuminates how students at this school may be different as a result of the school's culture: "One difference I notice here compared to other schools is that they [students] let themselves be overcome by the wonder of nature. I haven't seen other schools like this...the openness they seem to have."

The Head of School succinctly stated how this school's approach differs from many other schools that pursue green building practices. The researcher's experiences in the field of green building, and observations onsite at the Ethics School, are resonant with this quote:

> *Many schools come at the sustainability piece through the facilities part, especially going for the various certifications. We were fortunate enough, because we are only 10 years old, to really start with that in mind. And then it wasn't imposed as something potentially superficial, it was because this is what we value in our own behavior. We were able to be really intentional about how we built.*

One key advantage to early identification of the four pillars, and the early emergence of an environmental philosophy, is that the school has attracted and hired faculty and staff over the years who deeply believe in the school's driving mission. The Head of School continues to explain how there is no one environmental coordinator for the school, but that the sensibility is endemic. The Ethics School could be considered a fairly extreme example of a supportive environment for environmental sustainability, where both the socio-cultural and the built environment support learning and taking action.

School Buildings

If the Teaching Green School Building is a recent cultural experiment, the Ethics School could be considered a pioneer of the movement. This school built the first school building ever to be LEED certified by the United States Green Building Council, and at a time when the modern green building industry was just beginning to gain traction. School 3 is thus the longest standing Teaching Green Building in this study, with a LEED campus building that dates back to 2003, another LEED platinum building completed in 2007, and a third building on the drawing board at the time of this study. Over the last decade, their students have not only used green campus buildings daily, but have also, at different times, witnessed the process of green building design and construction.

The overall aesthetic of the buildings is one of harmony with nature, achieved by the generous use of natural materials such as stone and wood, deep earthy colors throughout the buildings, and with windows in nearly every space that view out to the native landscape that surrounds the buildings. One half of the middle school building is a large barn relocated from Pennsylvania, which thus juxtaposes new construction green building techniques with the method of achieving green buildings through historic preservation. There are inspiring stories embedded in the architecture, such as the charming allure of the old barn and outdoor parts made of stones from Boston's "big dig," but there are also small informational signs throughout the campus buildings that point to interesting facts about the buildings. For example, the bathroom has signs that tell the story of the recycled tiles and water recycling to flush toilets. Another area of interest is a glass plane that offers a view into the building insulation, which is made from recycled blue jeans. There is an array of solar panels on the roof of the building, but the designer also placed one panel on the ground level next to the garden to increase visibility and ability for teachers to use it in instruction. These are some of the many design choices made to increase the use of the building as a teaching tool for green building issues.

Interestingly, the architectural consultant, who was a core visionary for the project, disagrees with the teaching tool frame for describing the campus buildings. In an onsite interview, he explained:

> *It's not about the "it." "Building" is not a noun, it's a verb. And it's really important that we are sustaining life, not an object. So when we focus on objects, that is actually what has gotten LEED into trouble with checklist approach. It is killing life when you do that, breaking it into pieces. The building is a catalyst, a germ, a seed, for building relationships. I just think that that is really important. The building itself is never a teaching tool, it is really a catalyst. Then it's not about the thing, it's about the frame. It's the values. It never would have taught [students] anything if those values were not in place.*

Conversations like this, and others the researcher had on campus, pointed to a school building that is deeply intertwined with the school culture.

Environmental Education Efforts

As an independent school, the Ethics School has developed its own unique curriculum designed with four pillars at the base, which are, again: academic excellence, joy in learning, language, and ethical relationships. Integral to their approach is an ongoing series they call the Virtues Program, which introduces core values such as honesty, respect, and integrity one-by-one over the course of the school year. These are the foundational virtues that are used to teach students about relationships to themselves, to other people, and to the natural world. Virtues, and examining ethical relationships, are the lens through which students learn about environmental sustainability. This approach is quite distinct compared to others that begin with fiscal sustainability or inroads through efficient technologies. At the Ethics School, these aspects of sustainability are important, but not the starting point for the conversation. Instead of starting with a solar panel, this school might start with such foundational questions as what do we need to power and why?

The curriculum is a hybrid of state and national standards, lesson planning from The Cloud Institute (The Cloud Institute for Sustainability Education), and internally designed lesson plans and frameworks. They did not have a published or shareable curriculum at the time of this study. While the science teachers have taken a clear lead on explicit school-wide environmental education efforts, it was apparent from a faculty focus group that every, or nearly every, educator on campus is involved with place-based sustainability education regardless of the subject matter, from studying the on-campus stream in biology class to photographing building architecture geometries to writing place narratives in history class. When asked what is next for sustainability education at their school, the faculty noted that they were working toward a higher degree of connection between the natural and social sciences in the coming years.

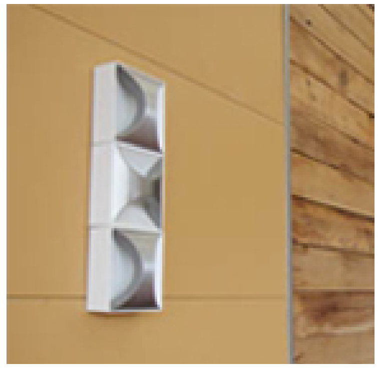
In focus group format, teachers were asked about ways in which the green campus buildings are integrated into their lessons. Few of their formal lesson plans connect directly to the buildings, though many educators use features of the schoolyard pedagogically, where the trees and the on-campus steam and pond are common sites for classroom activities. One teacher mentioned that the rotating, sun-seeking solar panel constitutes a nice opportunity to talk about the biomimicry of sunflowers and artic poppies. Overall, it appears that much of what students learn about the green buildings they inhabit happens informally by reading signage and through anecdotal teachable moments provided by educators. Informal as it may be, educators seem to agree that the green buildings are incredible support for the education they aspire to provide. The middle school science teacher explained it well when asked about his environmental education efforts over time:

> *Absolutely, I always did EE back when I was in a brick and mortar building…and the big difference is that the topics that I taught about were more global, they were more intangible. Every now and again I would say what was wrong with the environment versus what was right with it. Here, I can talk about all of the benefits and the rationale behind it... there are just so many opportunities to explain, yes, this is why something is built that way, and that's why the windows are facing this direction. This is definitely a topic of conversation a lot more because of the building. And the outside of the building, you know, is more spectacular than most school campuses.*

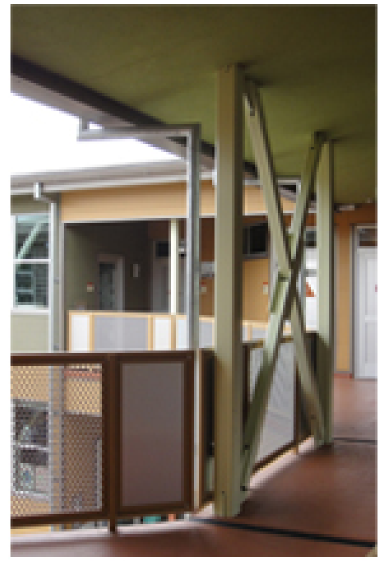
In sum, the Ethics School offers a snapshot of a fairly special, nearly 10-year old educational experiment. The built environment is an integral part of this experiment, and the environmental philosophy stems from the core curricular mission to teach about ethical relationships, where students are encouraged to reflect on relationships to themselves, to other people, and to the natural world.

Figure 5-1 shows images from Schools 1, 2, and 3, the Teaching Green Buildings just discussed.

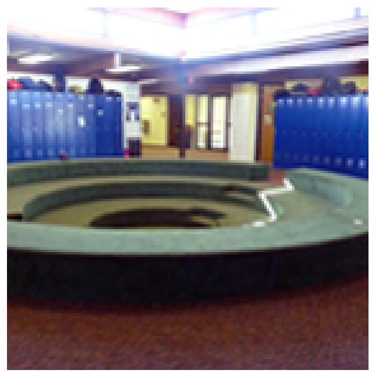
School 1: Natural building techniques demonstrated in clay wall



School 1: Energy feedback light fixture (above); Open air corridors (right)



School 2: Greenhouse located in green wing



School 2: Social forms offer a central gathering space for each grade level.

School 2: Wind turbine on green wing

School 3: Sun-seeking solar panel moves with sunlight to maximize solar intake.

School 3: Green light helps occupants know when to open windows.

School 3: Signage throughout the building tells about the buildings' many green features.

Figure 5-1 A selection of features found in Teaching Green Buildings

Non-Teaching Green School Buildings

School 4: Technology School

The second West Coast school, like the Arts School (School 1), is also a K-8 public charter school. It was chosen as a school that would be comparable to School 1 in terms of geography and student demographics, but on a campus that does not contain green buildings. This school was a late addition to the study, and therefore the Green Building Literacy Survey (GBLS) was the only form of data collection conducted at School 4. (Seventh grade students were not engaged in a photography project as in the other four schools). Further, timing of survey administration did not align with the researcher's site visit, and the survey was administered to students by a substitute teacher. The researcher made one visit to the site at the end of a school day. Thus, the researcher did not have the chance to experience the school culture first-hand as was possible in the other four school settings.

One overall note to make about the Arts and Technology Schools is that they are located on the West Coast, but in a region that does not host a major university nor is proximate to a major urban center. The regional politics are eclectic leaning toward conservative. The environmental culture, characteristic of many other regions in the Western U.S., does not seem to be an influence in the community within which the two schools are located. This perception was confirmed by conversations with educators and administrators in both West Coast schools. Additionally, conversations with the funding foundation of the Art School's building illuminated the need for environmental demonstration projects in their local community given the lack of green infrastructure. Indeed, the Arts School was intended to be one such project.

The Technology School does not have an overt environmental mission, and the researcher learned that some parents in the school community would not be particularly interested in this agenda. The science teacher noted some necessary caution with teaching evolution in the classroom, which signposts the presence of conservative values held by at least some families at the school.

School Buildings

With a need to expand into a larger space in the early 2000's, this school was able to move into the site of a recently vacated school campus, which was then renovated and restored for use by the Technology School. The most spectacular physical feature of this campus is its view to the mountains and a surrounding forest. However, the campus buildings themselves, and the concrete-scapes in between, are fairly uninspired. As Table 5-2 illustrates, there are several environmentally friendly features on campus, including bike racks, native plants, and operable windows in classrooms. These features, while beneficial, are few in number and common to many non-green school buildings.

Environmental Education Efforts

The educational emphases of the Technology School are in technology, math, science, the fine arts, and literacy. As mentioned previously, environmentalism is not an explicit part of the school's culture or mission, and thus students likely receive a basic level of environmental education as embedded in the state standards, and any other learning about the environment likely happens anecdotally with interested teachers. Survey results in the following chapter will show that students at the Technology School indicate a similar (low) level of environmental education exposure compared to other schools in the study (with the Ethics School as an exception) (Table 6-4).

School 5: Waldorf School

The Waldorf educational model is known for its child-centered approach to education (Association of Waldorf Schools of North America). This school shares the Ethics School's (School 3's) mission to "celebrate the joy of learning."[18] This mission manifests in the freedom, space, and time given to students to explore themes in their own unique ways, and an acceptance of aptitudes beyond the traditional reading, writing, and arithmetic. Like schools 1 and 3, there is an exceptional emphasis on the arts in the Waldorf School,

[18] In an interview, the Head of School at the Ethics School mentioned the alignment of her school's philosophy with the Waldorf model of education.

including curriculum across grade levels for music, art, handwork, and movement classes. The small class sizes, at approximately 25 students per grade level, allow for much hands-on learning, which takes place in the classroom as well as across the impressive grounds that surround the school building.

One unusual aspect of the Waldorf School in this study is that the teacher moves with the students across grade levels, which range from 1st to 8th grade (though the school also has a kindergarten and pre-kindergarten). This means that, by middle school, the educators know most of the students quite intimately and have witnessed their development from an early age.

School Building

The Waldorf School is in the same city at the College Preparatory School (School 2), and was originally chosen as a non-green building comparison school. The Waldorf School lives in a mid-century school building that has not undergone significant renovation. At the time of selecting sites, this school was primarily assessed for the greenness of the school building itself. As the project progressed, it became clear that the school campus contained numerous added-on green features, particularly in the surrounding school landscape. The campus contains a garden with a composting system, a rain garden built by students, native plantings, and a mud oven for low energy outdoor cooking. With these features woven into the built environment, it is difficult to clearly classify this school building as non-green. That said, the building itself is unexceptional in terms of environmental performance, and beyond the landscape features and indoor recycling, there are few features that would be informally pedagogical regarding green building issues.

Environmental Education Efforts

Formal, explicit environmental education efforts at the Waldorf School are modest to non-existent. When asked about the term that educators at the school use for environmental education, the seventh grade teacher told the researcher that “it doesn’t really come up." That said, a long conversation with the same teacher revealed that students at the Waldorf School are not only receiving environmental education, but numerous lessons that could be considered green building education (particularly regarding outdoor landscape issues).

At the time of the study, the seventh grade educator had recently begun experimenting with a new environmental curriculum developed at a nearby sister school. The three major units included transportation and energy, cycles of nature, and human-plant interactions. In the instance of the transportation and energy unit, the teacher took advantage of the school's grounds in numerous ways, including the building of fire as an energy source and the discussion of materials used in the different walkways around campus. Students did not receive the full three week curriculum, but experienced a shortened version of it.

At the Waldorf School, students additionally learn about construction as third graders. Every year, third graders in the school engage in a building project of some kind. The seventh graders in my photography project, as third graders, built a shelter to protect the mud oven on campus. As a fairly simple timber structure that supports off-grid cooking, this project engaged several aspects of green building, though on a very small scale.

While the school does not have a written environmental curriculum, the educational environment offers numerous cues of environmental sensibilities. Beyond those already mentioned, there are also visible classrooms near the building entry that are dedicated to hand crafts such as woodworking and hand sewing and other types of traditional skills that are low-energy in nature. Thus, while the building itself does not demonstrate green building practices, nor does the curriculum overtly address the issues, there are numerous influences at work in the school environment – via educators and visible artifacts – that convey an ethic of environmental sustainability.

Differences among Schools

It is difficult to conduct social research of this nature where the school building itself is a truly independent variable. The schools in this study were selected on the basis of fundamental differences in school architecture. The scarcity of Teaching Green Building exemplars in practice, and the need to control for age group, necessitated a national-level search for appropriate settings to study. Thus, based on the information gathered on each of the five school settings, there are several key differences between schools, beyond the greenness of the school buildings, that are important to note. Key differences across the settings include: geographic location and tuition costs, school type, school age, school size, grade level composition, and overall school culture. These differences are summarized in

Table 5-3, and then elaborated in turn below for the relevance of each factor to the current study. Where possible, the Green Building Literacy Survey (GBLS) is used to reinforce the information presented.

Table 5-3. Key differences among school settings

School	ID	Building Type	U.S. Region	Type of School	Estab.	Grades	# of students in middle school	Annual Tuition Cost	Unique Curricular Emphases
1	Arts School	TGB	West	Public Charter	1999	K-8	150	$0	Emphasis on visual & performing arts
2	College Preparatory School	TGB (Renovation)	Midwest	Private	1968	6-12	225	$18-19,000	Diverse emphases
3	Ethics School	TGB	East	Private	2002	PreK-8	44	NA	Virtues Program
4	Technology School	Non-TGB	West	Public Charter	2001	K-8	65	$0	Emphasis on science & technology
5	Waldorf School	Non-TGB	Midwest	Private	1980	PreK-8	75	$12,800	Diverse emphases

TGB = Teaching Green Building

Geographic Location and Tuition Cost

There are three very different geographic locations in this study, which introduces variance across the school settings in factors ecological, economic, political, demographic, and the list goes on. The data from the most recent American Community

Survey (Table 5-1) revealed several basic similarities and differences among these three areas.

Of the differences in Table 5-1, perhaps the most striking are the differences in affluence and education level between the West Coast census tracts and the other two regions. This difference in financial resources is also reflected at the level of the school where the West Coast schools are both public charter schools with no tuition costs and the rest of the schools are independent schools with tuition starting at $12,000/year. The general data trends would suggest that West Coast school students in this study are the most likely to come from homes of modest financial means. In the School Accountability Report Cards (SARC) for each West Coast charter school, the percent of low-income students is quite different, with the Arts School at approximately 15% low-income students and the Technology School closer to 60%.

Annual tuition costs among the five schools range from zero in the public charter schools to greater than $20,000 in the private schools. Further, the American Community Survey data, by census tract, reveals great differences in the immediate communities in which schools are located in terms of household income, percent of college graduates, and in one particular tract, unemployment levels. Taken together, this information points to the likelihood that significant differences in affluence exist across students in the study sample.

Relative to family affluence, the question of greatest interest in this study would be: are affluent students more likely to benefit from observing green building practices at home? In attempting to measure this possibility, the GBLS asked students to rate the "extent to which they learn about green buildings in activities outside of class." Interestingly, the Arts School students on the West Coast, located in a less affluent and politically conservative region, rated themselves higher than students in other schools on this metric ($p<0.05$). There are no other significant differences, and it appears that students in wealthy communities and expensive schools do not have a systematically higher exposure to green building issues outside the classroom.

Another factor that varies greatly by region is political leanings. Within this study, two schools are in a politically conservative West Coast town, two schools are in a politically liberal Midwestern college town, and the final school is in an affluent ex-urban East Coast community that is approximately 90 minutes from New York City by train. This study did not measure political factors directly, but focused on the student assessments of their own families' environmental sensitivity (ES). While ES may correlate with political leanings, it was not sensible to ask 10-13 year-old students to assess family politics. ES is more directly related to the outcomes of interest in this study, and it is possible that family politics are embedded in this measurement. One particular ES scale item asked students to rate "the extent to which your family is environmentally sensitive." The Waldorf School has the highest mean on this item, and a mean comparison of this item across all five schools reveals that the Waldorf School is significantly higher than the two West Coast schools ($p<0.05$). No other significant differences were detected.

Further, regional environmental concerns might be expected to impact student orientation to particular green building knowledge content areas. Consider the example of water issues. In terms of regional ecology, the West Coast schools and the Midwest schools both share an interest in water issues, where drought is a concern for the former and proximity to the Great Lakes is an opportunity for the latter. In the Green Building Literacy Survey, no differences were detected on correct answers to water questions across schools and regions. In fact, the East Coast school performed as well or better on water questions compared to peers in more water-conscious regions of the U.S. ($p>0.05$).

School Type

This study features a mixture of private and public charter schools. The question of family affluence and tuition costs are discussed elsewhere in this section. When comparing school settings with fundamentally different organizational structures, however, other areas of concern include differences in curricular freedom and the school's financial resources.

The charter school movement emerged as a way for communities to revitalize struggling public school systems. Charter schools operate in a landscape that is performance-based over rule-based, and thus have curricular freedom that is similar in nature to private schools. California, the home of the West Coast public charter schools in this study, was the second state to pass charter school legislation. Intent of the Charter Schools Act of 1992 was:

> *...to provide opportunities for teachers, parents, pupils, and community members to establish and maintain schools that operate independently from the existing school district structure... (California Charter Schools Association)*

While California charter schools have more flexibility than neighboring public schools, they are also supposed to be held more accountable to producing results with performance reviews every five years. A recent report out of Stanford University, however, notes that across the nation, low-performing charter schools are not typically shut down, and that this is a problem for the movement as a whole. Out of their large-scale study across 25 states, they found that only 17% of charter schools performed better than nearby traditional public schools (Center for Research on Education Outcomes [CREDO], 2009). The two charter schools in this study are close to the expected Academic Performance Index (API) of 800, with one school just above and the other just below.

The second question related to school structure is that of financial resources. The private schools rely on tuition dollars, the charter schools have access to public funds, and both school types engage in fund-raising efforts for special projects. Regardless of school structure, all three Teaching Green Buildings in this study (The Arts, College Preparatory, and Ethics Schools) benefit from corporate and foundation donations to make their green schools a reality.

School Age

The College Preparatory School and the Waldorf School have each been in operation for over three decades, the other three schools are approximately 10 years old. On one hand, this factor is not of extreme relevance to this study, since the middle school students who participated in the study all had the possibility of being acculturated to each school setting starting at the earliest grade level offered (*e.g.*, an 8th grader in 2011 started kindergarten in 2003). On the other hand, it would seem that the younger schools have the advantage of growing alongside the modern environmental movement, incorporating environmental principles into their constitution at earlier stages in school formation. However, no school in this study, including those started around the year 2000, was founded as an explicitly environmental school. The Ethics School is the only exception in that the founders developed an environmental philosophy within the first years and quickly became known for environmentalism due to their campus buildings. Thus, unlike the other schools, the Ethics School has not faced needs for the significant institutional culture change needed to incorporate environmental thinking across diverse facets and factions of the school community. The West Coast schools were founded in the same time period, and one has not adopted an environmental agenda and the other school would not have moved in this direction if not for the collaborative opportunity with an outside foundation interested in environmental initiatives.

School Size

In educational research, there are sizeable bodies of literature that examine the effects of school size on outcomes for students. For an overview of research see Cotton (1996). This area of research points to numerous benefits of small school size, including positive attitudes towards school, fewer negative social behaviors, and higher participation in extracurricular activities. Student achievement is a more contested outcome, with evidence that small schools are the same, and sometimes higher performing, compared to larger schools (Cotton, 1996).

The largest school in the study is the College Preparatory School with approximately 225 middle school students (of nearly 550 students total on campus, including the high school). The Arts School (1) is roughly the same size with 150 middle school students on a campus of 540 students in K-8th grades. Considering the total school populations, both schools sit within the acceptable limits of school size delineated by educational researchers, which is roughly 300-400 for elementary schools and 400-800 for secondary schools (Cotton, 1996; Williams, 1990). The other three schools in this study are markedly smaller with as few as 12-25 students per middle school grade level.

Grade-Level Composition

Another potentially important difference to note is the grade-level composition of the schools. Four of the five schools offer grade levels Kindergarten through 8th grade (where two of those schools also have a preschool). The one outlier in this regard is the College Preparatory School, which offers education for grades 6-12. In terms of grade-level composition, there are two potential impacts for the Teaching Green Building.

The first consideration is that middle school students in School 2 are new to the school building, and have not grown up on this campus – especially compared to students in K-8 schools. One student at Ethics School, for example, in conversation with the researcher, pointed to a tree he had planted as a kindergartener. Another student at the Ethics School animatedly described the location of the fort he had built in the woods as a younger student. The students who spent formative years on these school campuses are much more likely to have formed place attachment, which research has begun to link with place-based environmental concern (Kudryavtsev et al., 2011). Additionally, being new to campus can mean being overwhelmed for the first year or two while taking in an environment where everything, not just the green features, are new and require adjustment. One way to look at this set of factors is a variable that measures number of years on campus as a way to determine amount of exposure to the green building. Hypothetically, more time exposure to a green environment would lead to a richer understanding of campus sustainability as students have various and repeated experiences with their campus over a longer period of time. For this reason, the years on campus variable was measured as a personal context control variable in analyses to come (Table 6-1).

A second consideration related to grade levels on campus is the overlay of space and social hierarchy. Where middle school students in most of the study school settings are at the top of the social hierarchy with 8th grade being a student's final year on campus, College Preparatory students are at the bottom of the grade-level hierarchy in their own school. Consider further that the green wing of the renovated building is the wing occupied by 11th graders, and a newcomer 6th grader is not likely to feel comfortable walking through this part of the building without a teacher or peer group. This dynamic can obviously affect the ways in which middle school students in this school are exposed to many of the building's green features.

School Culture

Of all the differences noted between school settings, perhaps the difference of greatest interest to this study is the ways in which schools differ in their cultures and driving philosophies. Indeed, these sensibilities are not easily disentangled from the built environment of each school. That is to say, when data are compared school-to-school, the variable of school encapsulates both a unique building *and* a unique culture.

Chapter 2 discussed at length the importance of the many factors that contribute to whole-school sustainability, of which the building is but one. The Higgs & McMillan (2006) definition of school culture was presented and is worth quoting again here:

> *The strong influence that culture has on people's actions, thoughts, and feelings makes it a powerful teaching tool. Culture is a pattern of shared assumptions, values, beliefs, and norms of behavior that is considered valid and is taught to new members of a group…School culture is manifested through the school's rituals, traditions, buildings, programs, instructional methods, and extracurricular activities (Higgs & McMillan 2006, 47).*

One previous study investigated Teaching Green Buildings from a cultural standpoint, with a focus on describing cultural traits of existing case study schools (Barr, 2011). In this master's thesis on Teaching Green Buildings, Barr (2011) identified three foundational attributes of schools pursuing whole-school sustainability[19]. Those attributes were: shared values amongst educational professionals at the school, leanings toward a constructivist philosophy of education, and opportunities provided by the school facility (Barr, 2011, p. 88). Two of these attributes are explicitly about school culture, suggesting that existing school culture plays a key role in the daily workings of a Teaching Green Building.

The compatibility between a constructivist educational philosophy and a Teaching Green Building is an interesting finding from Barr's work (Barr, 2011). For numerous reasons, a constructivist educational philosophy aligns well with the prospects to teach with and through architecture. Constructivism is a learner-centered approach to education, where students frequently engage in place-based, hands-on projects, and educators strive to create time and space for students to discover the joy of learning (e.g., Joyce, Weil, & Calhoun, 2009; Miami Museum of Science, 2001; Palincsar, 1998). Architecture can constitutes the place for place-based environmental learning, and can facilitate hands-on learning about green building issues (a theme elaborated in Chapter 2). For a school that already endeavors to deliver this kind of education, it is not a leap to conceptualize the school building and grounds as a laboratory for learning about environmental sustainability.

Two schools in the study, the Ethics School (School 3) and the Waldorf School (School 5), have overtly social constructivist school philosophies, where the former has a Teaching Green Building and the latter does not.

An interesting extension of school philosophy is the philosophical stance a school takes toward environmental issues. Just as there is no one brand of environmentalism, so are

[19] Note that Barr's study included perspectives from educators of the Ethics School, and thus shares a school setting with this study.

there many manifestations of sustainability in the built environment. As Guy and Farmer (2001) note, the definition of green building is itself socially constructed, and the guiding logics can be very different from one building to the next. They lay out six competing conceptualizations of green building from eco-technic buildings that emphasize innovative green technologies to eco-cultural and eco-social sensibilities that highlight the regional vernacular and local community (Guy & Farmer, 2001). What does school building design say about a school's underlying environmental philosophy, or what is the lesson it has to teach about environmental problems and solutions? An illustration of this question was provided in Chapter 2 within the discussion of "Meaningful Environment" (p.34).

Commonalities across schools

Despite numerous differences, there are also a number of important similarities between the five schools. These major similarities are suburban location, selective entry, low ethnic diversity, absence of sustainability in the founding mission, and low levels of formal green building education. Each of these commonalities will be discussed below.

Suburban Location

All schools are located in suburban areas with school campuses that are proximate to wooded areas. Each campus is spread out with numerous green areas, fields, and trees. All schools have at least some portion of classrooms with views to this greenery. Due to suburban locations, the primary access to all five schools is by car. The use of cars is compounded by the fact that none of the school populations are determined by district, but by special interest. Thus, families drive anywhere from 5 minutes to an hour to bring students to school. Even though 3 out of 5 schools have at least one nearby bus line (Table 5-2), no school is part of a densely connected public transit system, and it is therefore unlikely that many students utilize public transit. The GBLS asked students to indicate their frequency of taking the bus and carpooling (combined in 1 survey question) on a 5-point scale where 1 is never and 5 is always. All five schools had a mean below 2.0 on this survey question, suggesting that students *never* to *rarely* arrive at school via bus or carpool. The population density calculations in Table 5-1 further underline the low density of the areas in which each school sits.

Selective Entry and Caregiver Effort

All students, whether at private or public charter institutions, have caregivers who have taken the initiative to enroll them in these schools. While the public charter schools do not have tuition costs, they do involve an application process and a lottery for students to be admitted. In the words of the co-founder of the public charter Arts School: "Let me put it this way: everybody [every child] has someone who loves them." Thus, while socio-economic situations likely vary across families in the case study schools (as indicated by census data and tuition), the presence of at least one involved parent is a constant for students across schools.

Low in ethnic diversity

In all schools, a majority of students taking the survey were white or white mixed with another ethnicity. In fact, amongst survey participants, the ethnic demographic in all schools was over 80% white, except in College Preparatory School with 59% white students (where Asian American was the next highest percentage at 25%). One reason the College Preparatory School may differ is that the administration places an emphasis on recruiting children of nearby University faculty members, a population that may inherently contain more ethnic diversity than the general population. The census data in Table 5-1 further shows that School 2, compared to the other school settings, is located in a census tract that has the lowest percent of white residents (at 75.7%), where the next largest ethnic group is Asian (19.5%). All of the school neighborhoods in this study range from 75-94% white, where the second largest ethnic group is Asian in almost every tract in this study.

Environmental sustainability not explicit part of founding mission

One interesting phenomenon across the three Teaching Green Buildings in this study is that the need to build or update facilities pulled the green mission of the schools into focus. How and when this manifested for each school is a different story. A closer look reveals the Ethics School as an outlier.

With the construction of new buildings at the start, the Ethics School faced the facility question before their doors opened to students. Thus, while the co-founder speaks of the environmental mission as emergent, it emerged so early that it is not perceptible as added on, as is the case with many other green schools. This school had the benefit of an early environmental sensibility that led to enthusiasm to build the first school building to ever by certified by the U.S. Green Building Council.

The College Preparatory School, in stark comparison, was established as an elite private school in the 1960's. As mentioned in the school description of the school above, the renovation project was necessary, but the green aspects were contentious among the board. Eventually, the green approach was accepted, and it was adherence to the LEED credit system that ultimately inspired the concept to use their renovated wing as a teaching tool. The science teacher, when asked about the pursuit of the teaching tool concept, commented that: "yes, and it has to be because we have made a pledge to gain a LEED point that students will get at least 10 hours a year, and that is now in curriculum starting this year." This school is, thus, an example where the allure of LEED system credits helped faculty to instigate innovative practices.

The story behind the Arts School (1) is yet another very different case compared to the other Teaching Green Buildings in the study. As a school founded with an emphasis on integrating the arts with academics, the green mission was incorporated based on a partnership with the foundation that financed the new school building. The founders are clear about adopting sustainability due to outside forces; at the same time, they see the mission as highly compatible with the founding mission, and eagerly embrace the new direction.

No formal green building education

No schools in this study, not even the schools with green buildings, have a formal green building curriculum. Further, no school in the study has a highly standardized environmental education curriculum. Interviews with administrators and focus groups with teachers revealed that green building education is ad hoc and anecdotal.

However, isolated green building lesson plans do exist in several schools in this study, and many of those lessons deal with landscape features versus indoor building features. Notable examples include the ways in which the College Preparatory and Ethics Schools use onsite streams in biology classes and there are gardening classes or clubs in all schools except the Technology School. Eighth graders in the College Preparatory School learn about electronics in alternative energy systems. And third graders in the Waldorf School engage in an on-campus construction project that typically involves simple, natural building techniques.

Beyond an array of lesson plans, it is clear that educators in several school settings use the environment anecdotally in their teaching, referencing the green building features in passing. Examples include the science teacher at the Ethics School who likens the solar panel to a sunflower for his students and the physical education teacher at the Arts School who talks to his students about the school's open-air corridors and bodily adaptation to high and low temperatures. Examples such as these abound across school settings, and highly depend on the teacher's own consciousness of the built environment.

No green school in the study has a formal orientation or written manual for teachers to learn about the green building themselves. Indeed, this omission may be a critical missing piece in the pursuit to connect green school buildings to informal environmental education. A comparison can be made to the open-school movement in school architecture in the 1970's where architects and educators sought to literally break down walls between classrooms. The experiment led to costly, hard to change physical realities that, in hindsight, brought some unexpected social and psychological consequences (Margaret, 1999). Among numerous failures of the open-school movement was the lack of training to help teachers adjust to the architectural changes (David, 1974).

One way to alleviate the knowledge gap is to involve teachers in the green building design process in more than a cursory way. At the College Preparatory School, for example, several members of the science faculty were highly involved in the design and *installation* of several green building features. From this involvement, teachers gained the ability to speak confidently about the building and re-imagine a science curriculum that uses the green building pedagogically. In contrast, teachers at the Arts School (1) were much less involved in the technical aspects of their new building, and in focus groups some educators at this school were frustrated about the lack of teacher education on their new green building. Regardless of involvement in the design process, an orientation or manual is advisable for teacher orientation over time. And ultimately, unless a formal curriculum is instituted, the adoption of green building lesson plans will be highly dependent on teacher interests and motivations.

Chapter Summary

By looking at the emergent findings from five distinct buildings, and with schools cultures that are just as diverse, it becomes clear that school culture and the physical environment are not easily untangled when it comes to measuring green building literacy outcomes. For this reason, this chapter has endeavored to unpack three major questions for each setting: the characteristics of the physical environments, major aspects of each school's culture, and the environmental education efforts in each setting. Next, key differences and similarities between settings were discussed as they relate to the prospects for studying the phenomenon of the Teaching Green Building. These differences and similarities are summarized in Table 5-4.

Table 5-4. Summary of key differences and similarities across school settings

Key Differences	*Key Similarities*
Geographic Location	Suburban Location
School Type	Selective Entry
School Age	Low Ethnic Diversity
School Size	Absence of Sustainability in Founding Mission
Grade-level composition	Little to no formal green building curricula
Tuition Costs	
School Culture	

In the chapter to follow, the variable of school is used in regression analyses. This variable thus contains the many levels of variation in physical and social school factors outlined above. The school variable will be tested as a predictor of numerous outcomes, but it also, by inclusion in the model, allows for school to be held constant when examining the influence of other predictors.

Based on Chapter 5 findings from interviews and observations alone, it is evident that the Ethics School is a potential outlier in this study. This school is a fairly extreme example of a sustainable school given the buildings, constructivist educational philosophy, small school size, early adoption of environmentalism. The school has two exemplar buildings on campus, and they are the longest standing green buildings in this study, which also means that students have had the longest amount of exposure. Based on Chapter 5 findings, School 3 would be expected to outperform all other schools in green building literacy measures.

Chapter 6
Fostering Green Building Knowledge and Environmentally Responsible Behaviors: a Multi-School Comparison

This chapter presents findings from the Green Building Literacy Survey (GBLS), with a focus on predictors of Green building knowledge and environmentally responsible behaviors at school, referred to as School behaviors. The theoretical foundations of the analyses in this chapter are described in Chapter 3, which outlined the major features of green building literacy and offered two propositional frameworks for the factors that influence green building knowledge (the contextual model for learning in green buildings, Figure 3-2) and environmentally responsible behaviors at school (The Hines et al. model, Figure 3-3).

Research Design

This study is designed as an exploratory investigation of green building literacy outcomes for middle school students in a range of school cultures and a mixture of green and non-green buildings. The Green Building Literacy Survey (GBLS), described in Chapter 4, was administered in five school settings in the academic year of 2011-12. Three of these schools have Teaching Green School Buildings (Schools 1, 2, and 3), and the other two are comparison schools in non-green buildings (Schools 4 and 5). It should be noted, however, that School 5 has a unique campus with numerous green features outside the school building, and results will show that this school aligns well with the green schools on numerous metrics.

Overview of Study Variables

Table 6-1 summarizes the variables measured in the GBLS. The basic categories of variables include green building literacy outcomes (knowledge, affect, and behavior, as conceptualized in 3-1), educational context variables (a fusion of socio-cultural and physical context factors), and demographic variables. Table 6-1 additionally provides variable descriptions and an indication of the variable type, categorical or Likert scale, which is relevant to the analyses in the sections to follow. The number of survey items per category is listed to offer transparency on the robustness of the categories. Categories with multiple items have been subject to a series of reliability and factor analyses as described in Appendix D.

Research Questions & Hypotheses

Central here is the question of environmental influences on green building literacy outcomes. While it is complicated to connect outcomes directly to architecture, the information from the GBLS can be analyzed in productive ways to bear on questions at the intersection of the built environment and environmental education.

Basic descriptions of between-group differences are foundational to the analysis reported here. The first research questions are:

1. **In terms of green building literacy and educational context factors, are there significant differences observed between:**
    a. school settings?
    b. grade levels?

It is predicted that students who use green school buildings day-to-day would have significantly higher levels of Green building knowledge, School behaviors, and more positive assessments of the educational context, including Supportive environment, Environmental conditions, and Environmental education opportunities. Differences observed in outside-of-school factors -- such as Home behaviors, Environmental sensitivity, and Behavioral willingness – are important to note where they occur.

Table 6-1. Descriptions of variables used in analyses

					Variable Type	
		Variable	**Description**	**No. of Survey Items***	**Categor-ical**	**Likert Scale****
		School	Distinguishes between the five school settings that were part of this study		X	
		Grade Level	Grade level 6, 7, or 8		X	
Green Building Literacy Outcomes	Knowledge	**Green Building Knowledge**	The test score from a 29-item test on green building knowledge	29		X
	Behavior	**School Behaviors**	Environmentally friendly behaviors conducted at school	6		X
		Home Behaviors	Environmentally friendly behaviors conducted at home	4		X
	Affect	**Behavioral Willingness**	Environmentally responsible behaviors students are willing to do (all are behaviors likely to be done at home)	4		X
		Environmental Sensitivity	A collection of metrics including general ratings of self and family, watching environmental programs, and having an environmental role model.	4		X
	Educational Context	**Supportive Environment**	Student rating of the building, teachers, and peers as supportive of learning and taking action on environmental issues	5		X
		Environmental Conditions	Student satisfaction with lighting, general environmental conditions of school building, and feeling of connection to nature from inside the school building	3		X
		Environmental Education	Student rating of enviornmental education opporutnities in general and green building education specifically both inside and outside of the classroom	4		X
	Demographic Variables	**Been to a Green Building (GB)**	Whether or not a student has visited a green building (not including their own school building, where applicable)	1	X	
		Years on Campus	Number of years the student has been at their current school campus (not including the academic year in which data was collected)	1		X
		Gender	Male or female		X	
		Ethnicity	Student ethnic group (White or Non-white)		X	

** Indicates number of questions retained after scale development (Appendix B)*

*** All categories/variables are Likert-scale rated on a 1 to 5 scale, except for the green building knowledge test score and the years on campus variable*

Differences in outside-of-school factors confound the attribution of green building literacy differences to the school environment alone, and point toward the possibility that the families that choose to attend one school may be significantly different from families at other schools on metrics important to this study.

In terms of grade level, older students are predicted to do better on the green building knowledge test due to higher levels of cognitive development and academic skills. Older students have also typically been in the building longer and have had more time to absorb their surroundings, though years on campus has also been measured as a variable in later analyses, since this factor varies by school grade-level composition (*e.g.*, School 2 starts at grade level 6, while other schools start at kindergarten, see Table 4-1). Further, in terms of differences between grade levels, previous studies in environmental education have observed that younger students tend to rate higher on affective dimensions and self-reported measures such as environmental sensitivity and environmentally responsible behaviors (McBeth et al., 2008; Zint, 2012). If differences are observed between younger and older students (i.e., 6^{th}-8^{th} graders), it would replicate results observed by others. In sum, there are numerous reasons to believe that numerous green building literacy outcomes will vary significantly by grade level.

With a better understanding of cross-school and cross-grade dynamics, the next analytical step combines schools into one predictive model to better understand two key green building literacy outcomes of knowledge and behavior. The second half of Chapter 3 on Theorizing Green Building Literacy presented the theoretical frameworks that are used to guide this portion of the analysis. Chapter 3 additionally elaborated on the reasoning for investigating the two dependent variables of knowledge and school behaviors, but not affective dimensions. The outcomes of behavioral willingness and environmental sensitivity typically change slowly over time and experience, and are not expected to vary across schools in this study. Home behaviors are not treated as a dependent variable because the goal of this work is to inform interventions made by architects and educators in the school environment. Thus, the next research questions include:

2. **What factors in the Contextual Model for Learning in Green Buildings (Figure 3-2) predict variance in levels of student Green building knowledge?**

3. **What factors in Hines et al. Environmental Education Model (adapted for green building themes) (Figure 3-3) predict variance in levels of student School behaviors?**

The analyses that investigate research questions two and three are exploratory in nature, seeking to determine significant predictors, and with a special interest in learning whether or not factors in the school environment appear to influence these two key outcomes. Based on previous literature [reviewed in Chapters 2 and 3], it is predicted that both dependent variables will be multiply-determined by a range of factors. If the school environment is influential, we would expect to see school-level variables - such as the school student attends and student assessments of the educational context - emerge as significant predictors.

Research Participants

Table 6-2 offers basic demographic information about the students who participated in the Green Building Literacy Survey (GBLS) across the five schools. The College Preparatory School is the largest school in the study, and had a high response rate. It is important to note that students from this school comprise approximately 45% of the whole sample. Adjustments have been made where necessary to take this large percentage of School 2 students into account.

The sample is split fairly equally across grades 6-8 and across gender. There is little ethnic diversity in the sample with 75% of the students identifying themselves as White American (American and/or European Descent) or White American mixed with another ethnicity. The next largest ethnic group is Asian American students. For analytical purposes, ethnicity in this study is a binary variable of white and non-white students due to the small numbers of minority students in this study.

Table 6-2. Survey participant demographics

	n	%
School		
School 1: Arts School	85	22
School 2: College Preparatory School	175	45
School 3: Ethics School	44	11
School 4: Technology School	32	8
School 5: Waldorf School	56	14
Grade		
6th Graders	142	36
7th Graders	132	34
8th Graders	118	30
Gender		
Male	181	46
Female	210	54
Ethnicity		
White (or white mixed with another ethnicity)	281	76
Asian American	46	12
African American	18	5
Hispanic	7	2
Other	18	5
Years on Campus (before year of survey)		
0 years	115	30
1-2 years	192	50
3+ years	74	19
Been to a Green Building before (not including students' own school building)		
Yes	210	54
No	53	14
Not Sure	126	32

Half of the students have been on their current school campus one to two years (50%)[20] and almost a third of the students (30%) were new to their school building the year the

[20] Note that School 1 students moved into their new Teaching Green School Building nine months prior to the survey administration. All students at this school were assigned the value

survey was completed. A fifth of the students (19%) have been on their campuses for more than three years, with approximately 15% of those students being on their campuses for 6 years or more.

Finally, more than half of the students indicated that they have been to a green building (other than their own school building if student attends a green school). However, nearly a third of students (32%) were not certain if they had been to a green building or not, suggesting that a large number of students may not be exactly sure what a green building is.

Results

The results presented here first examine important differences across groups and then offer prediction models for two key green building literacy outcomes. The first phase of data analysis involved descriptive statistics, where comparisons are made first by school setting and by grade level. These results indicate where significant differences are observed between settings and age groups. From there, two models are presented investigating the factors that predict each dependent variable of 1) Green building knowledge, and 2) School behaviors.

Mean Comparisons by School and Grade Level

Before combining variables into regression models and analyzing results, it is useful to understand dynamics that are occurring between important sub-groups within the survey sample. Perhaps the most important distinction between students is the school they attend, since this factor alone contains differences in geography, school culture, and architectural environment [among other differences discussed in length in Chapter 5]. Second, student grade level is an important factor given the significant personal and

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of one year on campus. For all other schools, the years on Campus value was determined by subtracting the number of years in attendance at their current school from the student's grade level.

Table 6-3. Means by school and grade level

	School Means				Grade Level Means*			
	School	Mean	S.D.	n	Grade Level	Mean	S.E.	n
Green Building Knowledge	**1. Arts**	**30.66**	10.34	85	**6**	**28.27**	.92	142
	2. College Prep	**30.98**	10.92	175	**7**	**30.07**	.92	132
	3. Ethics	**35.98**	9.07	44	**8**	**32.80**	.99	118
	4. Technology	**21.42**	10.23	32				
	5. Waldorf	**32.12**	8.07	56				
	Total	**30.86**	10.63	392				
School Behaviors	**1. Arts**	**2.99**	.73	84	**6**	**3.33**	.07	136
	2. College Prep	**3.01**	.79	169	**7**	**3.13**	.07	131
	3. Ethics	**3.97**	.41	43	**8**	**3.09**	.07	113
	4. Technology	**2.51**	.61	28				
	5. Waldorf	**3.23**	.68	56				
	Total	**3.11**	.79	380				
Home Behaviors	**1. Arts**	**3.13**	.83	84	**6**	**3.37**	.08	137
	2. College Prep	**3.01**	.86	169	**7**	**2.99**	.08	131
	3. Ethics	**3.31**	.76	43	**8**	**3.12**	.08	113
	4. Technology	**2.86**	.79	29				
	5. Waldorf	**3.47**	.77	56				
	Total	**3.12**	.84	381				
Behavioral Willingness	**1. Arts**	**3.71**	.87	84	**6**	**3.87**	.08	138
	2. College Prep	**3.68**	.91	174	**7**	**3.57**	.08	131
	3. Ethics	**3.86**	.62	43	**8**	**3.49**	.08	118
	4. Technology	**3.21**	.95	30				
	5. Waldorf	**3.78**	.73	56				
	Total	**3.69**	.86	387				
Environmental Sensitivity	**1. Arts**	**2.97**	.85	84	**6**	**3.32**	.07	139
	2. College Prep	**2.90**	.79	172	**7**	**2.82**	.07	132
	3. Ethics	**3.44**	.66	44	**8**	**2.87**	.08	117
	4. Technology	**2.63**	.74	32				
	5. Waldorf	**3.09**	.84	56				
	Total	**2.98**	.81	388				
Supportive Environment	**1. Arts**	**2.94**	.84	82	**6**	**3.09**	.08	133
	2. College Prep	**3.00**	.88	170	**7**	**2.76**	.08	130
	3. Ethics	**3.84**	.66	43	**8**	**2.78**	.08	117
	4. Technology	**1.92**	.69	29				
	5. Waldorf	**2.68**	.88	56				
	Total	**2.95**	.94	380				
Environmental Conditions	**1. Arts**	**3.60**	.96	85	**6**	**3.79**	.07	141
	2. College Prep	**3.58**	.75	175	**7**	**3.45**	.07	132
	3. Ethics	**4.39**	.52	43	**8**	**3.29**	.07	117
	4. Technology	**2.54**	1.03	31				
	5. Waldorf	**3.51**	.67	56				
	Total	**3.58**	.88	390				
Environmental Education	**1. Arts**	**2.63**	.96	84	**6**	**2.78**	.08	139
	2. College Prep	**2.46**	.84	172	**7**	**2.46**	.08	132
	3. Ethics	**3.15**	.80	44	**8**	**2.45**	.08	117
	4. Technology	**2.20**	.72	32				
	5. Waldorf	**2.38**	.80	56				
	Total	**2.54**	.88	388				

* While School Means are the raw means from the data files, Grade Level Means are estimated marginal means from univariate regression models that controlled for school due to the large differences in school sizes.

intellectual development that occurs between 6th and 8th grade. Results from the grade-level comparisons can illuminate interesting trends that occur over this critical three-year period for students. Table 6-3 shows the means for survey category analyzed by school and by grade level.

Comparing Schools

A school-by-school view of the data creates the opportunity to detect differences among the Teaching Green Buildings and the non-green buildings. A review of these data trends reveals a few aspects in which green schools excel, but in most cases the results vary little across the different school environments. Overall, the analysis documents that the Ethics School is exceptional in nearly every measure. Mean comparisons were conducted using a one-way Analysis of Variance (ANOVA). Post hoc pairwise comparisons with Bonferonni correction were used to examine the levels at which meaningful differences exist (Table 6-4). This table shows mean differences between each pair of schools where significant differences ($p<0.05$) are noted with an asterisk.

Assessment of student Green building knowledge is one of the primary dependent variables in this study. It was hypothesized that students in green buildings would do significantly better on this test. The data show that this is the case, except for the high performance of students in the Waldorf School (School 5), where students are in a non-green building, but do not perform significantly different from the students in green schools[21]. Students in the other non-green building, the Technology School (School 4), however, performed significantly lower than all other schools. A significant difference can additionally be observed between the longest standing, new construction Teaching Green Building, the Ethics School (School 3), and the recently renovated partial Teaching Green Building, the College Preparatory School (School 2). The longer standing school performed significantly higher on the test.

[21] This finding will be discussed in more depth in the discussion on green building knowledge later in the chapter.

Table 6-4. Mean differences, by school

		Green Building Literacy										Educational Context					
		Green Building Knowledge		School Behaviors		Home Behaviors		Behavioral Willingness		Environmental Sensitivity		Supportive Environment		Environmental Conditions		Environmental Education	
(I) School	(J) School	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.
1. Arts	2. College	-.32	1	-.02	1	.12	1	.03	1	.07	1	-.07	1	.02	1	.17	1
	3. Ethics	-5.31	.052	-.98	.000***	-.18	1	-.16	1	-.47	.016*	-.91	.000***	-.79	.000***	-.51	.013*
	4. Technology	9.24	.000***	.48	.021*	.26	1	.50	.063	.34	.394	1.01	.000***	1.06	.000***	.43	.144
	5. Waldorf	-1.45	1	-.24	.512	-.34	.159	-.08	1	-.12	1	.26	.771	.09	1	.26	.824
2. College Preparatory	1. Arts	.32	1	.02	1	-.12	1	-.03	1	-.07	1	.07	1	-.02	1	-.17	1
	3. Ethics	-4.99	.038*	-.96*	.000***	-.30	.321	-.18	1	-.54	.001**	-.84	.000***	-.81	.000***	-.69	.000***
	4. Technology	9.56	.000***	.50*	.007**	.14	1	.47	.054	.27	.800	1.08	.000***	1.04	.000***	.26	1
	5. Waldorf	-1.13	1	-.22	.435	-.46	.003**	-.10	1	-.19	1	.33	.121	.07	1	.08	1
3. Ethics	1. Arts	5.31	.052	.98*	.000***	.18	1	.16	1	.47	.016*	.91	.000***	.79	.000***	.51	.013*
	2. College	4.99	.038*	.96*	.000***	.30	.321	.18	1	.54	.001**	.84	.000***	.81	.000***	.69	.000***
	4. Technology	14.56	.000***	1.46*	.000***	.45	.244	.65	.014*	.81	.000***	1.92	.000***	1.85	.000***	.95	.000***
	5. Waldorf	3.86	.605	.74*	.000***	-.16	1	.08	1	.35	.293	1.16	.000***	.87	.000***	.77	.000***
4. Technology	1. Arts	-9.24	.000***	-.48*	.021*	-.26	1	-.50	.063	-.34	.394	-1.01	.000***	-1.06	.000***	-.43	.144
	2. College	-9.56	.000***	-.50*	.007**	-.14	1	-.47	.054	-.27	.800	-1.08	.000***	-1.04	.000***	-.26	1
	3. Ethics	-14.56	.000***	-1.46*	.000***	-.45	.244	-.65	.014*	-.81	.000***	-1.92	.000***	-1.85	.000***	-.95	.000***
	5. Waldorf	-10.69	.000***	-.72*	.000***	-.61	.013*	-.57	.031*	-.46	.090	-.75	.000***	-.98	.000***	-.18	1
5. Waldorf	1. Arts	1.45	1	.24	.512	.34	.159	.08	1	.12	1	-.26	.771	-.09	1	-.26	.824
	2. College	1.13	1	.22	.435	.46*	.003**	.10	1	.19	1	-.33	.121	-.07	1	-.08	1
	3. Ethics	-3.86	.605	-.74*	.000***	.16	1	-.08	1	-.35	.293	-1.16	.000***	-.87	.000***	-.77*	.000***
	4. Technology	10.69	.000***	.72*	.000***	.61*	.013*	.57	.031*	.46	.090	.75	.001**	.98	.000***	.18	1

*p < .05, ** p < .01, *** p < .001

In terms of the affective dispositions of behavioral willingness and Environmental sensitivity (ES), students across schools are not highly differentiated. Though, the Ethics School students score significantly higher on ES compared to all schools except the Waldorf School.

The mean comparisons in Table 6-4 additionally illuminate students' environmentally responsible behaviors at home and school. Here, the Waldorf School emerges as significantly different in regard to behaviors at home. This finding indicates that students in the Waldorf School, despite attending school in a non-green building, may have above average opportunities to engage with environmental issues outside of school.

We can also examine levels of student environmentally responsible behaviors conducted at school (Table 6-3 and Table 6-4). Here, the Ethics School is clearly distinguished with a mean of 3.97 (*SD*=0.41) on a 5-point frequency scale, a value significantly higher than all other schools. Additionally, the Waldorf School, as a non-green school, appears to conduct significantly more behaviors at school compared to the other non-green Technology School.

Finally, Table 6-4 depicts student assessments of the educational context, where differences between green and non-green school buildings are observable. To start, students are moderately to greatly satisfied with the Environmental conditions of their school buildings with an overall mean of 3.58 (*SD*=0.88). The Ethics School is distinguished as significantly higher than all others, and the Technology School significantly lower. A similar trend occurs in the rating of the school environment as supportive for learning and taking action on environmental issues. Note that the Waldorf School, a school in a non-green campus building, is not differentiated on these metrics from two of the green school buildings (the Arts and College Preparatory Schools).

Lastly, students in the different schools can be compared on their assessments of Environmental education opportunities. This survey category included four questions that asked students to rate the frequency of environmental education broadly and green building education specifically in each the classroom and in activities outside the classroom. There are few observable differences among the schools with the exception of the Ethics School. Note also that the student assessments of environmental education are generally low with an overall mean of 2.53 (*SD*=0.88) (Table 6-3), a finding that is consistent with the findings from teacher interviews and focus groups reported in Chapter 5 (and summarized on p.121). Within the category of Environmental education opportunities was a question that asked students about green building education in the classroom. Comparative ANOVA results for this single survey item reveal that the three Teaching Green Buildings (Schools 1-3) rate significantly higher than the other two non-green schools (Schools 4-5) ($p < 0.05$). Further, on this single metric, the Ethics School rates significantly higher than all other schools ($p < 0.05$).

Comparing Grade Levels

This section highlights the same categories analyzed in the previous section, but here analyzes the results differentiated by grade level. The trends here bring to light ways in which 6th graders can be distinguished from older middle school peers, a trend that will be examined in greater depth in the discussion section of this chapter.

Because the College Preparatory School is disproportionately large compared to the other schools, the mean comparisons in this section were conducted using estimated marginal means obtained from a series of univariate regression analyses (instead of ANOVA procedures used above). This analysis computes mean estimates controlling for school, and thus reduces the influence of the College Preparatory School in grade level estimates. Each analysis contained the dependent variable of interest with school and grade level input as fixed factors. Estimated marginal means were then subject to pairwise comparisons using Bonferonni adjustment. The results of this series of analyses are summarized in Table 6-5.

Table 6-5. Mean differences, by grade level (school controlled for)

		Green Building Literacy										Educational Context					
		Green Building Knowledge		School Behaviors		Home Behaviors		Behavioral Willingness		Environmental Sensitivity		Supportive Environment		Environmental Conditions		Environmental Education	
(I) Grade	(J) Grade	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.
6	7	-1.80	.424	.20	.061	.38	**.000***	.30	**.010***	.50	**.000***	.33	**.004***	.34	**.001***	.32	**.005***
	8	-4.53	**.001***	.25	**.019***	.27	**.032***	.38	**.001***	.45	**.000***	.32	**.008***	.50	**.000***	.33	**.006***
7	6	1.80	.424	-.20	.061	-.38	**.000***	-.30	**.010***	-.50	**.000***	-.33	**.004***	-.34	**.001***	-.32	**.005***
	8	-2.73	.107	.05	1	-.12	.833	.07	1	-.06	1	-.02	1.000	.16	.324	.01	1
8	6	4.53	**.001***	-.25	**.019***	-.27	**.032***	-.38	**.001***	-.45	**.000***	-.32	**.008***	-.50	**.000***	-.33	**.006***
	7	2.72	.107	-.05	1	.12	.833	-.07	1	.06	1	.02	1.000	-.16	.324	-.01	1

*** The mean difference is significant at the 0.05 level.**

First, as hypothesized, there is an upward trend in green building knowledge test performance from grade level 6 to 8 (Table 6-5). This is possibly due to the fact that student academic abilities steadily increase as students move closer to high school. The knowledge test required much reading and writing on the part of students; it also involved questions that tested factual as well as conceptual knowledge. The only significant difference in Green building knowledge (GBK) was between 6th and 8th graders. Thus, it does not appear that GBK increases step-wise by year.

While 6th graders performed lower on Green building knowledge, they rate higher, and often significantly higher, on every other metric shown in Table 6-5. For example, 6th graders indicate conducting a higher frequency of Home behaviors than older peers and higher School behaviors than 8th graders. Further, 6th grade students rate themselves higher in terms of both behavioral willingness and Environmental sensitivity compared to 7-8th graders, who are undifferentiated.

Sixth graders also have a tendency to give a higher assessment of factors in the educational context. For example, 6th graders rate their environment as more supportive than their 7th and 8th grade peers (Table 6-5). Further, 6th graders appear more satisfied in the area of Environmental conditions compared to other grade levels (Table 6-5). Finally, 6th graders also report a significantly higher level of environmental education compared to 7th and 8th graders (Table 6-5). Thus, there is an overall tendency for 6th grade students to rate their school environment more positively compared to peers in higher grade levels.

Predicting Green Building Literacy Outcomes

To answer the research questions two and three, a series of regression analyses were used to predict students' Green building knowledge and their environmentally responsible behaviors at school. Each model is described below in detail. To begin, it is useful to explore the interrelationships among model variables (those summarized in the Table 6-1 overview of study variables).

Relationships between Study Variables

The Table 6-6 correlation matrix shows the relationships between variables used in the regression models to follow. Pearson correlation values are shown with the significance (2-tailed) flagged for each value. This table shows that there are numerous significant correlations between variables.

The variable of years on campus had the lowest number of significant correlations, and among the significant correlations, the lowest Pearson correlation values. The variable of grade level had many significant correlations, but the Pearson correlation values are lower compared to all other categories except years on campus.

High correlation values can present multicollinearity issues in regression analyses, leading to unreliable estimates of the regression coefficients. The regression analyses to follow report collinearity diagnostics to determine if there are linear relationships among independent variables that may be of concern.

Table 6-6. Correlation Matrix

	Grade Level	GBK-Test	School Behaviors	Home Behaviors	Behavioral Willingness	Env. Sensitivity	Support	Environmental Conditions	Environmental Education	Years on Campus
Grade Level	1									
Green Building Knowledge - Test (GBK-Test)	**.171****	1								
School Behaviors	**-.142****	**.276****	1							
Home Behaviors	**-.145****	**.336****	**.526****	1						
Behavioral Willingness	**-.184****	**.291****	**.428****	**.496****	1					
Environmental Sensitivity	**-.229****	**.343****	**.493****	**.589****	**.469****	1				
Supportive Environment	**-.124***	**.203****	**.593****	**.331****	**.345****	**.513****	1			
Environmental Conditions	**-.227****	**.240****	**.490****	**.261****	**.371****	**.393****	**.582****	1		
Environmental Education Opportunities	**-.145****	**.271****	**.503****	**.409****	**.382****	**.604****	**.561****	**.386****	1	
Years on Campus	**.201****	**.126***	**.132***	.084	.006	.064	-.013	-.001	.047	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Predictors of Green Building Knowledge

Due to the exploratory nature of this study, and a multitude of variable types, three stages of regression analyses were used to arrive at a combined model for predicting Green building knowledge (GBK). The first step used Ordinary Least Squares (OLS) regression analysis to test for main effects of all predictor variables from Table 6-1 on GBK as the dependent variable. The second step sought to further refine the results through forward stepwise regression. Conducting this method in SPSS (the data analysis package used in this study) excludes categorical variables with more than two levels, and thus can only include scaled and binary variables. Despite this limitation, the stepwise regression process is valuable in that it determines a subset of variables that achieve the best predictive power with the least number of variables. The stepwise method thus offers the most parsimonious set of predictor variables. Finally, a combined OLS model is presented based on the dual insights from the first exploratory OLS model and the stepwise regression model.

In this set of analyses, the Green building knowledge value is the test score derived from the 29-question green building knowledge test that comprised the first half of the Green Building Literacy Survey. This test included write-in, multiple choice, photo identification, and fill-in-the-blank questions. All qualitative responses were given a numeric score, and numbers were summed across test sections to arrive at a final test score for each student. The total score possible was 54, where the mean was 30.71 (*SD*=10.64). There was high range of scores, where the low score was 2.00 and the high score 51.50. Neither the high or low scores are statistical outliers, however. There were 15 out of 392 (3.8% of) students who scored below ten on the test. All of these students responded to test questions, where the lowest performers typically checked the “I don’t know” option for numerous test questions (all portions of test offered the option to state “I don’t know.” See Appendix A). With this format, it is difficult to ascertain if students truly did not know the answers or did not want to try. The scores for all students who responded to test questions, even if they marked “I don’t know” for nearly every question, were kept in the analysis.

Step 1: Exploratory OLS Regression Results

When all factors measured in the study (those summarized in Table 6-1) are included in a prediction model for Green building knowledge, five out of thirteen variables emerge as significant predictors (Table 6-7). These factors are: Home behaviors, Environmental sensitivity, school, been to a green building, and grade level. The significance value of Supportive environment, Environmental conditions, and gender are only slightly above 0.05, indicating that they might be significant factors in a more powerful model. Together, the factors measured in this study explain 25.4% of the variance in Green building knowledge, $F(18, 329) = 7.55$, $p < .05$, $R^2 = .292$, 95% CI.

Table 6-7. Regression results to predict GBK (Exploratory Model)

Dependent Variable: Green Building Knowledge Test Score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10473.849[a]	18	581.880	7.554	.000
Intercept	886.791	1	886.791	11.513	.001
School Behaviors	39.123	1	39.123	.508	.477
Home Behaviors	584.306	1	584.306	7.586	**.006***
Behavioral Willingness	150.120	1	150.120	1.949	.164
Environmental Sensitivity	373.865	1	373.865	4.854	**.028***
School	815.192	4	203.798	2.646	**.034***
Supportive Environment	296.698	1	296.698	3.852	.051
Environmental Conditions	266.382	1	266.382	3.458	.064
Environmental Education	6.822	1	6.822	.089	.766
Been to a Green Building (GB)	1151.950	2	575.975	7.478	**.001***
Years on Campus	140.278	1	140.278	1.821	.178
Gender	256.913	1	256.913	3.335	.069
Ethnicity	47.539	1	47.539	.617	.433
Grade Level	1498.664	2	749.332	9.728	**.000***
Error	25341.220	329	77.025		
Total	379985.000	348			
Corrected Total	35815.069	347			

a. R Squared = .292 (Adjusted R Squared = .254)

*** Significant at p<0.05**

n = 348

Table 6-8 offers further detail on the differences observed between levels of the categorical variables in the Table 6-7 exploratory model. For these fixed factor variables, the model holds one level at zero for reference, and then compares each other level to the variable held at zero to determine significance. The results show, for example, that students who have been to a green building [been to a GB] are significantly different from students who were not sure (p=0.003), but there does not appear to be a significant difference between students who have not been to a green building and those unsure (p=0.283). In terms of grade level differences in Green building knowledge, 6th (p=0.000) and 7th graders (p=0.021) are clearly distinguished from 8th graders. The differences between the Technology School (School 4), the reference school, and the green schools (Schools 1-3) is notable.

Table 6-8. Regression parameter estimates for predicting GBK

Dependent Variable: Green Building Knowledge Test Score

Parameter	B	Std. Error	t	Sig.	95% Confidence Lower Bound	95% Confidence Upper Bound
Intercept	8.288	3.344	2.479	.014	1.710	14.867
[Grade Level=6]	-5.825	1.321	-4.410	**.000***	-8.424	-3.227
[Grade Level=7]	-2.763	1.187	-2.327	**.021***	-5.098	-.428
[Grade Level=8]	0[a]	.	.	.	.	.
[Gender=male]	-1.833	1.004	-1.826	.069	-3.808	.141
[Gender=female]	0[a]	.	.	.	.	.
[School=1]	6.850	2.416	2.836	**.005***	2.098	11.602
[School=2]	6.306	2.382	2.647	**.009***	1.620	10.993
[School=3]	8.221	2.783	2.954	**.003***	2.746	13.695
[School=5]	4.164	2.375	1.753	.080	-.508	8.837
[School=4]	0[a]	.	.	.	.	.
[Ethnicity=White]	.812	1.033	.786	.433	-1.221	2.845
[Ethnicity=Non-white]	0[a]	.	.	.	.	.
[Been to a GB=No]	-1.707	1.586	-1.076	.283	-4.827	1.414
[Been to a GB=Yes]	3.469	1.163	2.984	**.003***	1.182	5.756
[Been to a GB=Not sure]	0[a]	.	.	.	.	.
Environmental Sensitivity	1.945	.883	2.203	**.028***	.208	3.682
Environmental Education	-.232	.780	-.298	.766	-1.767	1.303
Environmental Conditions	1.403	.755	1.860	.064	-.081	2.888
Supportive Environment	-1.557	.793	-1.963	.051	-3.117	.004
Behavioral Willingness	.970	.695	1.396	.164	-.397	2.336
School Behaviors	.645	.905	.713	.477	-1.135	2.424
Home Behaviors	2.195	.797	2.754	**.006***	.627	3.764
Years on Campus	.382	.283	1.350	.178	-.175	.940

a. This parameter is set to zero because it is redundant.

*** Significant at p<0.05**

n = 348

Step 2: Stepwise Regression Results

The OLS regression model presented above (Table 6-7) offered one way to identify predictor variables given the long list of independent variables potentially affecting Green building knowledge. The use of a stepwise regression method can further assist in the process of variable elimination. As noted earlier, the stepwise process results in a subset of variables and attempts to achieve the best predictive power with the least number of variables. The method seeks the most parsimonious set of predictor variables. The data analysis package used in this study (SPSS) can do this process with scale variables and binary categorical variables, but not multi-level categorical variables. The variables that could not be included in this analysis are school, which has five levels for each of the five school settings, and been to a green building, which has three levels. The OLS regression results (Table 6-7 and Table 6-8) both indicate that these categorical variables appear to be of importance to Green building knowledge. This insight could not have emerged from the stepwise regression approach.

The model presented here (Table 6-9) uses forward selection, where the model systematically adds predictors one at a time based on the F-values until no more variables can be added to improve the model. Forward was chosen based on the simplicity in reporting compared to other stepwise methods. The same model variables were tested in each backward elimination and stepwise regression with equal resultant R-squared values (all had an adjusted R-squared of .208) and the same four variables in each final model.

The forward selection Table 6-9 results show the four variables that emerged as the most significant predictors of Green building knowledge, which together explain 20.8% of the variance. These factors were: Home behaviors, grade level, Environmental conditions, and Environmental sensitivity.

The Table 6-9 column with collinearity diagnostics indicates that multicollinearity is not a concern in this model with variance inflation factors (VIF) all below 5-10, the standard cut-off above which multicollinearity may be a problem (O'Brien, 2007).

Table 6-9. Forward stepwise regression to predict GBK

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	18.161	1.980		9.171	.000		
	Home Behaviors	4.242	.613	.349	6.924	.000	1.000	1.000
2	(Constant)	-2.000	5.054		-.396	.693		
	Home Behaviors	4.594	.603	.378	7.617	.000	.982	1.019
	Grade Level	2.729	.632	.214	4.317	.000	.982	1.019
3	(Constant)	-12.836	5.623		-2.283	.023		
	Home Behaviors	4.051	.605	.333	6.695	.000	.934	1.071
	Grade Level	3.254	.632	.255	5.149	.000	.940	1.063
	Environmental Conditions	2.462	.608	.205	4.049	.000	.901	1.110
4	(Constant)	-15.468	5.704		-2.712	.007		
	Home Behaviors	3.165	.714	.260	4.433	.000	.662	1.510
	Grade Level	3.458	.634	.271	5.452	.000	.922	1.085
	Environmental Conditions	2.084	.626	.174	3.326	.001	.838	1.193
	Environmental Sensitivity	1.788	.777	.143	2.300	.022	.595	1.681

a. **Dependent Variable:** Green Building Knowledge Test Score

Forward Criterion: Probability of F to enter <= .050

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.349[a]	.122	.119	9.543
2	.408[b]	.167	.162	9.309
3	.452[c]	.205	.198	9.108
4	.466[d]	.217	.208	9.051

a. Predictors: (Constant), Home Behaviors
b. Predictors: (Constant), Home Behaviors, Grade Level
c. Predictors: (Constant), Home Behaviors, Grade Level, Environmental Conditions
d. Predictors: (Constant), Home Behaviors, Grade Level, Environmental Conditions, Environmental Sensitivity

Step 3: A Combined Model for predicting Green Building Knowledge

Based on the regression results from the two previous sections, eight predictors of Green building knowledge can be identified. These predictors are:

- Home Behaviors
- Grade level
- Environmental Conditions
- Environmental Sensitivity

- School Student Attends
- Been to a Green Building
- **Borderline variables:** *gender and Supportive environment*

These variables were placed in a new OLS regression model to predict Green building knowledge. The new model explains only slightly more variance (25.8%) than the first OLS model (25.4%), where new model: $F(13, 353) = 10.79$, $p < .05$, $R^2 = .284$, 95% CI. In this new combined model, the majority of variables remain significant (p<0.05), though Environmental conditions (p=0.060), Supportive environment (p=0.072) and gender (p=0.090) are all just above the significance level cut-off of 0.05. As mentioned earlier, a model with more power may tip these factors back into the realm of significance, and they are thus termed here "borderline predictors."

Table 6-10. Regression results to predict GBK (Combined Model)

Dependent Variable: Green Building Knowledge Test Score

Source	Squares	df	Square	F	Sig.
Corrected Model	11055.733[a]	13	850.441	10.785	.000
Intercept	1476.596	1	1476.596	18.726	.000
Home Behaviors	1134.380	1	1134.380	14.386	**.000***
Grade Level	2266.853	2	1133.427	14.374	**.000***
Environmental Conditions	280.493	1	280.493	3.557	.060
Environmental Sensitivity	986.153	1	986.153	12.506	**.000***
School	832.562	4	208.141	2.640	**.034***
Been to a GB	1024.060	2	512.030	6.493	**.002***
Gender	228.170	1	228.170	2.894	.090
Supportive Environment	256.571	1	256.571	3.254	.072
Error	27835.624	353	78.854		
Total	399559.000	367			
Corrected Total	38891.357	366			

a. R Squared = .284 (Adjusted R Squared = .258)

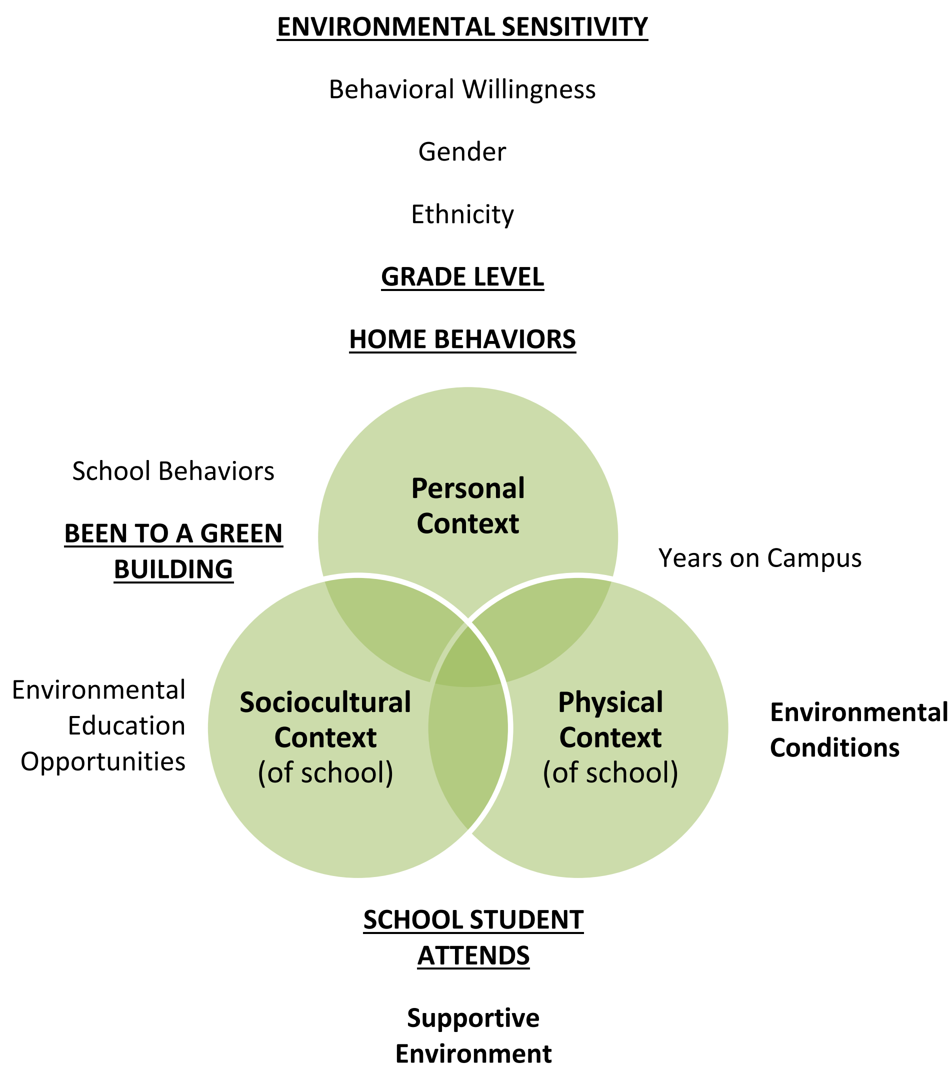
*** Significant at p<0.05**

n = 367

The Contextual Model for Learning in Green Buildings

Scholarship in museum studies points toward three major domains of influence on informal learning in museum settings. These influences come from each the personal, sociocultural, and physical contexts. The Falk et al. (2007) model, with its focus on museum and museum-like settings, was adapted into a propositional diagram of the influential factors on contextual learning in green buildings (Figure 3-2). The analyses presented in this chapter sought to uncover factors in each major domain that bear on student levels of GBK. The results above showed that factors in each domain emerge as significant predictors.

There are significant predictors of GBK in all domains physical, sociocultural, and personal. However, as visible in the Figure 6-1 diagram, there are numerous important personal context factors that emerged from the analyses in this section. Thus, while school-level factors appear to be important, many of the factors that explain variance in GBK are qualities that students have when they arrive at the school building. This finding will be elaborated in greater detail in the discussion section of this chapter.



Bold Text = Variable/category in final GBK regression model (Table 6-10)

CAPITALIZED TEXT = Variable/category in final GBK regression model that was statistically significant in final model ($p<0.05$) (Table 6-10)

Figure 6-1. The contextual model for learning in green buildings with final GBK regression results

Predictors of Environmentally Responsible Behaviors (ERB's)

The second major green building literacy outcome investigated in this chapter is that of student environmentally responsible behaviors (ERB's) at school (abbreviated as School behaviors). Where Green building knowledge (GBK), presented above, is a newly studied outcome variable, the study of ERB's is well chartered territory. Thus, the overall investigation of ERB's is somewhat less exploratory and more confirmatory compared to the results presented for GBK. Chapter 3 offered an overview of behavior change models and predictors that lay the groundwork for thinking about influences on ERB's in and out of the school environment. As will become clear in the sections to follow, the variables in this study do a much better job of predicting behavior than they did knowledge.

The School behaviors category is a mean composite of six survey questions relating to the frequency of environmentally responsible actions students conduct at school (Cronbach's Alpha = 0.71) (See Appendix D for survey category development process). These six behaviors include: general assessment of School behaviors, helping peers take action at school, recycling, turning off lights, composting, and picking up litter on the school grounds. This measure had an overall mean of 3.11 (*SD*=0.79), where a 3 on the likert-scale questions indicated that students sometimes do environmentally responsible behaviors at school.

The regression analyses predicting ERB's follow the same three step process used with GBK regression analyses (rationale explained on p.140). To summarize the process, the first step is an exploratory OLS regression model that inputs all predictor variables from Table 6-1. The second steps seeks the most parsimonious model possible using stepwise regression analysis. The third and final model combines insights into a final OLS prediction model.

Step 1: Exploratory OLS Regression Results

The main effects of 14 study variables were investigated in a single regression model with School behaviors as a dependent variable (Table 6-11). The model is a good fit for the dependent variable, with the independent variables explaining 55% of the variance in student behaviors at school, $F(18, 329) = 25.07$, $p < .05$, $R^2 = .578$, 95% CI.

Four variables emerged as significant predictors of School ERB's: Home behaviors, school, Supportive environment, and Environmental conditions (p<0.05). In reviewing these four predictors, it is interesting to note that the numerous factors that involve the physical environment, a point which will be elaborated in more length in the discussion section of this chapter.

Table 6-11. Regression results for School behaviors (Exploratory Model)

Dependent Variable: School Behaviors

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	128.950[a]	18	7.164	25.074	.000
Intercept	2.572	1	2.572	9.002	.003
Green Building Knowledge Test Score	.145	1	.145	.508	.477
Home Behaviors	9.607	1	9.607	33.624	**.000***
Behavioral Willingness	.712	1	.712	2.493	.115
Environmental Sensitivity	.001	1	.001	.004	.951
School	6.186	4	1.547	5.413	**.000***
Supportive Environment	8.521	1	8.521	29.823	**.000***
Environmental Conditions	2.282	1	2.282	7.987	**.005***
Environmental Education	1.045	1	1.045	3.656	.057
Been to a Green Building (GB)	.362	2	.181	.634	.531
Years on Campus	.000	1	.000	.001	.969
Gender	.835	1	.835	2.922	.088
Ethnicity	.101	1	.101	.354	.552
Grade Level	.249	2	.124	.435	.647
Error	93.998	329	.286		
Total	3608.897	348			
Corrected Total	222.948	347			

a. R Squared = .578 (Adjusted R Squared = .555)

*** Significant at p<0.05**

n = 348

The parameter estimates for the Table 6-11 regression model (such as those presented in Table 6-8 for GBK) were not revelatory in terms of significant differences amongst levels of categorical variables. The estimates are thus not shown here.

While Home behaviors did predict School behaviors, it is striking to see that behavioral willingness is not a significant predictor given that behavioral intent is one of the most reliable predictors of behavior in previous studies (Azjen, 1991; Hines et al., 1987; Hungerford & Volk, 1990). However, in the Green Building Literacy Survey, behavioral willingness was measured in terms of home behaviors (such as saving water when bathing and using dimmer lights). Therefore, this may explain the disconnect between willingness at home and behaviors at school.

Step 2: Stepwise Regression Results

Just as stepwise regression methods were used to determine the most parsimonious model for green building education, the same methods were used again here with behavior. Again, the categorical variables of School and been to a green building could not be included due to having more than two categorical levels due to limitations in using SPSS statistical software.

A series of stepwise regression analyses were conducted, including forward selection, backward elimination, and stepwise methods. All methods resulted in an adjusted R-squared of approximately 0.52, and each model had the same basic resultant predictors. Table 6-12 presents the results of forward stepwise regression. The predictors in the final model are: Environmental education, Environmental conditions, Supportive environment, Home behaviors, and years on campus. This result is fairly well aligned with the OLS regression results in Table 6-11, where stepwise methods additionally include years on campus and Environmental education. Also, the variable of School was significant in OLS regression, but could not be included in the stepwise methods.

Table 6-12. Forward stepwise regression for School behaviors

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.576	.111		14.161	.000
	Supportive Environment	.523	.036	.606	14.510	.000
2	(Constant)	.808	.129		6.258	.000
	Supportive Environment	.412	.034	.477	11.943	.000
	Home Behaviors	.352	.038	.375	9.377	.000
3	(Constant)	.498	.147		3.378	.001
	Supportive Environment	.321	.040	.372	7.976	.000
	Home Behaviors	.337	.037	.359	9.144	.000
	Environmental Conditions	.173	.042	.188	4.116	.000
4	(Constant)	.451	.147		3.071	.002
	Supportive Environment	.327	.040	.379	8.176	.000
	Home Behaviors	.326	.037	.348	8.889	.000
	Environmental Conditions	.173	.042	.187	4.141	.000
	Years on Campus	.035	.013	.103	2.808	.005
5	(Constant)	.421	.146		2.880	.004
	Supportive Environment	.282	.043	.327	6.488	.000
	Home Behaviors	.300	.038	.320	7.904	.000
	Environmental Conditions	.165	.042	.179	3.984	.000
	Years on Campus	.034	.012	.098	2.704	.007
	Environmental Education	.107	.043	.116	2.520	.012

a. Dependent Variable: School Behaviors

Forward Criterion: Probability of F to enter <= .050

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.606[a]	.368	.366	.63690
2	.701[b]	.492	.489	.57192
3	.717[c]	.514	.510	.55970
4	.724[d]	.525	.520	.55442
5	.730[e]	.533	.527	.55034

a. Predictors: (Constant), Supportive environment

b. Predictors: (Constant), Supportive environment, Home behaviors

c. Predictors: (Constant), Supportive environment, Home behaviors, Environmental conditio

d. Predictors: (Constant), Supportive environment, Home behaviors, Environmental conditio

e. Predictors: (Constant), Supportive environment, Home behaviors, Environmental conditions, Years on Campus, Environmental Education

Step 3: A Combined Model for Predicting ERB's

Based on the regression results from the two previous sections, seven predictors of student School behaviors can be identified. These predictors are:

- Supportive Environment
- Home Behaviors
- Environmental Conditions
- Years on Campus
- Environmental Education
- School Student Attends
- **Borderline variable:** *gender*

These variables are included in a new OLS regression model to predict School behaviors (Table 6-13). The new model explains nearly the same amount of variance (55.6%) compared to the first OLS model (55.5%), where new model: $F(10, 353) = 46.41$, $p < .05$, $R^2 = .568$, 95% CI. While there is no increase in variance explained, the combined model has the same fit with less variables, meaning that it is the most parsimonious model possible with the predictors measured in this study. In this new combined model, the majority of variables remain significant ($p<0.05$), though gender ($p=0.144$) and years on Campus ($p=0.775$) are further distanced from significance level cut-off of 0.05. Based on the first two steps of the process, these are two variables that are best left in the model as control variables even if they are not significant in the final model.

Table 6-13. Regression results to predict School behaviors (Combined Model)

Dependent Variable: School Behaviors

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	131.913[a]	10	13.191	46.412	.000
Intercept	6.749	1	6.749	23.746	.000
School	7.920	4	1.980	6.966	**.000***
Gender	.610	1	.610	2.146	.144
Environmental Conditions	2.690	1	2.690	9.463	**.002***
Home Behaviors	16.872	1	16.872	59.362	**.000***
Supportive Environment	9.174	1	9.174	32.276	**.000***
Environmental Education	1.995	1	1.995	7.020	**.008***
Years on Campus	.023	1	.023	.082	.775
Error	100.330	353	.284		
Total	3767.375	364			
Corrected Total	232.244	363			

a. R Squared = .568 (Adjusted R Squared = .556)

*** Significant at p<0.05**

n = 364

Discussion

The goal of this chapter is to explore the predictors of the two green building literacy outcomes of Green building knowledge (GBK) and environmentally responsible behaviors (ERB's) at school (School behaviors). The lens for this work expands beyond personal and sociocultural factors by also measuring student orientations toward the physical environment. The findings here can potentially inform those interested in crafting both the social and physical environments that support informal learning and the adoption of environmentally responsible behaviors in green school buildings. The discussion begins with an in-depth look at each outcome variable in turn.

Green Building Knowledge

The Figure 6-1 diagram combined the Contextual Model for Learning in Green Buildings (Figure 3-2) with the final GBK regression results reported in this chapter (Table 6-10). This overlay of information allows a deeper exploration of GBK predictors in each the physical, socio-cultural, and personal contexts presented in the Figure 3-2 framework. The sections that follow will unpack each of these domains, reflecting on knowledge gained from regression analyses.

Physical + Sociocultural Contextual Factors

In this study, physical and social concepts are intertwined in the measurements. This section thus combines discussion of the physical and sociocultural contexts. Amongst the variables studied, several significant predictors of GBK were contextual factors related to the social and physical environment. These variables were: School student attends, Environmental conditions, and Supportive environment.

The School Student Attends

The mean comparisons in Table 6-4 showed that there were significant differences in knowledge between schools in this study – where one green school was higher than several others and one non-green school was lower than all others. Regression results from both regression analyses revealed School as a significant predictor of GBK, indicating that this is a strong predictor amongst the variables measured. It should be noted, however, that clear differences were not observed between green and non-green school buildings. Students in Teaching Green School buildings do not necessarily excel above and beyond their peers in non-green buildings. The non-green Waldorf School (School 5) had a higher test mean than green Schools 1 and 2, though means were not statistically different from each other. The Waldorf School was also not statistically differentiated from the green school with the highest test mean, the Ethics School (School 3). It is interesting to note, however, that the Waldorf School test mean adjusts down when estimated marginal means are computed in OLS regression. When numerous variables are accounted for in the regression model, the Waldorf School test mean is not significantly different from the other non-green Technology School [see the parameter estimates in Table 6-8].

As was detailed in Chapter 5, the Waldorf School does not have access to a Teaching Green Building, though there are numerous green features outdoors on the school campus and a middle school science teacher who occasionally uses the built school environment in his lesson plans. The green building knowledge test included questions about the outdoor environment, such as test questions about pervious surfaces, gardening, and composting – all features found on the School 5 campus. Thus, while School 5 was selected for the study as a non-green school, and indeed the school building is not green, there are many aspects within the total school environment that comprise an informal green building education.

The second non-green school in the study, the Technology School, is more exemplar of a typical non-green school building and culture. The Technology School is the one school in the study that does not have green features on campus, indoors or out. Additionally, there were few indicators of environmental sensibilities offered from teachers or the administration at School 4. Students in this school performed significantly lower on the green building knowledge test than students in Teaching Green Buildings.

The emergent story across these data is that green features in the physical environment appear to make a difference for student green building knowledge. However, outcomes may be just as possible on a non-green campus with green sensibilities as at a state-of-the-art, LEED certified Teaching Green Building.

Environmental Conditions

The category of Environmental conditions measured student satisfaction with the building lighting, connection to nature from indoors, and the school building in general. This category was a significant predictor of GBK in the forward stepwise regression model (Table 6-9). This result is consistent with findings of Matsouka (2008), who investigated the presence of daylight and greenery on high school campuses, and presents compelling results for the importance of such features to student academic achievement. The significance of this factor in the current study suggests the possibility that a comfortable environment relates to student learning. However, the mechanisms at work in a Teaching Green Building would require a more detailed investigation.

Supportive Environment

The Supportive environment category includes measures of different types of support for environmentally responsible behaviors (ERB) – from support provided by teachers, to peers, to the building itself. Averaged together, this category measures a student's rating of the supportiveness of their school environment for ERB's. Thus, this category relates more clearly to ERB's. However, in the exploratory regression model (Table 6-7), this factor is on the borderline of significance, and may prove significant in a more powerful model. If a student receives support for ERB's at school, it is possible that those same sources of support help the student to learn about environmental issues and thus perform higher on a test of green building knowledge.

The Personal Context

Personal factors dominated the set of predictors of GBK. In particular, a student's behaviors at home, Environmental sensitivity, and grade level are each significant predictors of GBK, and remained consistently significant across the different regression methods. Whether or not the student had been to a green building (outside of their own school building) was also a significant predictor in both OLS regression models. While the personal context of the student cannot be manipulated by educators or architects (other than increasing the number of field trips to local green buildings), each of these elements is important to understand in the quest to educate students about green building issues. A deeper look at each of these student characteristics can illuminate the traits that potentially affect the way unique individuals learn inside their green school building.

Home Behaviors

Student behaviors at home are a better predictor of GBK than student behaviors at school. There are several potential explanations for this. A first possibility is that the absence of a formal green building curriculum at school minimizes the chance that students connect knowledge to behaviors. Further, students may have a chance to engage with environmental issues in a more hands-on, close-up way at home, increasing the possibility that the learning outcomes are more potent. In addition, students who conduct environmentally responsible behaviors at home may live in home environments that are supportive of environmentalism. Student Home behaviors have a significant positive correlation with student rating of family environmental sensitivity (Pearson correlation value of 0.58, p=.000). Though, it is difficult to say if family environment influences the student or the student influences the family given the nature of the data.

Environmental Sensitivity

Environmental Sensitivity (ES) is a measure of student predisposition to care about environmental issues. Levels of student ES explain variance in student knowledge about green buildings. Students with high ES in this study were those who indicated a higher frequency of reading or watching programs about the environment and they also indicated having environmental role models both inside and outside their families. Family members, outside role models, and media, being potential sources of learning about issues relevant to green buildings outside of the classroom, may contribute to higher levels of student green building knowledge.

Grade Level

Student grade level is a significant predictor of Green building knowledge. As mentioned previously, this is possibly the result of academic skills, and particularly test-taking skills, that steadily increase for students from 6^{th} to 8^{th} grade. The data in this study offer no other explanations for the grade level differences. There are no data to support the idea that 8^{th} graders receive more green building education than 6^{th} graders. To the contrary, 6^{th} graders actually perceive higher levels of Environmental education opportunities in their lives (Table 6-5). It is possible that 8^{th} graders score higher on the GBK test because they have had more years of exposure to green buildings (whether their own school building or through field trips to green buildings). However, as discussed below, the years on campus variable did not emerge as a significant predictor of GBK. Finally, there was not a steady increase in GBK from grade 6 to 7 to 8. The only observed difference was between 6^{th} and 8^{th} graders (Table 6-5), thus the difference observed could be due to academic skills alone given the small increases from year to year.

While the explanation of grade level effect on GBK is yet lacking, the implication for future research is clear. This finding suggests that grade level is an important control variable for examining other predictors of GBK, and cannot be omitted from predictor models.

Having been to a green building

Of the significant personal context factors, having been to a green building is perhaps the easiest variable to influence in the school environment by taking students on field trips to local green buildings. Analyses here showed that students who indicated having been to a green building[22] perform higher on the GBK test than students who haven't and students who were not sure (Table 6-8). This is an interesting result, and warrants further investigation, especially since previous studies in environmental education have questioned the effectiveness of time-limited field trips compared to more prolonged interventions (Hines et al., 1987; Leeming et al., 1993; Zint, 2012), though these studies have focused a range of behavioral, attitudinal, and knowledge outcomes, not just knowledge. The research presented here suggests that a field trip to a green building can make a difference for GBK. The implication for practice is that teachers should strive to organize such field trips for their students. Even students who use green buildings daily could benefit from seeing diverse examples of green buildings in practice.

In this study, the variable of been to a green building was one question on the front page of the GBLS (See Appendix A). It is unclear if students who answered "yes" to this question have been on field trips or have seen green residential buildings of friends or

[22] This was one survey question that defined what a green building is and asked students if they had been to a green building (other than their own school building in schools where applicable).

family. Based on the regression findings presented in this chapter, a more thorough examination could advance our understanding of the types of exposure students have to other green buildings, and how that exposure relates to increases in Green building knowledge.

Non-significant factors

There are two factors that did not emerge as significant. The first is Environmental education opportunities. From mean comparison results, we know that green buildings issues are rarely covered in the classroom, though the Ethics School students indicated receiving more opportunities than all other schools (Table 6-4). An understanding of broad environmental issues would hypothetically prepare students to answer questions regarding green buildings. However, it appears that access to broad environmental education does not predict performance on a test of green building knowledge.

A second slightly surprising non-significant factor is years on campus. Since much of what students learn is expected to happen through informal channels in the day-to-day green school environment, it was hypothesized that more time on campus would lead to heightened understanding of the physical environment. An explanation for the lack of significance of years on campus cannot be determined with the data available.

Environmentally Responsible Behaviors (ERB's) at School

The predictor models in this study explained more variance in School behaviors than they did Green building knowledge (GBK), where approximately 56% of variance was explained in the former and 27% in the latter. Where predictors of GBK were dominantly personal context variables, the analyses of ERB predictors uncovered numerous significant factors in the social and physical school environment. In fact, except Home behaviors (and the borderline predictor of gender) all significant predictors of ERB are contextual factors within the school environment. These factors are: School student attends, Environmental Conditions, Supportive environment, and Environmental education. Years on campus is a borderline predictor. Where GBK appears to be influenced by internal traits of the student (such as Environmental sensitivity, Home behaviors, and been to a green building), it appears that ERB's at school are highly influenced by external environmental factors. Significant predictors of ERB will be discussed below.

Situational Factors

The Hines et al. (1987) model for environmental education proposed that situational factors matter for environmental behavior change (Figure 3-3). This model described situational factors as social and physical environmental factors such as financial constraints or social pressures. The current study investigated a range of situational factors that were hypothesized to influence School behaviors.

Numerous environmental factors predicted School behaviors, and variation was observed in environmental factors across schools in this study. Reviewing mean comparisons and regression analyses together, a case can be made for the importance of situational factors. Consider several of the important environmental factors that emerged. First, the supportiveness of a school environment for ERB's is one of the top predictors of School behaviors. That is, students who perceive support from teachers, peers, and the school building are more likely to conduct ERB's at school. This variable was the first variable mathematically entered by the forward stepwise regression model (Table 6-12) and remained significant throughout regression analyses. Environmental conditions was another factor that emerged as a significant predictor of School behaviors, suggesting that a student's satisfaction and comfort in the building relates to behavioral decisions. Both of these factors, Supportive environment and Environmental conditions, varied by school environment. Results in Table 6-4 showed that the exemplar green building, the Ethics School, students rated their environment significantly higher for supportiveness and environmental comfort compared to all other schools. The students at the exemplar non-green school in this study, the Technology School, rated their environment significantly lower in these areas compared to all other schools (Table 6-4). Students at the Ethics School performed ERB's at school at a high frequency (overall mean of 3.97 on a 5-point scale, *SD*=0.41, Table 6-3), and significantly higher than all other schools. Notably, students at the Ethics School were not significantly different from their peers in terms of Home behaviors (Table 6-4), indicating that Ethics School students are likely being influenced by school environment factors, such as supportiveness and comfort, during their time at school. Environmental education was another factor that predicted School behaviors, a result that suggests that the social environment, including the curricula established by teachers, can be influential for student behaviors at school. Finally, years on campus was a borderline predictor of School behaviors, suggesting the possibility that as amount of time on campus increases (i.e., as exposure to the social and physical school environment increases), so does the likelihood of participating in environmentally responsible behaviors on campus.

It is further interesting to juxtapose the above results, which indicate the importance of the social and physical school environment, with the fact that few personal context factors emerged as significant predictors of ERB's. In particular, student dispositions such as Environmental sensitivity and Behavioral willingness did not emerge as significant predictors of School behaviors. Previous studies on environmentally responsible behaviors have found that affective dispositions do matter for behavior change (Hines et al., 1987; Hungerford & Volk, 1990). Despite these previous findings, the results in the current study show that external contextual factors appear to be more significant in behavioral choices at school. With the data available, it is difficult to determine an explanation for this outcome. It may be a peculiarity of the age group and the school setting. Middle school students do not typically have the same levels of autonomy on campus compared to college students or high school students, and thus may yet be under tighter control and supervision of teachers. It is also possible that teachers structure ERB's into classroom operations for middle schoolers. The seventh grade teacher at the Waldorf School, for example, assigns students days to take out the recycling. Thus, students may conduct higher levels of School behaviors irrespective of their own feelings about environmental issues.

Taken together, these results present a compelling case for green building design and environmental education curricula as catalyzing factors for student environmentally responsible behaviors. It appears that architects and educators can make decisions that influence student behaviors, since many factors external to the student affect behavioral decisions. However, an important question emerges: would students continue to conduct ERB's in the absence of external motivations? The goal of encouraging student ERB's at school is not simply to improve the environmental performance of the building, but to foster life-long habits of environmental stewardship. Ideally, these habits would endure across time and contexts. Research in conservation psychology presents a strong case for considering both extrinsic and intrinsic motivations (De Young, 1986, 1993, 2000), where scholarship indicates that extrinsic motivations alone may be challenged to promote long-lasting behavior change (Clary & Snyder, 1999; Lepper, Greene, & Nisbett, 1973).

This study uncovers a number of questions that can be advanced in future research on situational factors in the school environment. The question of extrinsic versus intrinsic motivations was discussed above. There is also more to be learned about the Supportive environment and Environmental condition factors that emerged as significant predictors of ERB's. Future work could expand the investigation of Supportive environment by isolating teachers, peers, and the building in separate categories to better understand the ways that social pressure, social norms, role models, and facility opportunities shape student behavioral decisions. The exploratory work presented here suggests that this category of influences is potentially among the strongest set of predictors of ERB's. Further research could additionally unpack the relationship between Environmental conditions – such as air flow, temperature, lighting – and ERB's. It is possible that satisfaction with Environmental conditions relates to a person's overall feelings toward the building, which affect the ways in which that person participates in environmental efforts within the building. From the data presented here, we cannot discern the pathways between predictors and the outcome; we can, however, identify promising directions for future study.

Personal Contextual Factors

One personal context factor clearly predicts School behaviors, and that is whether or not students conduct ERB's at home. Home behaviors was a significant predictor in all regression analyses presented, and the second predictor included by forward stepwise regression (second to Supportive environment) (Table 6-12). It appears that actions a student takes at home – such as recycling, composting, and talking to their parents about environmental issues – affects decisions the student makes at school. Further, gender was a borderline predictor of ERB, where females appear to conduct slightly more environmentally responsible behaviors at school compared to males.[23] Given the borderline nature of the gender variable, it is wise to control for this variable in future analyses, but not put too much weight on the result based on the current study. Future research with more powerful statistical models can confirm the importance of gender to promoting ERB's at school.

Both of these factors, Home behaviors and gender, are factors out of the control of architects and school administrators, but may be important to understand as buildings and policies are designed.

Chapter Summary

To the author's knowledge, there has been no empirical study of this kind that attempts to measure green building literacy outcomes in Teaching Green School Buildings. The measurement of Green building knowledge is a particularly unique aspect of the current study. Due to this lack of precedent research, the analyses in this chapter sought to offer an exploratory study of factors that predict a student's level of Green building knowledge. The results show a complex landscape of significant factors across contexts physical, sociocultural, and personal.

[23] Mean comparisons by gender were not presented due to the low significance of this variable across survey categories. For School behaviors, the mean difference for female minus male was 0.13, which is not a significant difference in an independent samples T-test.

The results in this chapter further shed light on predictors of student behaviors at school. While much past research has focused on the adoption of environmentally responsible behaviors (ERB's), this study sought to investigate the relationship between the physical environment and ERB's. The results showed that external social and physical environment factors, together with student Home behaviors, determine the behavioral decisions a student will make at school.

This chapter sought general trends across five schools, three of which are Teaching Green Schools. The differences between green buildings and non-green buildings in the study were not straightforward. To the contrary, the data revealed that the non-green Waldorf School may be unique in ways important to the outcome variables in this study. We are thus left with a comparison of the Teaching Green Schools to one, more typical non-green school. In this case, the differences are more clear. Students in the non-green Technology School have significantly lower scores on nearly all green building literacy metrics.

Looking across the data, it appears that Green building knowledge is determined predominantly by student personal factors while School behaviors are determined predominantly by social and physical environment factors. Knowledge, thus, appears to be a more gradual acquisition over time and place, whereas School behaviors are being greatly influenced by external factors of the school environment such as teachers, peers, and facility opportunities. While knowledge likely translates across settings, the continuation of positive behaviors across settings and time is more dubious. External influences on student school behaviors are clear, but given the data presented here, it is unclear if students will continue ERB's in the absence of external forces at school. This is, again, a question for future research.

Chapter 7
Pre and Post Occupancy Evaluation of a Teaching Green School Building

The Arts School (School 1), with a new construction Teaching Green Building completed in August 2011, presented an ideal opportunity to work with students before and after their move between campus buildings. This chapter focuses on the one year period in which the Arts School moved into their new green building. The Green Building Literacy Survey (GBLS) and the photography project were both administered during the pre- and post-move conditions, and each data collection method measured a variety of student green building literacy outcomes. The approach to data analysis was largely explorative. The primary goal of this chapter is to report those measures that showed significant change over the course of one year, where students had been using the new building for nine months at the time post-move data were collected.

In addition to comparing the Arts School to its own pre-move baseline, comparison will also be made to the Technology School, a local public charter school that does not have green campus buildings.

Research Design

The methods integral to this project were designed to advance understanding of numerous aspects of green building literacy (GBL). Chapter 3 offered an existing framework for conceptualizing the array of GBL outcomes (Table 3-1 from Chapter 3). Building off this framework, Chapter 4 described the research methodologies, including the specific GBL constructs that were measured in this study. Those categories of interest are re-summarized here in Table 7-1. Though the data reported in this chapter are limited to the West Coast schools, development for these survey categories was conducted using data from all five school settings that were part of the larger study across three regions of the U.S. Appendix D details the process of survey category development used for all analyses in the study.

Table 7-1. Green Building Literacy (GBL) Measures

GBL Category	GBL Sub-Categories measured in Survey
Knowledge	Green Building Knowledge (Test)
	Green Building Knowledge (Self-Assessment)
Affective Dispositions	Environmental Sensitivity
	Behavioral Willingness
Behavior	School Behaviors
	Home Behaviors
Educational Context	Supportive Environment (Environmental Support for Behaviors)
	Environmental Conditions
	Environmental Education Opportunities

Research Questions

In this chapter, there are two research questions: Are there significant differences in green building literacy (GBL) measures across 1) time and 2) schools? The questions are thus:

1. Are there significant differences in GBL in the Arts School before and after their move into a new Teaching Green Building?

2. Are there significant differences in GBL between the Arts School and the Technology School (where the former school is located in a new Teaching Green Building and a later school that is not in a green building, but is matched by age group, school type, student demographics, and geographic location)?

The hypothesis is that most GBL measures would be significantly higher in the Arts School post-move condition compared to itself at baseline (the pre-move condition) and its neighboring school that does not have green buildings on campus. If the Technology School and the Arts School are well matched as comparison schools, there should be little to no differences in environmentally responsible behaviors at home and few differences on affective dimensions. If outside-of-school factors are generally the same for the two schools, the connection between GBL outcomes and the new school environment will be more clear. Further, factors such as Home behaviors and affective dimensions are not hypothesized to change based on the move into a new school building with only one year between measurements. Affective dimensions change more slowly over time and are thus better investigated in a longitudinal study. The relationship between home and school behaviors is not the focus of the current study, though there are potentially interesting relationships between the two. In this study, Home behaviors were measured as a control variable that potentially affects what students know and do when they arrive at school (Chapter 6 regression models confirmed that Home behaviors is a significant predictor of both Green building knowledge and School behaviors).

The study is exploratory in the sense that no previous research exists with students in Teaching Green Buildings. The research design thus attempted to measure a broad spectrum of green building literacy outcomes to identify promising trends for future research.

Research Participants

The unique characters of each the Arts and Technology Schools were discussed at length in Chapter 5. Tables 7-2 and 7-3 each show basic demographic information for the schools of focus in the current chapter and for each data collection method. The information in Table 7-2 shows that the sample of students taking the Green Building Literacy Survey is fairly well-mixed across grade levels 6-8. Additionally, females are the majority in the Arts School in both pre and post conditions (>70%) and white students are the majority in both schools (>90%). Further, approximately a quarter of students (21-34%) say that they have been to a green building outside their own school building. It is notable that half of the students in each setting (50-53%) were not sure whether or not they had been to a green building, a figure that indicates that many students may have been unsure what a green building is at the time of taking the survey.

Table 7-3 shows basic demographic information of students in the Arts School who were involved in the photography data collection project pre-move (2011) and post-move (2012). This information was collected in a short survey students completed when they turned in their photos. The first year of the project 26 seventh grade students participated, and the following year 34 students mixed between 6-7th grades participated. Note that 22 students participated in the project both years. Table 7-3 shows that the participants both years are dominantly white females. It is also notable that nearly 40% of post-move students indicated that they knew quite a bit or a lot about environmental sustainability.

Table 7-2. Demographic Information of Survey Participants in West Coast Schools

		Arts School				**Technology School**	
		Pre		Post		Post	
		n	%	n	%	n	%
Grade Level	6th graders	21	55%	35	41%	11	34%
	7th graders	17	45%	27	32%	10	31%
	8th graders	0	0%	23	27%	11	34%
Gender	Male	8	21%	23	27%	15	48%
	Female	30	79%	62	73%	16	52%
Ethnicity	White	37	97%	72	95%	22	92%
	Asian American	0	0%	3	4%	0	0%
	African American	1	3%	0	0%	0	0%
	Hispanic American	0	0%	1	1%	2	8%
	Yes	14	37%	18	21%	7	23%
Been to a Green Building*	No	4	11%	24	28%	8	27%
	Not Sure	20	53%	43	51%	15	50%

**Not including students' own school building*

Table 7-3. Demographic Information of Arts School Photography Participants

		Arts School			
		Pre		Post	
		n	%	n	%
Grade Level	6th graders	26	100%	5	17%
	7th graders	0	0%	29	83%
Gender	Male	7	27%	5	17%
	Female	19	73%	29	83%
Ethnicity	White	24	92%	31	91%
	Non-White	2	8%	3	9%
How much do you know about environmental sustainability?*	Quite a bit to A lot			13	39%
	Some			18	55%
	Little to Nothing			2	6%

**Question asked of students post-move but not pre-move*

Mixed-Method Data Collection

Chapter 4 outlined the data collection methodologies of this study in detail. The two primary methods used with middle school students included 1) the Green Building Literacy Survey administered to all students in middle school grades 6-8, and 2) a photography documentation project conducted with 6-7th graders. This chapter will report findings from both methods of data collection.

Unfortunately, the Technology School was a late addition to this study, and it was not possible to arrange the photo documentation project in this particular site. Thus, photography data presented in this chapter are specific to the Arts School, where the project was conducted both before and after the move.

Data Analysis Procedures

Different analytical processes were conducted with each the survey data and the data from the photography documentation project.

The first analytical process used the data from the Green Building Literacy Survey. There are two data sets that correspond to each of the two major research questions (Figure 7-1). The first set of data includes the students who took the survey in both pre and post conditions at the Arts School (n=38). Eighth graders were not surveyed pre-move since at post-move they had moved on to high school. Thus, only 6th and 7th graders are included in this analysis. The second data set compares students in grades 6-8 between the Arts School post-move condition and the Technology School (n=117). The total number of surveys collected was 174, with 136 unique students given the overlap of students from pre to post move at the Arts School. Mean comparisons were the primary statistical procedure, with paired sample t-tests used for the comparison of results over time and independent sample t-tests were used for the comparisons between school settings.

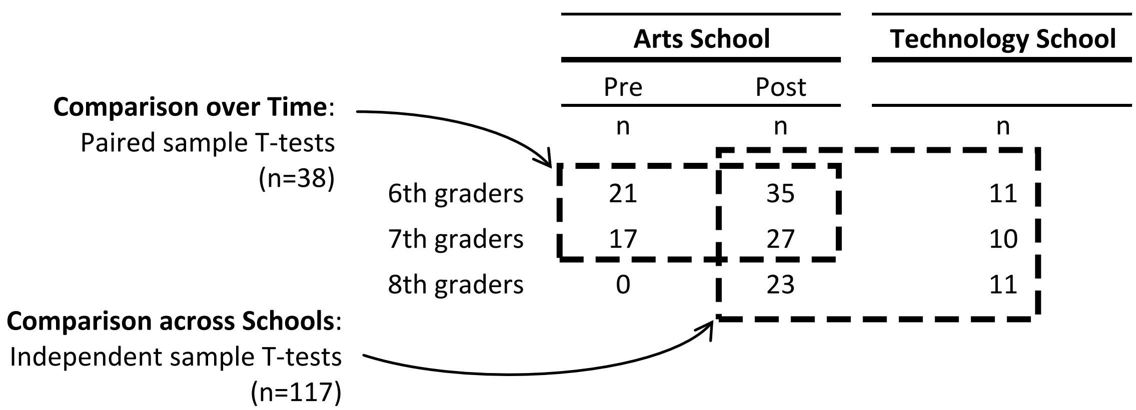


Figure 7-1. Two data sets used in West Coast school analyses

Beyond mean comparisons, one portion of the survey data entailed open-ended responses that were analyzed for content and then tabulated by frequencies (Appendix A, Survey PART I). The results from this section of the survey are reported below in the section titled Green Features Students Know About.

The second major analytical process used data from the photography documentation project. The process entailed a content analysis of images and text, which resulted in the categorization of photos. Basic descriptive statistics are then used to reveal trends in the photography data.

Results

The following sections outline the analyses that respond to the two research questions that examine significant change over both time and then school settings. Results are presented from both the Green Building Literacy Survey (GBLS) and the photography documentation project, which, taken together offer multiple angles from which to view student experiences of their schools and school buildings. After a summary of results, each of the four Green building literacy categories will be examined at length in the discussion.

The Green Building Literacy Survey

The first analysis uses data from the GBLS to compare the Arts School from pre- to post-move settings. The second analysis compares data across the Arts School and its comparison school, the Technology School. Table 7-4 shows the overall raw means for each GBLS survey category by school.

Comparing Results over Time: Pre- and Post-Move

The first set of analyses focuses on the Arts School before and after the move into their new Teaching Green Building. The approach to understanding differences in Green Building Literacy (GBL) outcomes over time relied on data from the set of students who took both the pre- and post-move surveys (n=38), examining significant changes through paired sample T-tests (Table 7-5). This analysis reveals GBL outcomes that have changed for students over the course of the year.

The paired sample t-tests reveal significant positive changes (two-tailed, $p < 0.05$) from pre- to post-move in the following five areas: Green building knowledge (test), School behaviors, and Supportive environment, and Environmental conditions of the school building. There was a significant change in Home behaviors, however, the trend was toward decreased behaviors at home from pre to post survey.

As predicted, affective dimensions of Environmental sensitivity and Behavioral willingness did not significantly change for students over the course of the year. As elaborated in Chapter 3 and again in the discussion section of this chapter, these GBL outcomes are more difficult to change, and there are numerous potential explanations for why students might not have shifted significantly in their affective dispositions relative to environmental issues.

Table 7-5 additionally shows that students did not perceive a change in Environmental education opportunities, a finding that is consistent with findings from the Arts School teacher focus group where teachers conveyed the difficulty of moving into the building and trying to start new curriculum at the same time.

Comparing Results across Settings: Green and Non-green School Buildings

The second set of analyses focuses on differences that can be observed between the Arts School post-move condition (in the Teaching Green Building) and the neighboring Technology School (in a conventional school building). Survey data at both schools were collected in the same month of May 2012 and with the same age groups. Table 7-6 shows the results of the independent samples T-tests used to compare means across school settings. The values reported as significant in Table 7-6 are based on Levene's Test for Equality of Variances, which is also reported in the table. Where the Levene's Test values were significant, equal variances were not assumed in the T-test results.

Table 7-4. Means by School, West Coast Schools

Category Name and Survey Items	Pre-Move			Post-Move			Comparison School		
	Mean	SD	n	Mean	SD	n	Mean	SD	n
Green Building Knowledge (Test)	**26.68**	(10.30)	38	**30.66**	(10.34)	85	**21.42**	(10.23)	32
Write-in, Multiple Choice, Photo ID, Fill-in-the-Blank									
Green Building Knowledge (Self-Assessment)	**3.00**	(0.70)	38	**3.28**	(0.75)	85	**2.29**	(0.94)	29
How much I know about green buildings									
Environmental Sensitivity	**2.92**	(0.82)	38	**2.97**	(.85)	84	**2.63**	(0.74)	32
My Environmental Sensitivity									
My Family's Environmental Sensitivity									
Watch programs or read about nature/environment									
Teacher or youth leader role model for ES									
Behavioral Willingness	**3.38**	(0.90)	38	**3.71**	(0.87)	84	**3.21**	0.95)	30
Less water when brushing teach									
Less water when bathing									
Walk more to reduce air pollution									
Use dimmer light bulbs									
Home Behaviors	**3.43**	(0.84)	38	**3.13**	(0.83)	84	**2.86**	(0.79)	29
General behaviors at home									
Talk with parents about environmental problems									
Recycle at home									
Turn off lights at home									
Compost at home									
School Behaviors	**2.69**	(0.54)	38	**2.99**	(0.72)	84	**2.51**	(0.61)	28
General behaviors at school									
Help others at school conduct behaviors									
Recycle at school									
Turn off lights at school									
Compost at school									
Pick up litter on school grounds									
Supportive Environment	**2.20**	(0.68)	38	**2.94**	(0.84)	82	**1.92**	(0.69)	29
Behavioral opportunities at school									
Building helps me learn									
Building helps me act									
Teachers help me act									
Peers help me act									
Environmental Conditions	**2.36**	(0.69)	38	**3.6**	(0.96)	85	**2.54**	(1.03)	31
Satisfaction with Lighting in School Building									
General Satisfaction with school building									
Connected to Nature inside school building									
Environmental Education Opportunities	**2.41**	(0.78)	38	**2.63**	(0.96)	84	**2.20**	(0.71)	32
Environmental education classroom activities									
Environmental education out-of-class activities									
Green building classroom activities									
Green building out-of-class activities									

Notes:

- All survey items were measured for frequency on a 5-point scale from 1=low to 5=high. See Appendix A survey for survey instrument. The n values indicate the number of valid responses per survey item.
- Means used for post-move students in Table 7-5 paired sample T-tests are different from those reported here since the sample reduces to the 38 students who had also taken the pre-move survey.

Table 7-5. Paired samples T-tests of GBL measures pre to post-move

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean (Pre-Post)	Std. Deviation	Std. Error Mean	Lower	Upper			
Knowledge	**Green Building Knowledge** (Test)	-7.408	6.552	1.063	-9.562	-5.254	-6.970	37	**.000*** **
	Green Building Knowledge (Self-Assessment)	-.132	.741	.120	-.375	.112	-1.094	37	.281
Affective Dispositions	**Environmental Sensitivity**	.069	.577	.094	-.121	.259	.738	37	.465
	Behavioral Willingness	-.145	.720	.117	-.382	.092	-1.238	37	.223
Environmentally Responsible Behaviors	**School Behaviors**	-.245	.734	.119	-.486	-.003	-2.055	37	**.047***
	Home Behaviors	.225	.647	.105	.012	.437	2.142	37	**.039***
Educational Context	**Environmental Support for Behaviors**	-.525	.857	.139	-.807	-.243	-3.777	37	**.001****
	Environmental Conditions	-.982	1.274	.207	-1.401	-.564	-4.752	37	**.000*** **
	Environmental Education Opportunities	-.125	.974	.158	-.445	.195	-.791	37	.434

**p < .05, ** p < .01, *** p < .001*
n = 38 students (the number of students to take both the pre- and post-move surveys)
Notes:
- Where the term behavior is used here, it is short form to refer to environmentally responsible behaviors
- Note that means used for post-move condition are different from Table 7-4 since the sample is here reduced to the 38 students who took both pre- and post-move surveys.

This set of independent T-tests show that the Arts School post-move students were significantly higher than Technology School students (two-tailed, $p < 0.05$) in the areas of: Green building knowledge (test and self-assessment), Environmental sensitivity, Behavioral willingness, School behaviors, Supportive environment, Environmental conditions of the school building, and Environmental education opportunities. The only GBL measure in which students are not differentiated is Home behaviors.

Table 7-6. Independent samples T-tests of GBL measures for comparison across schools (Arts School compared to Technology School)

		Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Knowledge	**Green Building Knowledge** (Test)	.000	.988	4.321	115	**.000*** **	9.243	2.139	5.006	13.480
	Green Building Knowledge (Self-Assessment)	2.662	.106	5.501	111	**.000*** **	.961	.175	.615	1.307
Affective Dispositions	**Environmental Sensitivity**	1.322	.253	2.002	114	**.048***	.340	.170	.004	.677
	Behavioral Willingness	.005	.943	2.627	112	**.010***	.496	.189	.122	.870
Environmentally Responsible Behaviors	**School Behaviors**	2.162	.144	3.152	110	**.002****	.482	.153	.179	.785
	Home Behaviors	.824	.366	1.495	111	.138	.265	.177	-.086	.616
Educational Context	**Supportive Environment**	1.282	.260	5.833	109	**.000*** **	1.011	.173	.668	1.355
	Environmental Conditions	1.079	.301	5.190	114	**.000*** **	1.062	.205	.657	1.468
	Environmental Education Opportunities	5.393	.022	2.325	114	**.010***	.434	.187	.064	.805

**p < .05, ** p < .01, *** p < .001*

n = 117 students

Notes:

- Where the term behavior is used here, it is short form to refer to environmentally responsible behaviors
- Note that means used for post-move condition are those presented in Table 7-4

Overview of Mean Comparisons

Looking across time and settings, the information from the previous analyses can be synthesized to draw out GBL outcomes that are higher for students at the Arts School in the Teaching Green Building. Table 7-7 summarizes the significant changes that emerged from statistical analyses presented in Tables 7-5 and 7-6. Taken together, we see four GBL measures for which the students in the new school building are most clearly set apart: 1) Green building knowledge, 2) School behaviors, 3) Supportive environment, and 4) Environmental conditions. Affective dispositions were statistically different across Schools 1 and 4, but did not change for Arts School students over time. In the following sections of this chapter, both significant and non-significant differences will be discussed in detail for each of the major GBL categories.

Table 7-7. Summary of mean differences in West Coast schools

		Teaching Green Building students (Post-move) higher scoring compared to	
GBL Category	**GBL Sub-Categories measured in Survey**	**Baseline (Pre-move)***	**Non-green comparison school ****
Knowledge	Green Building Knowledge (Test)	X	X
	Green Building Knowledge (Self-Assessment)		X
Affective Dispositions	Environmental Sensitivity		X
	Behavioral Willingness		X
Environmentally Friendly Behaviors	Home Behaviors		
	School Behaviors	X	X
Assessment of Educational Context (Physical + Social-Cultural Contexts)	Environmental Support for Behaviors	X	X
	Environmental Conditions	X	X
	Environmental Education Opportunities		X

GBL = Green Building Literacy
* Paired Sample T-tests (n=38), $p < 0.05$ (Statistical data in Table 7-5)
** Independent Sample T-Tests (n=124), $p < 0.05$ (Statistical data in Table 7-6)

Note that several comparison results between the Arts School and the Technology School are different here compared to results presented in Chapter 6 (Table 6-4). This is due to using two different statistical procedures. Chapter 6 presented ANOVA results across all five school settings with a Bonferonni post-hoc correction, whereas Chapter 7 presents a simpler set of T-tests with only two schools in the analysis. Bonferonni post-hoc tests from ANOVA (Table 6-4) are a more conservative test, and agreed with independent sample T-tests (Table 7-6) on significant differences in three variables: Green building knowledge, Supportive environment, and Environmental conditions. However, in the ANOVA results, Environmental sensitivity, Behavioral willingness, School behaviors, and Environmental education opportunities did not emerge as significant – though T-tests indicated significant differences in each of these four areas. Both statistical procedures agreed that Home behaviors are not statistically different across the two schools.

These differences between mean comparison techniques are noted because it is important to understand the story the data are telling. Another way to view the data is to look at the precise mean differences at face value. For example, the difference for Environmental sensitivity means between schools is 0.34 on a 5-point scale, whereas the difference for Supportive environment is 1.02, also on a 5-point scale. Students are more clearly differentiated on their assessments of environmental support than they are on Environmental sensitivity.

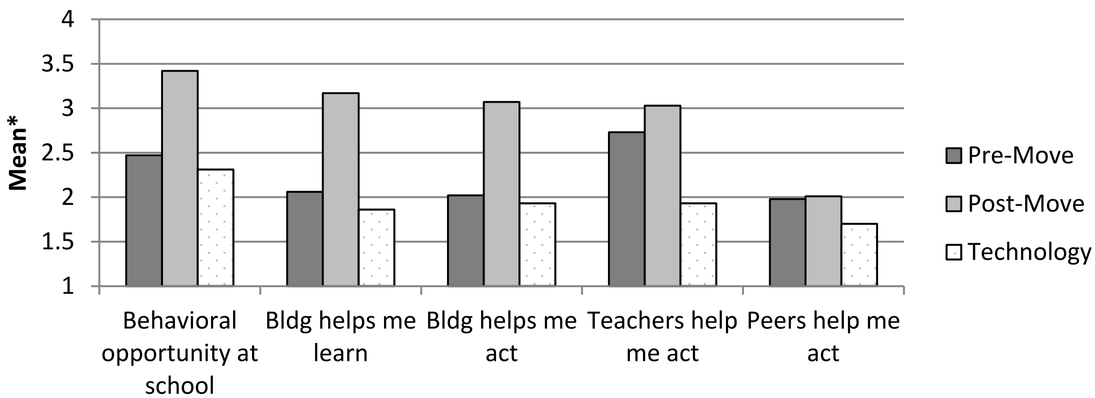
A closer look at each GBL outcome of interest can offer a more fine-grained understanding. The GBL categories of affective dispositions, behaviors, educational context, and green building knowledge will be elaborated on in the following sections. Knowledge will be discussed last as a way to segue into results from the photography project that offers additional insights on what students see and know.

Affective Dispositions: There were no significant changes in Environmental sensitivity or behavioral willingness for students in the Arts School over time. However, differences were observed between the Arts School and the Technology School (Table 7-6). This result is slightly unstable, however, depending on the statistical analysis conducted. The mean comparisons using ANOVA procedures with Bonferonni post-hoc tests presented in Chapter 6 (Table 6-4) revealed that the Arts School (post-move) is not significantly different on Environmental sensitivity or Behavioral willingness than the Technology School. The Bonferonni post-hoc test is a more conservative estimate compared to independent samples T-tests presented in this chapter, and calls into question the true difference in affective dimensions between students at each school.

Environmentally Responsible Behaviors: Results indicate that students in the post-move Teaching Green Building more frequently partake in environmentally responsible behaviors (ERB's) at school compared to both the pre-move setting and the comparison school (Table 7-5 and 7-6). Notable is the fact that Arts School students in the post-move building actually decreased their ERB's at home over time, but increased ERB's at school over time. Further note that a significant difference was not detected between the Arts School and the Technology School in ANOVA results (Table 6-4), and therefore the difference between schools is questionable. The Arts School post-move School behaviors mean was 2.99 (*SD*=0.72) on a 5-point scale, which means that students only sometimes conduct ERB's at school. The data shows School behaviors increasing over time, however, given the new school building with expanded opportunities for ERB's, higher levels of School behaviors would have been predicted.

Assessment of the Educational Context: Students in the Teaching Green Building rate their school environment higher in the categories of Supportive environment, Environmental conditions, and Environmental education opportunities. The significant differences in these categories were primarily in the realms of student assessment of their physical school buildings, where Teaching Green Building students clearly rate their environment higher for supporting environmentally behaviors and comfort. The category that was used to rate environmental support contained questions about both the physical and social environment. By looking at these five items that make up this category, it appears that the breadth of support is provided by the building itself (Figure 7-2).

We see that teacher support is ranked nearly as high as the building in both the Arts School and the Technology School, though the Arts School means are significantly higher than the comparison school in all measures. Notice in the Arts School that teacher support was ranked higher than the building in the Pre-move condition, and the building achieves approximately the same ranking as teacher support in the post-move condition. Students across settings consistently rated their peers as offering little to no help in terms of taking environmentally responsible actions.



*Survey items were ranked on a 5-point scale where 1= Not at all and 5 = A great amount.

Figure 7-2. Assessment of educational context by survey item

Green Building Knowledge: Despite the fact that student performance significantly increased on the Green building knowledge (GBK) test, it is difficult to untangle this improvement with the fact that the students are a year older, and therefore a year smarter.[24] One observable trend in the data is that older students generally do better on the knowledge test portion of the survey. Recall that Chapter 6 regression results revealed grade level as a significant predictor of Green building knowledge (Table 6-5).

Tables 7-8 through 7-11 offer a more detailed analysis of the dynamics between Green building knowledge and grade level for students at the Arts School. First, we can look at grade levels across time (with independent groups of students) to understand if, for

[24] Analyzing significant differences in GBK controlled by student grade level requires a more sophisticated set of statistical procedures, such as using linear mixed models. In this study, such tests would have reduced the intuitiveness of the results with a questionable gain in understanding.

example, post-move 6th graders performed better than pre-move 6th graders (as would be predicted because post-move 6th graders have the benefit of nine months in the green building). Table 7-8 shows the results of independent samples T-tests that indicate that there was no significant difference between pre- and post-move grade levels on the Green building knowledge test score. However, Table 7-9 shows that 7th graders are more confident about their levels of Green building knowledge when asked to self-assess their own GBK.

A second analysis shows cohort changes in GBK over time, using paired sample T-tests to analyze whether or not student scores changed as they moved from the pre-move non-green building to the post-move green building (Table 7-10 and Table 7-11). This data is the same data from Table 7-5, but looks in closer detail at each cohort of students who moved from grade 6 to 7 and then students who moved from grade 7 to 8. Results, in alignment with data previously reported, show that students in both cohorts significantly improved their test performance over time (Table 7-10), but neither cohort indicated a higher level of GBK via self-assessment (Table 7-11).

These results are presented to offer a better understanding of GBK, and whether changes in performance appear can be influenced by the new green building when grade level differences are accounted for. Taken together, these results show that, as measured on the Green building knowledge test within the GBLS, there was not a strong increase in GBK that can be attributed to the move between buildings. The following sections, however, will review data that is more qualitative in nature to gain more insight to possible knowledge increases experienced by students in the Arts School.

Table 7-8. GBK test scores, comparisons between grade levels

Grade Level	Pre-move	Post-move	Mean Diff. (Pre-Post)	Sig.
6	23.24	27.07	-3.83	0.207
7	30.18	30.80	-0.62	0.977

*p < .05, ** p < .01, *** p < .001

Table 7-9. GBK self-assessment, comparisons between grade levels

Grade Level	Pre-move	Post-move	Mean Diff. (Pre-Post)	Sig.
6	3.2	3.37	-0.17	0.397
7	2.68	3.3	-0.62	**.004****

*p < .05, ** p < .01, *** p < .001

Table 7-10. GBK test scores, cohort improvement over time

Cohort	Year 1 Score	Year 2 Score	Mean Diff. (Year 1-2)	Sig.
Cohort 1: 6th graders who became 7th graders	23.24	30.80	-7.56	**.000***
Cohort 2: 7th graders who became 8th graders	30.18	36.69	-6.51	**.000***

*p < .05, ** p < .01, *** p < .001

Table 7-11. GBK self-assessment, cohort change over time

Cohort	Year 1 Score	Year 2 Score	Mean Diff. (Year 1-2)	Sig.
Cohort 1: 6th graders who became 7th graders	3.2	3.3	-0.1	0.748
Cohort 2: 7th graders who became 8th graders	2.68	3.13	-0.45	0.281

*p < .05, ** p < .01, *** p < .001

Green Building Knowledge in Open-ended Responses

Beyond the results of the Green building knowledge test, there are other ways to examine what students see and know about green buildings. One way is to analyze the four green building features that the students report knowing about in PART I of the survey (Appendix A). The prompt used to elicit their response was meant to collect general green building knowledge that is not linked to a specific building. This part of the survey instrument was designed to determine the features of a green building that are most salient in students' minds. Students could indicate if they had difficulty filling out this part of the survey instrument. Students were informed that they need not complete all four features and that they had the option to "…check this box if you are not familiar with any green building features." The percentage of students who checked this box ranged from 31% of Technology School students to 12% pre-move Arts School students to 3% of students in the Arts School post-move condition. Another way to explore student understanding is to examine whether students in the Arts School post-move condition included a greater diversity of green building themes in their write-in responses. Figure 7-3 shows the mean number of diverse themes written in by students, where the maximum number of diverse themes is four (as noted, there were four blanks on the page). First, Arts School students were compared over time using a paired sample T-test, where the mean number of diverse categories increased from 2.05 (SD=1.05) to 3.05 (SD=0.97), which was a significant increase, $t(36)=-4.96$, $p<.000$. Next, a significant difference was also observed between the Arts School ($M= 2.71$, $SD= 1.10$) and the Technology School ($M= 1.63$, $SD= 1.21$), $t(115)=-4.68$, $p<.000$ (Figure 7-3). Through these analyses, we see that students in the Teaching Green Building are able to write-in a more diverse set of green building themes. It is additionally interesting to note that Arts School post-move students filled in more write-in blanks (79%) compared to Arts School pre-move students (60%) or Technology School students (50%).

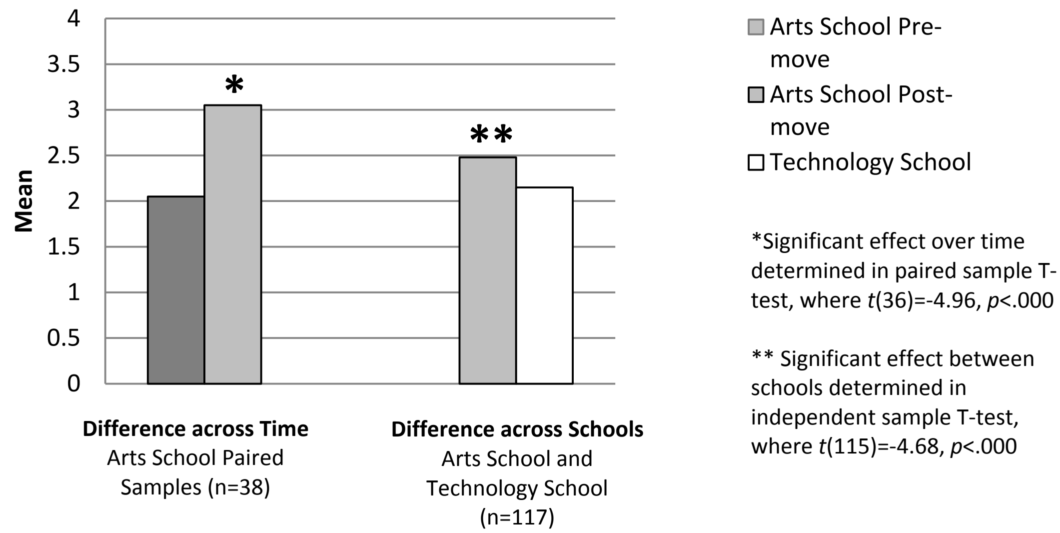


Figure 7-3. Percent of diverse categories in student written responses

A closer look at the data offers insight on the themes that were most salient to students in each school setting. Student responses were entered into a data base and a coding process was used to determine the major themes across responses. After inputting all student responses into a database, responses were coded through a grounded process (i.e., no a priori categories were used) and the categories here emerged. After coding themes, these themes were then grouped into a smaller number of categories. The broad categories were: alternative energy systems, water conservation, building materials, recycling/waste, light, sustainable sites issues, food-related, transit, signage, and energy conservation. The coding logic used in this process is summarized in Table 7-12.

The final themes are shown in Figure 7-4 with the percentage of responses that fell into each category stratified by school. The most popular green building categories for students are alternative energy systems, water conservation, building materials, recycling/waste, and light. Alternative energy systems (category including solar panels, wind energy, and geothermal systems) are the most cited by all students. In the next four high frequency categories (water, building materials, recycling/waste, and light), the post-move Arts School students are mentioning these features at a higher rate compared to pre-move and Technology School responses.

Table 7-12. Coded themes for green building feature written responses

Category	Sub-categories
Alternative Energy Systems	Solar panels; Wind turbine; Geothermal; General comments regarding alternative energy
Water Conservation	Rain catchment/reuse; Greywater systems; Water-saving toilets; Composting toilets; Faucets; General comments about water conservation in buildings
Building Materials	Material reuse; Recycled-content materials; Natural materials; Local materials; Furniture; General comments about building materials
Recycling/Waste	Recycling bins; Electronics recycling; Trash cans/litter; Technology that saves resources (*e.g.*, hand dryers save paper towels); General comments about recycling/reduction/reuse
Light	Efficient lighting systems; Motion/daylight sensor lights; Shading; Daylight; General comments about lighting
Sustainable Sites Issues	Green roof; Pervious surfaces; Plantings/Flowers; Trees; Rain gardens; Stormwater management; Wildlife amenities (*e.g.*, bird houses)
Food-related	Gardens; Greenhouses; Compost; Chickens; Cafeteria practices; Reusable drink containers
Transit	Bikes; Carpooling; Idle-free zones for cars; Electric car plug-in stations
Signage	Signage on recycling bins; Signage general
Energy Conservation	Thermostat; Insulation; Efficient Heating/Cooling systems; Energy efficient appliances & electronics; Turning off items; General comments about saving energy

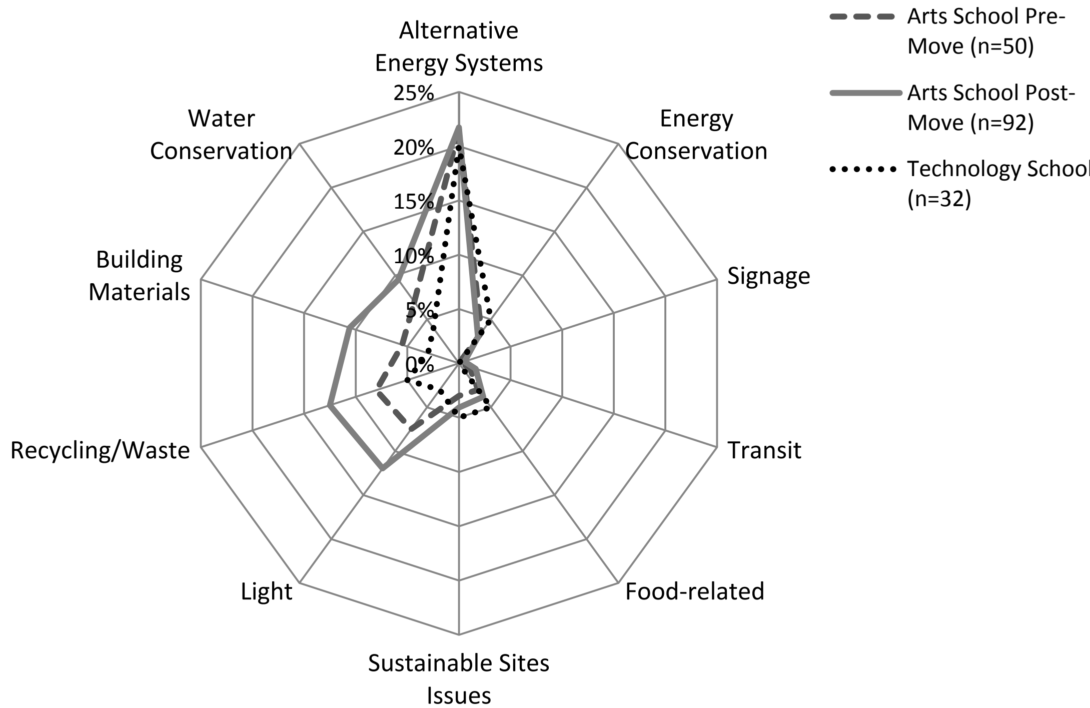


Figure 7-4. Percent of written responses in each green building category

The Photography Documentation Project

The photography project offers another lens from which to view student experiences related to sustainability issues. As described in Chapter 4, this project involved a small group of students and a week-long series of exercises that entailed photographing the school campus, editing photos, writing about photos, and then conducting one-on-one interviews with the researcher. Where the Green Building Literacy Survey was administered broadly to all middle school students in all settings, the photography project was conducted with a smaller number of students in the 6-7th grades, and did not include students in the Technology School. This section reports descriptive results that emerged from the photography data in the Arts School collected before and after the move.

Categorization of Photographs

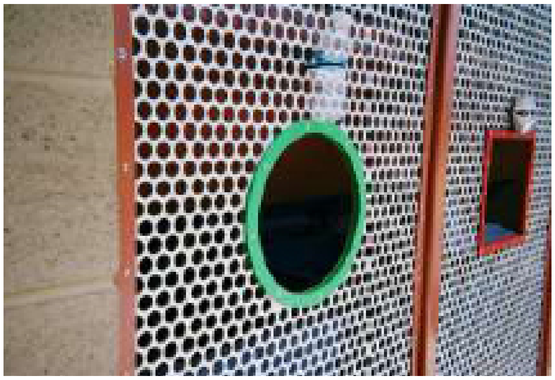
Each student photo board contained 12 photographs, each with a descriptive caption written by the student. To determine broad patterns across student photos, the images were categorized based on their content. The photo content and student-written text below the photo were used in tandem to place each photo in a category. Some photos eluded categorization (24/564 photos, or 4%), typically due to a photograph without an obvious subject matter or a missing or vague caption that did not help the researcher understand how the student connected the photo content to environmental sustainability. Appendix E describes the photograph categorization process in detail.

Figure 7-5 shows the categories that arose from the analysis with a sample picture and caption that is indicative of the category.[25] It should be noted that some categories included higher levels of diversity than others. For example, photos that were about recycling were typically straightforward photographs of indoor or outdoor recycling bins. By contrast, the Daylight/Air category included photographs that ranged from windows, to cooling ducts, to open-air corridors in the school.

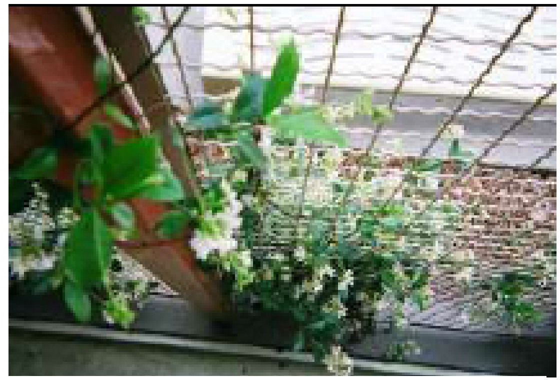
Frequencies of Photographic Themes

The Figure 7-6 bar chart organizes photography categories by greatest frequency in the pre-move condition on the left, and moving toward right, depicts the categories that emerged in the post-move that were not captured in the pre-move condition. Several striking decreases can be observed from pre to post move. For example, recycling issues, litter, and water issues were among the top photograph categories in the Pre-move condition, and each category experienced a sharp decline over time. By contrast, the category that included plants and animals stayed fairly stable over time.

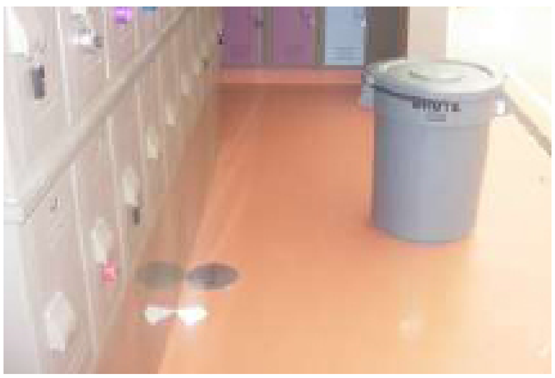
[25] Note that all Figure 7-5 examples are from the post-move Arts School photography project.



Recycling: *"This photo shows how the school recycles. We separate it into aluminum, paper, and plastic" (Student 38).*



Plants/Animals: *"This is Jasmine! The more plants you plant, the more air they create" (Student 36).*



Litter/Trash: *"This picture shows me that throwing away trash and keeping a clean area is helpful to the environment" (Student 22).*

Water: *"I chose the photo to show that there are other sources of water then just plastic water bottles that are bad for our environment" (Student 19).*

Socio-cultural: *"Physical activitys like basketball help people get outside in nature instead of using up energy on a t.v. or computer" (Student 37).*

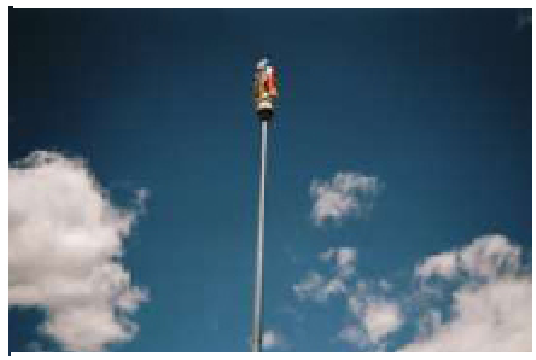
Energy Efficiency: *"This is a picture of lights that tell you if the energy in the school is low" (Student 10).*

Figure 7-5. Sample student photographs, by category

Transit: *"This teaches me about sustainability by using different kinds of transportation that are 'greener' than a car" (Student 27).*

Signage: *"People want to the world to be clean and I know I do, too" (Student 7).*

Garden/Composting: *"This picture shows me sustainability because not a lot of schools have gardens for their fruits and vegetables and if they do I doubt they let kids help out planting all these organic foods" (Student 16).*



Alternative Energy: *"I chose this photo because this is a wind turbine that generates power. This teaches me about sustainability by createing power out of wind" (Student 30).*

Building Materials: *"This picture shows one of the walls in the school that soaks up the heat, so that in the hot summer months, it's nice and cool inside" (Student 34).*

Building Artwork: *"I chose this photo to show that the words in the 'Gathering Circle' help us remember how we should act and treat the world" (Student 26).*

Figure 7-5. Sample student photographs, by category, continued

Daylight/Air (1): *"This picture teaches me about sustainability because it shows that if you have big windows you can use the suns light instead of electricity. Window out to a tree" (Student 35).*

Daylight/Air (2): *"The amphitheater has no roof, saving electrical, heating, and cooling costs" (Student 1).*

Figure 7-5. Sample student photographs, by category, continued

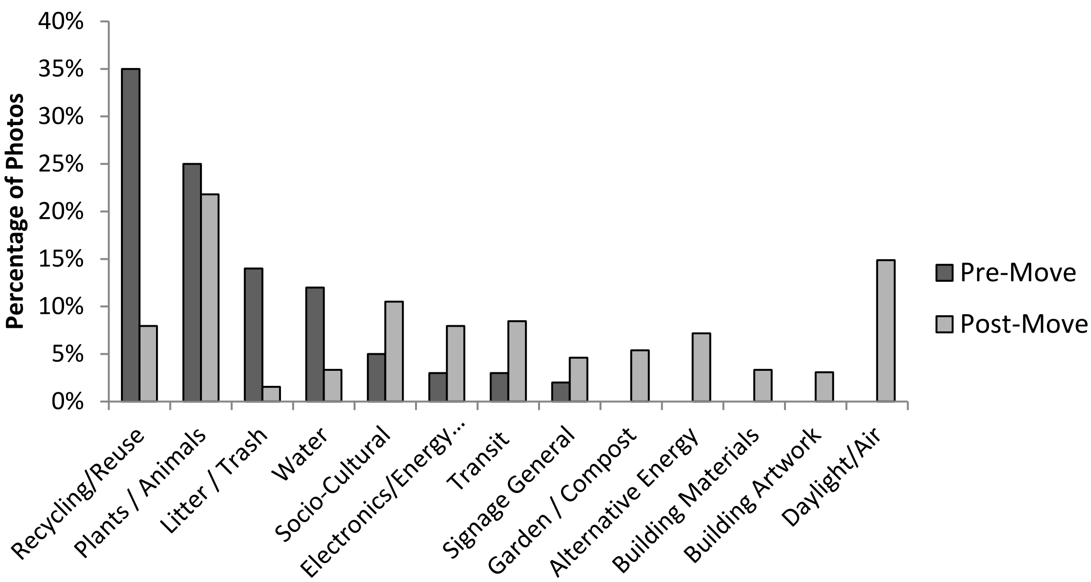


Figure 7-6. Percentage of photos in each category, pre and post

Another way to analyze the photo measurement is to examine the number taken indoors versus outdoors.[26] In both the pre- and post-move project rules, students were required to take a minimum of ten indoor photos.[27] In the editing process however, students could choose the mix of indoor/outdoor photos that constitute their top 12 photos with no stipulation on how many of each type to include. In ranking photos, the students were asked to choose their personal top 12 photos that best answered the project question of: "Where on my school campus do I learn about environmental sustainability?" Figure 7-7 shows the proportion of indoor to outdoor photos pre- and post-move for the 22 students who were part of the photography project both years.

First, we see that pre-move photos were dominantly outdoors.[28] We further see that overall the percentage of photos taken indoors shifts from 29% to 52%. Paired sample T-Tests confirm that there is a significant upward trend in indoor photos from pre- to post-move, $t(20)=-3.80$, $p=0.001$. This result is consistent with the fact that the new green building offers more opportunities to identify sustainability issues indoors.

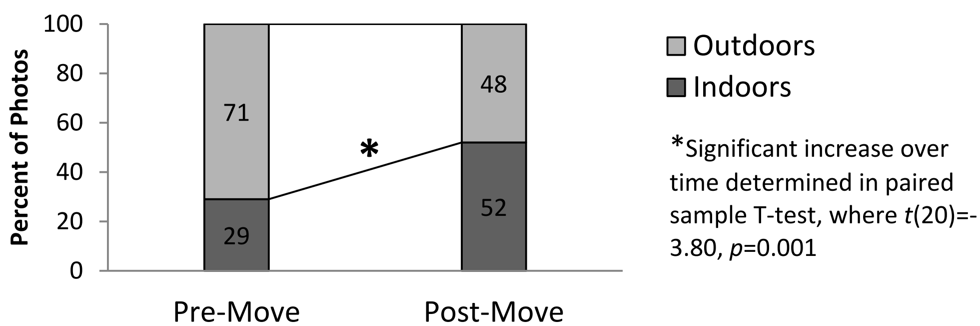


Figure 7-7. Photos taken indoor vs. outdoors, pre and post

[26] Indoor versus outdoor depended more on the subject of the photograph than the vantage point of the student. For example, if the student took a photo of an outdoor tree from inside the building the subject of the photo is coded as outdoor. Student written text below each picture was used in tandem to determine photo category.
[27] This rule was instituted after a pilot project was conducted by the researcher where it was noted that students enjoy the chance to go outside during the class period, and were neglecting to consider sustainability issues indoors.
[28] In nonparametric binomial tests, 71% significantly different than the expected ratio of 50%, 2-tailed, $p=.000$.

Discussion

The results show areas in which students in the Arts School Teaching Green Building excel in terms of green building literacy outcomes. Building on findings from the previous chapters, the results here provided evidence that significant changes for students can be linked to physical and socio-cultural aspects of the school environment. The following sections examine each green building literacy category in depth.

Green Building Knowledge

A central question in this study is whether or not students who use green buildings daily demonstrate increased levels of Green building knowledge. As no formal, integrated green building education program exists in the Arts School (Chapter 5), it is plausible that students are learning about their new green building in informal ways through means such as anecdotal teaching moments with educators, watching faculty and peers use the building, and personal experiences using the building day-to-day. Additionally, factors in the students' home environments could also play a role. Overall, green building learning likely is working through various channels of physical, socio-cultural, and personal context (Figure 3-2). Of particular interest to green building experts, the data presented here show that the physical environment of the Arts School appears to be influencing students' levels of Green building knowledge by providing a comfortable and supportive environment.

Pre- and Post-Move Changes in Knowledge

The pre-move versus post-move paired sample T-test results showed significantly improved performance on the Green building knowledge test. However, these data must be interpreted cautiously. The students have grown a year older, and have an additional year of cognitive development. It is reasonable to consider their improved test taking abilities as a confounding variable that might inflate the Green building knowledge test score independent of an actual increase in Green building knowledge.

Indeed, another analysis of the data (Table 7-8) reveals that independent T-tests across grade levels do not reveal statistically significant differences in test scores over time.

There are a number of possible explanations for this inability to observe strong knowledge changes across the year on the Green building knowledge test. The first involves limitations in the survey instrument itself. As discussed at length elsewhere (Chapter 4, pp.67-69), the knowledge test was developed for the current study, and was based on knowledge categories from the LEED Green Building Rating System. The test was designed to be a general survey of green building knowledge, and was not tailored to any one school's campus. That is to say, there may be lessons that students are learning from the building that are not adequately captured on a test based on the LEED system. One example observed in the photography project was that many students were connecting their playground to health, sometimes equating playing outdoors to saving energy (by not playing indoors) (See Figure 7-5, Socio-cultural photo example, p.187). This is a nuanced understanding of sustainability that was not part of the Green building knowledge test.

Two other factors that may have limited student knowledge development relate to curriculum and time. As noted previously, at the time that students moved into the new building, there was no formal curriculum in place to use the green building features in lesson plans. In addition to this, teachers in the focus group commented that they themselves still needed to be informed about the building, which means that many teachers may not feel confident taking their own initiatives to teach students about the building (Chapter 5). It is possible that the teachers' lack of confidence was conveyed in both direct and indirect ways to the students. The role of teachers and formal curriculum may be critical pieces of the puzzle in moving students toward higher levels of Green building knowledge.

The question of time is another confounding issue. At the time of post-move data collection, the students had experienced nearly nine months in the new building. Without previous research in Teaching Green Buildings, it is difficult to determine if nine months is an adequate amount of time to acquire Green building knowledge through informal means. On one hand, newness to the building means that students are taking in much information all at once, where green features are just one set of elements competing with other new elements for student attention. On the other hand, the green features may constitute novel experiences for students and stand out by the nature of their novelty. It could be argued that the current cohort of students, at the nine month mark, may yet be experiencing the green features as novel, and be more conscious of them compared to a later cohort of students in 3-5 years' time. The question of the role of novelty in the effect of building features on knowledge and behavior is potentially important, and could be better explored in a longitudinal study.

Another factor that may have minimized the knowledge differences between the pre- and post-move measures is the fact that students had been exposed to the construction process of their new building before moving into it. The building architect had presented the building to students in an assembly and some teachers mentioned aspects of the new building to their students during pre-move classes. While green building issues were not covered in depth, it is possible that students developed a baseline level of awareness that their new school was being designed to be more environmentally friendly than a typical building.

A final potential limitation is that the researcher collected post-move surveys closer to the end of the school year compared to the previous year. Students in the post-move condition were 10 days from the end of school, and very ready for the school year to be completed by the time the researcher visited. This end-of-semester anticipation may have affected student concentration levels while taking the post-move survey, an insight noted by the middle school teacher who knows the students well.

Although the knowledge test results must be interpreted with caution, the students' ability to write about green building features clearly expanded over time. The analysis of Part I of the Green Building Literacy survey offered evidence of this effect. In this exercise, students significantly increased the diversity of green building themes mentioned (Figure 7-3), filled in 19% more blanks from pre- to post-move, and significantly increased the mention of green building features in the areas of building materials, recycling/waste, and light.

The photography project results corroborate these findings and offer another angle from which to view student development. The bar chart in Figure 7-6 demonstrated the shift from four dominant categories in the Pre-move project to a more diverse and equal mix of 13 photo categories in the post-move condition. The increase in photo categories is consistent with the fact that the physical environment afforded new and different opportunities. Perhaps more interesting are the categories that emerged in the post-move photography project, such as daylight, gardening, and building materials. This photography project identifies aspects of the green building that are particularly salient for students.

Taken together, the results of the write-in and photograph categories show that building materials and light/daylight are the two most notable features for students at the post-move condition. Given that the formal curriculum did not address these aspects of the new green building, and that materiality and openness are two hallmarks of the building architecture, it is probable that students are gleaning information about these features through their informal day-to-day interactions with the building, teachers, and peers.

Finally, in regard to the write-in and photography data collection methods, there is a potentially important distinction to be made between awareness and knowledge of green building features. It is not assumed that students have in-depth knowledge of the items they photographed; however, it is assumed that if the student photographed a feature and chose to put it on the photo board and write about it, that the student is at least aware, if not knowledgeable, about that feature. Additional analyses of student-written text could help to illuminate this distinction in future studies.

Green Building Knowledge Comparison between Schools

Students at the Arts School demonstrated higher levels of Green building knowledge (GBK) compared to their peers at the nearby Technology School. If one looks at indicators beyond the knowledge test metrics, there are reasons to believe that the school environment accounts for some of the differences in GBK between schools.

To begin, Chapter 6 regression results showed that Home behaviors are among the top predictors of GBK, while mean comparison results showed no significant differences in Home behavior between the Arts School and the Technology School (Table 6-4 and Table 7-6). Other personal context predictors of GBK included grade level, been to a green building, and the borderline predictor of gender. The two schools were roughly equal in proportions for each of these categorical variables (see Table 7-2), with the exception of gender where the Arts School had a disproportionately high participation by female students (who tend to perform slightly higher than males on the test). Environmental sensitivity was another significant predictor of GBK, and students between schools were questionably differentiated on this measure.

Environmental conditions and Supportive environment are the school environment factors that significantly predicted GBK, and on these metrics students in the two schools are clearly differentiated. Arts School students rate their building significantly higher for both comfort and supportiveness. Thus, with some similarity across home environments and personal context factors for the two schools, and differences on school-level factors, it is reasonable to conclude that the school environment is exerting influence on student levels of Green building knowledge.

Affective Dispositions

The affective dispositions measured in this study included student Environmental sensitivity and student willingness to engage in environmentally responsible behaviors. No significant changes were observed on these measures after the Arts School students moved into the new building. This result might be explained by noting that of all the green building literacy outcomes measured in this study, these are arguably the most challenging to influence in a short span of time through singular interventions (Chawla, 1998; Marcinkowski, 2001; Tanner, 1980). Environmental sensitivity, or one's sense of empathy toward nature, further presents challenges for assessment given its somewhat amorphous shape and organic development over time (Marcinkowski, 2001). A student with high environmental sensitivity, for example, may be reading environmental books, spending above average amounts of time in nature, and have an environmentally sensitive role model, and all of this happening in happenstance ways across one's development over time. Some of these factors can be influenced by educators, but others are influences that come from arenas of life outside school.

In this study, the affective dispositions of Environmental sensitivity and Behavioral willingness were included as control variables rather than dependent variables. Results showed that the Arts School and the Technology School are not clearly distinguished on these variables – where T-tests indicated significant differences (Table 7-6), but more conservative mean comparisons did not detect such differences (Table 6-4). Thus, Arts School students rate themselves higher on affective dimensions, but only slightly so, compared to Technology School students. This result, taken together with the similarity in Home behaviors, indicates that students across schools receive comparable levels of outside influence (from home and the larger community) in the realm of environmental issues.

Assessment of the Educational Context

This study seeks to better understand particular features of the educational environment that support green building literacy outcomes. The features investigated here were: 1) environmental support for environmentally responsible action, 2) comfort with environmental conditions of the building, and 3) frequency of environmental education opportunities. In this study, the notion of educational context is a mixture of social and physical environmental factors. Regression analyses revealed that the first two features predict GBK, and all three factors are significant predictors of School behaviors.

Students in the post-move Teaching Green Building gave higher ratings to the educational context in nearly every domain compared to their pre-move baseline and to the Technology comparison school. The only difference that was not statistically significant was the difference in Environmental education opportunities from pre- to post-move.[29] Thus, with the exception of increases in Environmental education opportunities, students in the Teaching Green Building experienced changes in the environment that are known predictors of green building literacy outcomes.

Environmentally Responsible Behaviors

Students in the post-move Teaching Green Building are more likely to conduct environmentally responsible behaviors at the new school compared to the old school; they also have higher participation levels compared to their peers at the nearby non-green Technology School. This is perhaps a result of students having more opportunities to engage in environmentally friendly practices at their new green building. Additionally, at the post-move assessment, the students rated their physical school building higher in terms of being a supportive environment for taking action – and this variable of Supportive environment was a high predictor of ERB in regression analyses (Table 6-12).

Further evidence that the school environment influenced stewardship behaviors is the finding that, for Arts School students, School behaviors significantly increased while Home behaviors significantly *decreased* over the study period (Table 7-6). While the data available cannot explain the relationship between student choices at home and school, the trend is curious and suggests that factors in the school environment are helping to maintain or increase ERB's for students while they are at school. Note also that affective dispositions (measuring factors primarily outside of school) remained

[29] This is consistent with the findings from the post-move focus group with Arts School teachers (reported in Chapter 5), where teachers expressed difficulty in addressing curriculum change in the same year they moved between buildings.

constant over time. It does not appear that student feelings toward the natural environment changed over the study period, and thus would not be an explanation for behavior change. At the same time, students experienced significant changes in numerous school-level predictors of ERB (when reviewing Table 6-13 regression results and Table 7-5 T-tests together).

To further highlight the influence of the physical environment, there were no observed changes in Environmental education opportunities from one year to the next at the Arts School (Table 7-5). Additionally, under the survey items in the realm of Supportive environment, post-move students rated the physical environment as more supportive than teachers and peers in terms of helping the student take environmentally responsible actions (Figure 7-2). Thus, according to student ratings, social environment influences on behavior appear to be less supportive of behavior than physical environment factors. This collection of findings supports the notion that the school environment is an influential factor in student decisions to conduct environmentally responsible behaviors while at school.

Chapter Summary

This chapter focused on one new construction Teaching Green Building on the West Coast (the Arts School) where data was collected before and after the students moved into the new building. Additionally, data was collected in a nearby non-green school for comparison with the Art School's post-move data. The goal of the chapter was to present exploratory analyses that investigated green building literacy changes between 1) the Arts School post-move condition and its own baseline and 2) the post-move condition with the comparison school.

Table 7-7 summarized the results of the mean comparisons and highlighted the numerous categories in which post-move scores are significantly higher. More in-depth analyses followed the mean comparisons to further explore results. Across these analyses, it is clear that students increased Green building knowledge and School behaviors. Further, post-move students rated their environment significantly higher in terms of supporting environmentalism and comfort, both outcomes that tie directly to the physical environment of their new school. Of all of these results, the most questionable is the uptake in Green building knowledge given that the significant changes happened for students who also grew a year older. Qualitative analyses of written responses and photographic documentation offered a more convincing case for the ways in which student awareness and understanding of green building issues increased over the course of the year.

While Arts School green building literacy outcomes increased over the study period, they are still significantly lower on numerous metrics compared to the Teaching Green Building on the East Coast, the Ethics School (School 3). The Ethics school is more well-established with older campus buildings and many students who have experienced the green campus since early childhood. The differences suggest that the Arts School yet has room for improvement in terms of student green building literacy. Some improvements may come with time as the Arts School grows into their new building; some improvements will come by modeling successes observed in other Teaching Green Buildings such at the Ethics School.

Chapter 6 examined predictors of green building literacy outcomes, and found that important school-level factors include Environmental education opportunities, the provision of a supportive environment, and comfortable building environmental conditions. The Ethics School ranks significantly higher on all three of these factors compared to all other schools in this study. Thus, continuing to increase environmental education on campus and tending to the physical factors of the building that support behaviors and maintain student comfort are all efforts that could increase student green building literacy outcomes over time at the Arts School, and other similar schools that seek to foster environmental education through the intentional design of the school environment.

Chapter 8
Discussion and Recommendations

Contemporary green buildings are not typically designed to engage the users in the environmental story of the building. In the United States, the dominant lens for green buildings continues to be on questions of technological and ecological performance. Investigating social and behavioral performance, however, is a newer theme in green building literature.

Three of the schools in this study are pioneers in the experiment to use green buildings in environmental pedagogy. The architect of the newly constructed Arts School, who was interviewed during the study, indicated that resources on Teaching Green Buildings were scarce at the time his project began. In the design process, he relied on tangential resources and intuition, continually wondering if the building would work in reality as it did in his mind. Now his building and others like it stand as laboratories for social-environmental research.

A social research project of the kind presented here is a complex undertaking fraught with methodological challenges. Just as Teaching Green Buildings are relatively new to the scene, so too are the tools for studying them. This study offers a preliminary investigation from which theory and measurement instruments can be further developed and tested.

This chapter will highlight key findings from the present study, then discussing theoretical and methodological contributions. Future directions for research on Teaching Green Buildings will be suggested, and the chapter will conclude with key insights for practitioners who seek to design school environments to enhance outcomes for green building literacy. The limitations of the current study are outlined in Appendix F.

Summary of Findings

Based on empirical chapters 5-7, the major findings of this study are summarized into the six statements below. The first four findings highlight the outcome of Green building knowledge (GBK) as investigated from a mixture of methods, including survey research and the photography documentation project. The fifth finding highlights the outcome of student environmentally responsible behaviors (ERB's), noting the importance of the physical school environment to student behaviors. Finally, the difference between grade levels, and particularly the uniqueness of 6th graders, will be discussed as a finding potentially relevant to designers of Teaching Green Buildings.

Finding 1: Students are aware of numerous Teaching Green Building features on their school campus even when they have not received formal education about these features.

The photography project was a data collection method that uncovered themes that are difficult to capture with survey methods. The photography data enabled the researcher to see the school environment through the eyes of the middle school students, and hear about the green building features in language chosen by the students. The pictures that students took, edited, and then wrote about indicate the parts of the green school campus that students are aware of, if not knowledgeable about[30].

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[30] Though the photography project was not a knowledge test, the manner in which students put together photo boards allowed the researcher to see levels of depth in what students photographed and wrote about. However, it is not presumed that the photo boards capture the entirety of what students know. Further, it is not assumed that inclusion of a photo means that student is knowledgeable about the feature in the photography. Therefore, the term awareness is used here as the conservative choice to describe student orientation toward learning content.

Data from the photography project at the Arts School was presented in Chapter 7 (Figure 7-6). The results showed that students dramatically expanded their photo content from pre-move to post-move conditions in a move from a conventional school to a Teaching Green Building. Pre-move photos included eight categories total with four dominant categories (i.e., recycling, plants/animals, litter, water) and the photos taken in the new school included the eight categories from the previous year plus five new photo categories (a 38% expansion of themes). The new categories included: garden/compost, alternative energy, building materials, building artwork, and daylight/air.

It is fascinating to note that a formal green building curriculum did not exist at the Arts School at the time of this study. The photography project revealed that students can identify the features on campus that are environmentally friendly; however, elaborating on the greenness of features was difficult for some students.[31] Some students, for example, indicated that they knew the wind turbine was important, but forgot what it was called or were embarrassed to say the name in case they were wrong. Most student photos of the wind turbine were attended by one sentence that explained that it makes energy from wind. One student said that it "saves electricity," which is an inaccurate statement, but shows that she understood that the feature is about energy.

Based on these data, there are three green building features worth discussing in more depth.

First, one striking consistency between pre- and post-move photographs was the presence of plants and animals in the student photographs (from 25% of photographs pre-move to 22% of photographs post-move). This theme is highly salient for students in this age group, and is one they are inclined to capture regardless of the greenness of the school building.

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[31] Anecdotal speculation based on the researcher's experience working with and interviewing students in the project.

Second, there was an observable difference in the awareness of daylight issues for students in the Arts School from pre- to post-move conditions. The concept of daylight and open air increased in the photo content from 0% to 15% in the post-move condition (Figure 7-6) and 8% to 12% in PART I of the green building knowledge test (Figure 7-4). This finding is likely a result of the specific architectural design of the Arts School Teaching Green Building, where daylight and openness were key strategies for achieving a low energy building. It is likely that the openness of the new building also affects student exposure to hot and cold weather conditions throughout the school day, and thus heightens student awareness of the architecture because they feel the physiological effects of the building design (which the current middle school students can compare to their experiences in the old building that was much less open to the weather).

Third, alternative energy is one category that students – regardless of school – connected to green buildings (Figure 7-4). Analysis of the PART I open-ended portion on the green building knowledge test showed that alternative energy was the most common response for students in the West Coast schools. Over 20% of student responses in PART I mentioned some kind of alternative energy system (typically solar panels, wind energy, or, less often, geothermal energy). While these data cannot explain why this is the case, it is likely due to a mixture of reasons such as the high visibility of alternative energy features on buildings and the high coverage of the topic in the media.

Finding 2: Where no formal green building curriculum exists, students' Green building knowledge can be predicted by both school-level factors and personal factors.

Despite the occasional lesson plan about green buildings, no school in this study had an integrated green building curriculum at the time of data collection. Regression models presented in Chapter 6 uncovered numerous factors that are predictive of Green building knowledge (GBK) (Table 6-10). Due to the absence of formal curricula, the learning of GBK is likely to occur through informal means. The school-level factors included in the final prediction model are: the school a student attends[32] the supportiveness of the environment, and building environmental conditions, including satisfaction with lighting and access to nature indoors. The personal factors that predict GBK are Environmental sensitivity, Home behaviors, grade level, having been to a green building, and gender. Together, these variables explain approximately a quarter of the variance in student levels of GBK.

There is much variance in GBK (approximately 75%) left to explain. It is possible that a curriculum targeted at green building issues could help to cover part of that gap in explanation. This study illuminates important factors for GBK where little to no formal education currently exists. It also highlights that the school environment matters and that student environmental sensitivity, home lives, and experiences put students at different starting points relative to green building education.

Finding 3: High levels of student Green building knowledge (GBK) do not require attending a Teaching Green School Building.

The regression results in Chapter 6 showed that the school a student attends is predictive of student GBK. However, the line is not clearly drawn between green and non-green schools. One school in this study, the Waldorf School, does not have a Teaching Green School Building, yet performed well on the green building knowledge test that was part of the Green Building Literacy Survey. Other analyses revealed that the Waldorf School is unique in terms of the families who attend the school with higher levels of student behaviors at home compared to other schools. Additionally, 71% of Waldorf students report having been to a green building before, a number significantly

[32] The schools in this study vary in numerous ways, where the most notable differences are in geographic location, school culture, and the greenness their buildings (see Chapter 5 for a full discussion of school settings including commonalities and differences).

above the whole sample percentage of 54% (Table 6-2).[33] Regression analyses predicting GBK showed that Home behaviors and having been to a green building are significant predictors. The Waldorf School students are exemplary in these areas.

There are several potential explanations for the test performance of Waldorf students. First, the school campus contains numerous green landscape features. Thus, while the school building itself is not green per current standards, the landscape contains such features as pervious paving, a rain garden, a vegetable garden, a compost pile, and a mud oven. The green building knowledge test covered all of these topics except the mud oven, and thus students at the Waldorf School were likely well prepared for these questions (i.e., 28% of the test questions were about sustainable sites, and 8% of questions were food-related, see Figure 4-1). Second, an interview with the Waldorf School 7th grade teacher (discussed at length in Chapter 5, p.109) revealed that there are numerous instructional units throughout the grade levels that teach students about the built environment. It appears that the Waldorf School has, with the exception of an actual green school building, many of the key ingredients across the contextual model for learning about green buildings presented in Chapter 3 (Figure 3-2).

One implication of the Waldorf School finding is that making a minimal investment in adding teaching green features to a school yard might have a significant impact on student learning. Further, even students in a new construction Teaching Green Building have a tendency to connect outdoor features to environmental education more often than indoor features (see Finding 4 below). A compelling case might be made to start teaching green renovations from the outdoors in.

[33] It should be noted that the Waldorf and College Preparatory Schools are both in a college town where there is a Teaching Green Building on the university campus. Further, at the time of this study, this campus building offered programming for K-12 students to visit the green campus building. Students at both of these schools have had an opportunity to see this campus building. Sixty-six percent of the College Preparatory school students in the study indicate having been to a green building that is not their own school building.

The Waldorf School is an exception and ultimately revealed itself as a unique setting in between the green and non-green parameters set for this project. The Technology School, however, is a better representative of a non-green school. This school does not have green infrastructure on campus, indoors or out (Table 5-2). Generally, the students at the Technology School are not significantly different in terms of affective dispositions or Home behaviors compared to the other schools. As hypothesized, however, the students at the Technology School performed significantly lower on the GBK test compared to students in all three Teaching Green Schools.

In sum, access to a Teaching Green Building increases student Green building knowledge; however, a school in a non-green building can close the knowledge gap with the right mixture of contextual factors.

Finding 4: When asked to photograph places where they learn about sustainability on campus, students tend to cite outdoor features.

The photography project with middle school students revealed that students are drawn to the outdoors when prompted to think about sustainability issues on their school campuses. In the pre-move non-green building, 71% of Arts School students' photo board photos[34] were taken outdoors. In the post-move green building, the percentage of indoors photos significantly increased for the students who were involved in the project both years (n=21) (Figure 7-7), signaling that the green building has notable features for students. However, across the total sample of post-move students (n=34) there was still a 59% majority of outdoor photos compared to indoor photos. It appears that outdoor features are the most salient themes for students as they responded to the project prompt to photograph places where they learn about environmental sustainability on campus.

[34] These were the photos that students placed on their final photo boards after a process of elimination with the full set of photos.

This finding may be due in part to the photography project method, which allowed students to go outdoors during the class period – an opportunity students were eager to take. It is further possible that outdoor photos developed nicer than indoor photos when students failed to use the camera flash indoors. Thus, some students may have opted for nicer looking outdoor photos for their boards. A general preference for outdoor themes would not be surprising, however, given that traditional environmental education programming typically emphasizes nature-based outdoor education where plants, animals, and ecological functions are common themes.

In sum, there are reasons to believe that students are drawn outdoors when prompted to think about environmental sustainability on their school campuses. However, this trend would best be confirmed by triangulating the finding from data sources beyond the photography data presented here.

Finding 5: Environmentally responsible behaviors (ERB's) at school are better predicted by external factors rather than student personal factors, though student home behaviors are also an influential factor.

While many behavior change models have focused on personal and psychological factors, this study also explored physical context factors that also bear on behavioral decisions. When factors personal, social, and physical are included together in the same regression model, the results show that the social and physical environment of the school clearly plays a role in student adoption of ERB's at school (the measure of School behaviors in this study).

Supportive environment (an environment that offers opportunities to take action, and where teachers, peers, and the building support action) was the strongest predictor of School behaviors (explaining 37% of the variance in School behaviors) (Table 6-12).The Home behaviors category was a second significant predictor, and when combined with the Supportive environment measure they together explain 49% of the variance in

School behaviors. Student behavioral choices at school are primarily determined by a supportive school environment and what students do about the environment at home.

There were numerous significant predictors of School behaviors beyond the Supportive environment measure and Home behaviors, including: school student attends, Environmental education opportunities, Environmental conditions, and years on campus. The majority of these significant predictors span the social and physical environment, showing that School behaviors appear to be influenced by many factors external to the student.

These results partially echo findings of Schelly et al. (2011) study of conservation behavior change in high school students, where it was found that attitude change was less important than other factors. They conclude:

> *In this school, perceived efficacy, behavioral expectations, and organizational culture all motivated behavioral change, but no participants described changing their attitudes. Respondents indicated that even without a sense of environmental concern and without engaging in environmentally responsible behaviors at home, they participated in energy conservation and other efforts (such as recycling) within the organizational setting. This suggests that setting new standards is more important than changing environmental values (Schelly, Cross, Franzen, Hall, & Reeve, 2011, p. 338).*

While the current study found Home behaviors to be important, it also revealed that student environmentally responsible behaviors at school appear to be motivated dominantly by contextual factors.

Finding 6: Sixth graders perceive the school environment differently than 7th and 8th grade students. In particular, they are more positive about and attribute more support to the physical setting.

Results from the National Environmental Literacy Assessment (NELA) project show that younger students tend to differ significantly on environmental literacy measures – where sixth graders are lower on cognitive skills but higher in self-report measures such as affect and behavior (McBeth et al., 2008). That finding was replicated in this study on green building literacy, where sixth graders emerged as a singular group across numerous measures (see Table 6-5, where school was controlled for). Sixth graders rated themselves higher on environmental literacy measures, such as affect and behavior.

Further, and of special pertinence to an architectural audience, is the phenomenon that sixth graders tend to rate the physical environment higher than older peers. Sixth graders, for example, are more positive about building environmental conditions and the level of support provided by their environments (Table 6-5). They also indicate higher levels of Environmental education opportunities (Table 6-5).

The authors of the NELA project report did not speculate why 6th graders would differ significantly on self-report survey items.[35] It is unclear if differences are truly due to real differences among student cohorts or are a product of the assessment tool. For example, one reason for high sixth grader self-reports could be that the desire to please teachers and the researcher are higher for younger students. Another potential explanation is the difference in life experiences, which would potentially be greater for 8th graders, and might shift student attributions and assessments of the situation (*e.g.*, by 8th grade, students may have met more people outside of school compared to 6th grade, and knowing more people who are very environmentally friendly may shift your assessment of yourself relative to other people you know). On the other hand, it is possible that sixth graders truly feel more positive about the environment. Sixth graders in this study also indicate higher levels of Environmental education opportunities (Table 6-5), which may influence their attitudes. Further research is needed to understand this pattern of results.

[35] Report co-author T. Marcinkowski noted in personal communications with the researcher that an explanation of the differences between 6th graders and older middle school students has not been pursued to date in the research, though numerous findings in NELA and beyond confirm the phenomenon.

Contribution to Knowledge

This study investigated green school design as a catalyst for informal environmental education. The buildings at the center of this study, Teaching Green Buildings, are green middle schools that were designed explicitly to teach about the environment through architecture. Various authors have written about these school buildings as teaching tools or 3-dimensional textbooks, and the buildings themselves are the subject of inspired discourse (Nair & Fielding, 2005; Taylor, 1993; United States Green Building Council, 2008), but remain largely unexplored by empirical researchers. By offering an original framework and research findings from five case study school buildings, the work here seeks to advance our understanding of environmentally educational school architecture. It further proposes ways to evaluate success in Teaching Green Buildings via the conceptualization and measurement of green building literacy. This form of literacy encompasses not only green building knowledge, but also awareness, attitudes, skill, and behaviors relative to green building issues. In the Chapter 1 introduction, it is argued that this set of outcomes is of importance to both green building performance and the education of people who will be life-long users of buildings.

Two methods for measuring green building literacy were developed for middle school students: a survey instrument and qualitative information via a student photography project. This work thus offers contributions that are both theoretical and methodological.

Theoretical Contributions

The contributions to theory are achieved through an interdisciplinary review of literature and an empirical study across five middle schools in the United States.

Historically, the literature about Teaching Green Buildings has pointed to the idea of using buildings as teaching tools, sometimes with descriptions of design features, but less often engaging a theoretical literature base to outline prospects for such buildings. The first major theoretical contributions were presented in Chapters 2 and 3, where reviews of the literature culminated in frameworks for conceptualizing 1) the mechanisms through which a Teaching Green Building is expected to work (Figure 2-2), and 2) green building literacy as a set of outcomes to which Teaching Green Buildings may aspire (Table 3-1).

The Teaching Green Building model for learning (Figure 2-2) uses literature from museum studies, education, and architecture to build a framework for design patterns that can be used in Teaching Green Buildings to enhance learning outcomes. The design patterns presented (i.e., factual information, physical engagement, social interaction, social norms) are themselves grounded in research in psychology and education and presented as plausible mechanisms through which the physical environment can support learning and taking action on environmental issues. The goal of this framework is to highlight potential interventions that can be used in Teaching Green Buildings. The framework can additionally inspire future researchable questions.

Just as the "how" of the Teaching Green Building has not been elaborated in previous scholarship, the "why" of these buildings is often ill-defined, with assumptions that learning *of some kind* is occurring. Green building literacy is proposed as one set of stated goals for buildings that aspire to teach. Chapter 3 used foundational literature in the field of environmental education that describes environmental literacy, and adapted the Marcinkowski (2010) framework to outline prospects for green building literacy (Table 3-1).

It was the theory in Chapter 2 on the major features of green building literacy that was undertaken in the exploratory empirical research to follow in Chapters 5-7. Thus, after the literature reviews in Chapters 2 and 3, the second major theoretical contribution stems from the empirical research that investigated green building literacy outcomes in diverse school settings. These findings, presented at the beginning of this chapter are the basis of a research agenda in its early stages of development.

To the author's knowledge, the current study is the first of its kind to empirically study Teaching Green Buildings from the student viewpoint. Previous literature has celebrated the prospects for such buildings (Nair & Fielding, 2005; O'Donnell Wicklund Pigozzi Peterson Architects Inc. et al., 2010; Taylor, 1993), and a recent Master's thesis studied the topic from the viewpoint of parents, teachers, and administrators (Barr, 2011); however, lacking was empirical research from the vantage point of students who use these buildings day-to-day. The current study is among the first to shift the lens from adults to children.

Methodological Contributions

The development of research instruments for this study is in itself a contribution. Given the research focus on informal learning, the methodologies employed in the study relied on precedents in the fields of environmental education.

The Green Building Literacy Survey (GBLS) was adapted from the Middle School Environmental Literacy Survey (MSELS) used in a major national study of environmental literacy in middle schools across the United States (Bluhm et al., 1995; McBeth et al., 2008). The MSELS was first developed and field tested as part of the Environmental Education Literacy/Needs Assessment Project (Wilke, 1995). The MSELS has been rigorously tested and validated. The GBLS did not use the instrument in its entirety, and adapted it to the specific purpose of this study, and thus cannot claim the same level of validity or reliability. Nor can GBLS results be directly or easily compared to the MSELS. The choice to deviate from the MSELS was intentional, and allowed the researcher to 1) increase the measurement of built environment factors, and 2) develop a green building knowledge test for middle school students, which may be the first of its kind to be used in empirical research.

The second methodological contribution is the use of a student photography project in the data collection process. This process was modeled after a method called Photovoice that has been used in areas such as education and public health (Strack, 2004; Wang, 2001; N. Wilson, Stefan Dasho, Anna C. Martin, Nina Wallerstein, Caroline C. Wang, Mereditch Minkler, 2007). This data collection method resulted in a rich set of information that illuminates student environmental experiences in and around their school buildings. The project allowed for the primary content of analysis to be driven by the students themselves.

Photography as a method captured well the student viewpoint and offered multiple avenues for expression that included both visual and written means of communication. In this way, the method attempts to deal with the possibly high variation in verbal and written language skills amongst middle school students. The method is thus well-suited for the age group engaged in this research.

Future Research

There are numerous promising directions this research can take beyond the present study. Below are several suggestions for projects that would advance the study of green building literacy and the prospects for Teaching Green Buildings.

Phase II Survey Research

The next phase of research requires a refinement of the survey instrument based on study findings, and an administration of the survey to a larger number of students in a greater variety of school settings. Additional Teaching Green Buildings could be recruited, but the study could also expand to include more typical school buildings, such as the Waldorf School building that was non-green and incorporated outdoor green features. The second phase of the project with a greater number of schools would lend to more sophisticated analyses of variable relationships given a greater sample size. Expansion into non-charter public schools would increase the generalizability of the findings. Expanded in these ways, future studies could strengthen our conceptualization of Green Building Literacy and the environmental, personal, and social factors that impact it.

Investigate Specific Teaching Green Building Features and Building Configuration

The current study did not isolate a specific built environment intervention, such as an energy dashboard or building signage, to study the effects of a particular building feature. However, decades of research in conservation psychology can offer insight on the ways in which interventions such as feedback mechanisms, informational signage, and environmental prompts affect environmental outcomes. This literature forms the ideal base on which to expand concepts into the Teaching Green Building context, using precedent theory and methodologies.

Another dynamic of Teaching Green Buildings that was not addressed in the current study was the question of spatial configuration that was posed in Chapter 2. The Chapter 2 discussion of a well-configured environment proposed that the placement of a building feature within the building might make a difference in who sees it, uses it, talks about it, learns from it, and so on. Along with the study of individual features, it would be beneficial to additionally study the spatial properties that potentially impact the social and environmental benefits of a given feature.

Experiment with Green Building Curricula

The variables measured in this study were able to explain 25% of the variance in student Green building knowledge (GBK). It is predicted that a formal green building curriculum would significantly heighten student awareness and knowledge of green buildings, and therefore help to explain more variance in the dependent variable of GBK. Future research could evaluate specific green building lesson plans.

New Outcome Variables

This study investigated outcomes for green building knowledge and environmentally responsible behaviors at school. Future studies could research additional positive outcomes such as shifts in affective dispositions or the acquisition of green building skills, such as the skills needed to positively contribute to a green building's environmental performance.

In the current study, there were no significant changes observed in affective dispositions for Arts School students one year after moving into their new building (Table 7-7). This result is consistent with the slow and multi-faceted process of cultivating outcomes such as environmental sensitivity for students. However, we cannot say definitively that the building does not affect outcomes such as environmental sensitivity or behavioral willingness. A longitudinal study may be required to better understand the relationship between building design and student attitudes and feelings.

Another interesting outcome that was not well addressed in the current study is the development of skills related to green buildings. It is possible that green buildings not only teach students content knowledge (the what and why), but also ways to participate in stewardship activities related to green buildings (the how). Future research could examine the ways that students develop and transfer skills based on their experiences in green school buildings.

Many of the outcome variables studied in this research, and mentioned above, are specific constructs that can be operationalized in social research. What is more difficult to measure is the totality of the student experience of a Teaching Green Building, which may include positive outcomes that elude quantitative measurement. Increasing the use of qualitative measures, such as the photography project used in this research, can help to uncover the benefits of – and also the challenges within – Teaching Green Buildings.

Develop a Pattern Language for the Teaching Green Building

This dissertation offers a theoretical framework that proposes the broad mechanisms through which a building might teach (Chapter 2). The next step is to populate this framework with specific tactics that can be employed to foster educational outcomes. For example, the framework proposes hands-on educational features as a strategy, where particular tactics could include energy dashboard monitors, school vegetable gardens, and composting programs stewarded by students. A more far-reaching look at Teaching Green Buildings could uncover tactics common in these unique buildings. The result of such research could be a Pattern Language for Teaching Green Building

Features, a framework inspired by Christopher Alexander's work, that offers a toolbox of design patterns that can be woven into the architectural language of future Teaching Green Building designs (Alexander, Ishikawa, & Silverstein, 1977; Nair & Fielding, 2005). Literature across disciplines can be consulted to identify challenges and possibilities for each specific tactic based on existing empirical research. A project of this magnitude has not been undertaken for Teaching Green Buildings, yet would constitute a practice-oriented contribution targeted to architects, educators, and school administrators. It could additionally strengthen the theoretical case for buildings designed with pedagogical intent.

Implications for Practice

Based on the theory and empirical research presented in the previous chapters, there are specific implications for practice and policy. This section presents the top implications and recommendations for architects, educators, and administrators who aspire to create and maintain a successful Teaching Green Building and/or promote green building literacy. This study offers insights for a broad spectrum of applications: (1) schools that are being newly designed or renovated and (2) schools that do not have the opportunity to alter or build facilities, but wish to increase student green building literacy. The implications outlined below start with the decision to follow the Teaching Green Building path, and then cover several basic insights for building design based on the findings in this study. The final implications are those that can be applied widely to green and non-green buildings alike.

Students who don't experience environmentalism at home will benefit most from a Teaching Green Building.

One of the most fascinating findings in this study is that the Waldorf School performed as well on the green building knowledge (GBK) test as the Ethics School, where the latter school has two long-standing Teaching Green Buildings on campus and a significantly higher level of green building education in the classroom. A review of analyses beyond the GBK score show that the Waldorf School is exemplary in terms of student behaviors at home, and that Home behaviors is a significant predictor of GBK. This exceptionality in terms of student behaviors at home is likely due to the unique school philosophy, based on the Waldorf model of education that attracts environmentally-conscious families to this school. Additionally, this school is located in a university town where environmental consciousness may be more prevalent than in other regions of this study. This finding suggests that an environmentally-conscious family and community life is an independent means of increasing GBK. This is a hopeful finding since it implies that a school with a non-green building, and facing budgetary constraints, may nonetheless be able to increase GBK by leveraging family and community concern for the environment.

Not all schools, however, have the benefit of being located within communities with overt environmental sensibilities. This study found that informal adoption of GBK depends mostly on personal factors, and thus students who do not conduct environmentally responsible behaviors at home or have environmentally sensitive role models outside of school, for example, are more likely to benefit from formal green building interventions in the school environment.

There is more than one kind of green building knowledge.

Many past approaches to Teaching Green Buildings have used informational signage to convey factual knowledge about green buildings. At the same time, literature from the field of education illuminates an array of knowledge outcomes for learning that go well beyond factual knowledge. The Taxonomy Table (Table 3-2) offers the four knowledge dimensions of factual, conceptual, procedural, and metacognitive knowledge. It was argued that green building education can aspire to foster this range of knowledge outcomes for students. In the larger picture of green building education, students should be able to cite more than facts, they should be able to conceptually connect building concepts to other systems (*e.g.*, ecological and social systems) and further learn how to participate in buildings as environmental stewards. In effect, designers of Teaching Green Buildings – and designers of the curricula that attend such buildings –

can ask how knowledge about green buildings translates to the enacted skill sets needed for the next generation of building users and designers.

Teaching Green Buildings can offer content that connects to what students already know and care about, and then challenge students to build on that knowledge.

One way to think about the acquisition of green building knowledge is to consider that students are constantly building mental models of buildings over time and repeated experience. In theory, daily access to a green building should provide multiple opportunities to build and reinforce green building concepts for students. The green school building used by students is likely to become the primary reference point for the concept of green buildings in their minds. With this frame, there are several interesting ways to think about the design of Teaching Green Buildings.

First, we might consider how students new to a building encounter its features. The photography documentation project at the Arts School in this study revealed the green building features that were most salient for students in a new construction Teaching Green Building at the end of their first school year in the new building (Figure 7-6). Some of those top features are elaborated under Finding 1 above, and included plants/animals, daylight, and alternative energy, which were fairly prominent aspects of the architectural design of the Arts School building. With the exception of daylight, the other themes were popular for students *prior* to the move – the new building thus offered students a deeper engagement with features they already knew something about. As noted earlier, the affinity this age group has for plants and animals means that incorporating nature into the building design could be an important means for helping students to build on themes they already know and care about.

A second issue, then, is: how can the building offer graduated challenges to students as they grow older and increasingly savvy about green building issues? How can building design challenge students with new learning content and integrate across multiple elements of their existing knowledge? The concept of daylight and open air in the new

Arts School building is one potent example of how a building can do this. Arts School students were not accustomed to being outdoors in a range of temperatures, but the new school is designed in a way that students are exposed to the elements as they move between classrooms and on the way to their lockers. The lessons learned are numerous. First, students are aware of the open building design as a green building strategy. But students have also learned how to cope with a greater range of temperatures throughout the day (*e.g.,* what kinds of layers do I wear, how does my body adapt to temperature change), a type of learning that is more procedural, and quite practical, in nature. This is one way the green building has challenged students to think and act in new ways, and in a way that may apply beyond the school building itself.

A Teaching Green Building is more than an object or museum; it is a complex setting with social dynamics that impact the effectiveness of teaching green building features.

Based on theory from museum studies, the Teaching Green Building contextual model for learning was developed (Figure 2-2). This model proposed the many channels through which contextual learning may occur. The data presented in Chapter 6 showed that many factors -- personal, social, and physical -- affect student Green building knowledge (Figure 6-1).

The implication for practice and policy is that Teaching Green Building features are in a dynamic relationship with cultural factors such as school policies, curricula, and adult/peer role models for environmentalism. To use the Higgs & McMillan (2006) notion, the school environment models sustainability through a plethora of channels, one of which is the physical school facility. Conflicting information amongst channels can undermine the overall message. In school buildings all over the world, the majority of which are *not* designed to reduce impacts on nature, the message continues to be one of environmental destruction and disconnection. Schools fortunate enough to have green features on campus can leverage their facility as one piece of a multi-pronged environmental education effort, an effort that can permeate both tangible and intangible aspects of school culture.

But even schools in non-green facilities can work to change the story their building tells and simultaneously advance green building education. The findings in this study suggest that non-green buildings with green features in the schoolyard may yield increased environmental sensibilities for students. And, going one step further, non-green buildings might be combined with a curriculum to use their non-green features to promote green building literacy, perhaps even engaging students in projects that improve the non-green school building in environmentally beneficial ways.

Further, regardless of school building type, the environment can be fashioned to support environmentally responsible behaviors in the school environment. Results from the study showed that Supportive environment was the top predictor of School behaviors, meaning that support from the building, teacher, and peers together are the strongest predictors of a student's behavioral decisions (Table 6-12). While a Teaching Green Building likely expands behavioral opportunities (*e.g.*, food composting, monitoring alternative energy systems) compared to a conventional school building, there are certainly behaviors that can be promoted in a conventional building (*e.g.*, recycling, turning off lights).

When deciding to build or renovate on campus, choosing building features that aim to serve multiple educational functions may ultimately constitute the wisest investments. For example, native plantings on the schoolyard can have static signage that educates the passerby about the environmental benefits, but they can also be integrated into the biology curriculum for student observation. The view of such greenery through the classroom window additionally offers restorative benefits for mentally fatigued students and teachers. One design choice can have cascading positive benefits. Where project budgets are tight, and value engineering inevitable, features with the most benefits should stay in the design. Features with multiple benefits can improve the environmental performance of the building and offer formal and informal educational opportunities.

The point here is that social and physical environment factors are in constant interaction, where the social may determine the shape of the physical and the physical opens up possibilities and benefits to the social. The experience of the social and physical aspects of the school environment is a continuous one, where the boundaries between go largely unnoticed by occupants as they experience the building on a daily basis. Thus, the view of the building as a static object is not likely to serve the overall goals of the Teaching Green Building; the unique social culture of the school needs to also be considered.

If it is not possible to start inside, start outside.

Not every school has the budget to build a new construction Teaching Green Building or to substantially renovate. In fact, the vast majority of schools in the United States do not. Converting parts of the school yard piece-by-piece, however, might be done over time. Several results in the current research point toward the potential effectiveness of modest outdoor interventions.

First, it was found that students at the Waldorf School with a non-green school building did as well as the green school students in performance on a green building knowledge test. Finding three above discussed this phenomenon at length. One potential explanation, among several, is that the Waldorf School campus has numerous green outdoor features, such as a garden/compost area, and a rain garden. These features were constructed over time, and often with student involvement.

Second, it was observed in Chapter 7 that students have a tendency to photograph and write more about outdoor features than indoor features when asked “where do you learn about environmental sustainability around your school campus?” Many of these outdoor photos included features as simple as flowers, an orchard, the school garden, or playground structures made out of recycled content. Plants and animals was the one category of photographs that remained consistently high from pre-move to post-move data collection. It appears that, for middle school students, a green school building becomes green when it contains greenery that is easily perceived by students.

One implication for this finding is that landscape architecture should be a consideration that is integrated early in the process of a Teaching Green Building design or considered for any non-green school building where outdoor projects are possible.

Green building curricula may be the missing link.

Work by Kirschner et al. (2006) questions the value of "minimal guidance" educational experiences, or those lessons that students are expected to discover with little guidance from educators. The authors especially caution the use of minimal guidance pedagogy with novices (Kirschner, Sweller, & Clark, 2006). As stated numerous places in this dissertation, many people –adults and children alike – are likely to be green building novices given the dearth of green building educational opportunities for the public.

This study did not include a case study school that had both a green building and a fully integrated green building curriculum. Though students in the green buildings did indicate a significantly higher level of green building education in the classroom compared to non-green school peers, levels of green building education were generally low. Students indicated that they learned about green buildings only rarely to sometimes at school. Under these conditions, it was found that environmental education opportunities did not significantly predict student Green building knowledge. This is an interesting and perhaps unexpected result.

The question remains as to what impacts would be realized with a formal green building curriculum, and further a curriculum that facilitates hands-on engagement with the physical school building. The variables measured in this study were able to explain 25% of the variance in Green building knowledge. It is possible that experimenting with formal curriculum and testing students again would show an increase in the variance explained. While survey data in this study cannot further inform the question of curriculum, several recommendations can be formed based on interviews with educators, administrators, and architects.

First, teachers who work in Teaching Green Buildings desire training and resources if they are expected to integrate their lesson plans with the building architecture. As discussed in Chapter 1, green building education currently exists primarily within the bounds of built environment expertise. There are few inroads for adults outside the green building industry to learn about the ideas formally, or even informally. Thus, it cannot be expected that teachers themselves will feel confident enough with green building themes to teach those themes to their students. Comments heard at the focus group with Arts School faculty underlined these sentiments (see Chapter 5).

At the same time, architects are not typically versed in the complex world of educational standards and lesson planning. The architect of the Arts School attempted to create the outline for a curriculum, hoping that educators would take it up and finish the lesson planning. At the time of this study, the document had not advanced beyond the architect's initial suggestions. Among the many reasons for this was the lack of time amidst the frenzy of moving into a new building as expressed during the teacher focus group.

The Ethics School, being nearly ten years old at the time of this study, offers a snapshot of a matured Teaching Green Building where many of the faculty members have been able to absorb and use their surroundings in their educational programming. The students here indicated the highest level of environmental education opportunities at school. Even though the Ethics School teachers do not have a formal, integrated approach to teaching about green buildings, and there is no formal green building training for its teachers, the teachers in the focus group indicated a higher comfort level with green building concepts compared to the Arts School. While this could be due to teacher personal interests, it could also be related to the length of time on the green campus.

The Ethics School teachers appear more comfortable with green building themes; they also discussed how the green campus is utilized across subject matters.[36] The Ethics School teachers shared examples of how the green campus is integrated into social studies (*e.g.*, students write place narratives about the history of the school site) and art (*e.g.*, students study and sketch building geometries). In the teacher focus group, the Ethics School teachers shared their future goals for continuing to teach sustainability in a more cross-disciplinary way.

Across all the schools in this study, one story that emerges is that green building curriculum is an interdisciplinary effort that benefits from both educational and architectural expertise. Further, such curricula can benefit from the interdisciplinarity of the educators themselves, and need not be housed in the science classes alone. Another story emerging here is that teachers may desire training and resources, but that even in the absence of such support, teachers may acclimate to the green school environment and organically begin to include green building themes into their lesson planning, as did the teachers at the Ethics School.

A Focus on Relationships

The Teaching Green Building is the venue for an unfolding story about how we relate to the natural environment. As these buildings tell an ecological story, they can also support self-discovery and social interaction. Buildings can both communicate and support the relationships we have with ourselves, other people, and the natural world.

This triad aligns nicely with the domains of influence investigated in this study that included personal, social, and contextual factors. Variables in all three of these domains emerged as predictors of student knowledge and behavior, confirming the existing

36 This is somewhat unique, given that the other two Teaching Green Buildings in the study currently tie their aspirations for green building education most directly to science curricula. However, it should be recalled that the other two Teaching Green Buildings (the Arts School and College Preparatory School) are both fairly new construction, and are in the very early phases of integrating their Teaching Green Buildings into curricula.

literature that suggests the pathways to environmental education outcomes are varied and complex. Within that recognized complexity, and at the core of this study, is the question of ways in which the physical environment of the school matters for environmental education.

It is possible that many benefits of well-designed buildings elude measurement. Just as human relationships are complex and difficult to quantify, so are our relationships with the natural world. This is no less the case in attempting to uncover the ways these relationships are inscribed in, and reinforced by, the buildings we create and use.

That said, the advancement of qualitatively good building design, as Teaching Green Buildings are hoped to be, benefits from an evidence base that can inform the path forward. If environmental indicators are even partially correct, that path will be fraught with challenges that are not only technological, but also social and psychological. Teaching Green Buildings offer laboratories for innovation in all of these areas. The work here demonstrates promising results that connect school design to the pursuit of environmental literacy. It also outlined many exciting directions for future empirical research on Teaching Green Buildings. Continued study of these issues can make a contribution to the larger pursuit of addressing sustainability challenges through building design.

Appendices

Appendix A: Survey Instrument

The Green Building Literacy Survey (GBLS)

Laura Smith, PhD candidate at the University of Michigan, invites you to take this survey that will contribute to her dissertation work about school buildings. She is interested in what you think and know about environmental issues in your school building. Your responses here will contribute to future publications and presentations about green school building design. The purpose of her study is to help improve the design of environmentally friendly school buildings.

Participating in this study is completely voluntary. Even if you decide to participate now, you may change your mind and stop at any time. You may choose to not answer an individual question or you may skip any section of the survey. All answers will be kept strictly confidential. Nobody except the researcher will know what answers you gave. And your responses will have <u>no</u> impact on your grades in this class. Students who participate in this survey will have a chance at winning a $15 gift certificate to Borders bookstore. Thank you for your time today!

This survey should take about a half hour, and there are three parts:

Part I: The Building Features I Know About

Part II: Green Building Knowledge

Part III: What you Feel, Think and Do about Environmental Issues

Your Name:____

Grade Level:_________

"Green Buildings" are buildings that have been designed to better conserve resources, such as water and energy, and often include features that help to protect the natural environment. Please mark your answers to the questions below.

Have you been to a "green building" before?

___ Yes ___ No ___ Not sure

How much do you know about "**green buildings"**?

___A lot ___Quite a bit ___Some ___A Little ___Nothing

PART I

The Building Features I Know About

Directions: Below you are asked to list up to four (4) environmentally friendly features of green buildings. You don't need to think about a specific building, just features that can be found generally in any green building. The examples below show you ways to write items for your own list. It is important to include both **the building feature** and **the benefit to the environment**. Please write as many as you can.

Examples:

Example 1 (statement): **Recycling bins help to reduce the amount of trash that goes into the landfill.** *[In this example, the feature is a recycling bin. The environmental benefit is reducing the amount of trash that goes into the landfill.]*

Example 2 (if written as question): **Does a rain garden help to improve water quality?** *[In this example, the feature is a rain garden, and the environmental benefit is improving water quality.]*

Please write a list of environmentally friendly building features with which you are familiar. You do not have to fill in all the blanks if you do not know four (4) environmentally friendly building features.

1.____

2. ____

3. ____

4. ____

☐ Please check this box if you are **not familiar** with any green building features.

END OF PART I.

PART II

Green Building Questions

Multiple Choice Directions: Please **circle the letter of the correct response** for each multiple choice item. Circle ONLY ONE RESPONSE for each question.

Example: To travel downtown, which has the least environmental impact?

a. bus
(b.) bike
c. car

1. "Stormwater" is the term for rain water that falls around a building. In the landscaping around green buildings, we prefer to use ground surfaces that promote a more natural water cycle. Which group of ground surfaces would be the best for managing stormwater around a building?

    a. Asphalt, Concrete, and Gravel
    b. Grass, Plants, Gravel
    c. Plants, Concrete, and Gravel
    d. I don't know

2. Which one of the following is considered a renewable energy source?

    a. Coal
    b. Wind
    c. Oil
    d. Natural Gas
    e. I don't know

3. What percentage of your school building's energy comes from renewable energy sources?

    a. Less than 10%
    b. 10-20%
    c. 21-40%
    d. Greater than 40%
    e. I don't know

4. In your school building, which one of the following uses the **MOST** energy?
    a. Heating, ventilation and air conditioning
    b. Lighting
    c. Hot water heaters
    d. Equipment such as appliances and electronics
    e. I don't know

5. Which of the following *could* affect the quality of air that you breathe?
    a. Wet paint
    b. New furniture
    c. Cleaning supplies
    d. All of the above
    e. None of the above
    f. I don't know

6. All of the following are benefits of using native plants in landscaping, **EXCEPT**…
    a. Water conservation
    b. Wildlife habitat
    c. Bigger grassy lawns
    d. Use less polluting fertilizers
    e. I don't know

7. On a typical building in the United States, which direction should the solar panels face to collect the most solar energy?
    a. North
    b. East
    c. South
    d. West
    e. I don't know

8. Which of the following is **NOT** necessary for making a compost pile?
    a. Air
    b. Water
    c. Soil
    d. Fire
    e. Carbon
    f. I don't know

9. A light colored roof is good because…
    a. It absorbs heat from the sun and makes the building easier to heat
    b. It deflects heat from the sun and makes the building easier to cool
    c. It reduces light reflectance at night
    d. It increases light reflectance at night
    e. I don't know

10. For the green features pictured below, name the feature and briefly describe the environmental benefit.

Feature Name:________________________
Benefit to Environment: _______________

____

☐ I Don't Know

Feature Name: _______________________
Benefit to Environment: ______________

____

☐ I Don't Know

Feature Name:________________________
Benefit to Environment: _______________

____

☐ I Don't Know

Feature Name: ________________________
Benefit to Environment: ________________

____

☐ I Don't Know

Green Features around the School Building

Fill-in-the-Blank Directions: For each question below, fill in the blank to the best of your ability. If you do not know the answer and wish to skip the question, please mark the checkbox under "I don't know." For questions 1 and 2, the term "building material" refers to any material that is used in the construction of buildings. Examples could include materials used in flooring, walls, ceilings, and so on.

I don't know

☐ 1. Green buildings often contain building materials that are made of recycled content. Examples include ceiling tiles that are made out of recycled newspapers or counters that are made out of recycled plastics. Using building materials made of recycled content is good for the environment because ____
____.

☐ 2. Give one reason why *local building materials*, or building materials made close by, could be good for the environment: ____
____.

☐ 3. "kWh" stands for kilowatt hour and is a unit of measurement for _______________________.

☐ 4. A vegetable garden at school can help the *environment* by____________________________
____.

☐ 5. What are two environmentally friendly ways to reduce the amount of water used to water the grass and plants in the school yard?
A)____
B)____

☐ 6. Planting trees helps to absorb ___________________________, which is one of the major greenhouse gases that contributes to the problem of _________________________________.

☐ 7. Windows in the classroom provide daylight, and can impact energy consumption in the building in several ways. One way that windows impact energy usage is__________________
____. This is __________________
for the environment because ____.

PART III

Directions: Part III questions ask what you feel, think and do about the environment. There are <u>no right or wrong answers</u> for Part III questions. Please be completely honest.

You will be asked a number of questions about environmental sensitivity. ***Environmental sensitivity means having positive feelings toward the environment.*** Please **<u>check one box</u>** for each question below.

	Not at all	A little	A moderate amount	Quite a bit	A great amount
a. Please give your best estimate of the extent to which you are *environmentally sensitive*.	☐	☐	☐	☐	☐
b. Please give your best estimate of the extent to which your family is *environmentally sensitive*.	☐	☐	☐	☐	☐
What is the extent to which YOU…					
c. spend time in the out-of-doors alone – not as part of a class or youth group?	☐	☐	☐	☐	☐
d. enjoy watching programs or read about nature and the environment?	☐	☐	☐	☐	☐
e. have a teacher or youth leader who is a role model for environmental sensitivity?	☐	☐	☐	☐	☐
f. are involved in classroom activities where you learn about nature and the environment?	☐	☐	☐	☐	☐
g. are involved in activities *outside of class* that focus on nature and the environment?	☐	☐	☐	☐	☐
What is the extent to which you learn about <u>GREEN BUILDINGS</u> from…					
h. classroom activities?	☐	☐	☐	☐	☐
*Describe*______________________________					
i. **activities outside of class?**	☐	☐	☐	☐	☐
*Describe*______________________________					

Your Thoughts about Your School

Next we want to hear about comfort and satisfaction in your *current* school building. Please **check one box** for each question below.

To what extent do you agree with the following statements?	Not at all	A little	A moderate amount	Quite a bit	A great amount
a. The temperature in my school building is often uncomfortable for me.	☐	☐	☐	☐	☐
b. I am satisfied with the levels of light in the classrooms in my school building.	☐	☐	☐	☐	☐
c. I am often distracted by noise in my school building.	☐	☐	☐	☐	☐
d. In general, I am satisfied with my school BUILDING.	☐	☐	☐	☐	☐
e. I feel connected to nature when I am INSIDE the school building.	☐	☐	☐	☐	☐

If there is a place where you feel connected to nature INSIDE ONE OF YOUR SCHOOL'S BUILDINGS, please describe. Please be as specific as possible about the location inside the school building.

____

____

____

☐ There is **no** place INSIDE my school building where I feel connected to nature.

(Please continue)

How you think about the environment

In this section, you will be asked questions about environmentally responsible action. ***Environmentally responsible action refers to those activities that people do to help prevent or resolve environmental issues.*** Please **check one box** for each question below.

To what extent do you agree with the following?	**Not at all**	**A little**	**A moderate amount**	**Quite a bit**	**A great amount**	**I don't know**
a. There are opportunities to take environmentally responsible action in my SCHOOL BUILDING.	☐	☐	☐	☐	☐	☐
b. The SCHOOL BUILDING helps me learn to take environmentally responsible action while at school.	☐	☐	☐	☐	☐	☐
c. The SCHOOL BUILDING helps me learn to take environmentally responsible action elsewhere.	☐	☐	☐	☐	☐	☐
d. My TEACHERS help me learn to take environmentally responsible action while at school.	☐	☐	☐	☐	☐	☐
e. My PEERS help me learn to take environmentally responsible action while at school.	☐	☐	☐	☐	☐	☐

To what extent do you agree with the following?

I am…	**Not at all**	**A little**	**A moderate amount**	**Quite a bit**	**A great amount**
a. willing to turn off the water while I brush my teeth.	☐	☐	☐	☐	☐
b. **<u>not</u>** willing to save energy by using less air conditioning.	☐	☐	☐	☐	☐
c. willing to use less water when I bathe or shower.	☐	☐	☐	☐	☐
d. **<u>not</u>** willing to give my own money to help the environment.	☐	☐	☐	☐	☐
e. willing to walk more places to reduce air pollution.	☐	☐	☐	☐	☐
f. **<u>not</u>** willing to separate my family's trash for recycling.	☐	☐	☐	☐	☐
g. willing to use dimmer light bulbs.	☐	☐	☐	☐	☐

What you do about the environment

In general, how often do you…	Never	Rarely	Some-times	Frequently	Always
a. Do environmentally responsible actions at HOME?	☐	☐	☐	☐	☐
b. Do environmentally responsible actions at SCHOOL?	☐	☐	☐	☐	☐
c. Help others at SCHOOL to remember to do environmentally responsible actions	☐	☐	☐	☐	☐
d. Talk with your parents about how to help with environmental problems	☐	☐	☐	☐	☐
e. Walk or bike to get to school	☐	☐	☐	☐	☐
f. Carpool or take the bus to school	☐	☐	☐	☐	☐
g. Turn off the lights when leaving rooms in your SCHOOL building	☐	☐	☐	☐	☐
h. Turn off the lights when leaving rooms in your HOME	☐	☐	☐	☐	☐
i. Recycle things like paper, glass, plastic, or metals in your SCHOOL building	☐	☐	☐	☐	☐
j. Recycle things like paper, glass, plastic, or metals in your HOME	☐	☐	☐	☐	☐
k. Compost organic waste at HOME	☐	☐	☐	☐	☐
l. Compost organic waste at SCHOOL	☐	☐	☐	☐	☐
m. Pick up litter around your school building	☐	☐	☐	☐	☐
n. Bring your own lunch to school	☐	☐	☐	☐	☐

Write in other environmentally responsible actions (optional):

o. Other:________________________________	☐	☐	☐	☐	☐

Information about You

Your Gender: M ______ ; F ______

Your Birthday (month/day/year):_________________________________

Your ethnic group (check all that apply):

__ Asian American or Pacific Islander
__ Native American (American Indian/Eskimo/Aleut)
__ African American
__ Hispanic American
__ White American (American and/or European Descent)
__ Other ______________________________

Appendix B: Survey Consent Forms

Survey Parental Consent Form

Dear Parent:

Laura Smith, PhD candidate at the University of Michigan, College of Architecture and Urban Planning, invites your child to participate in a dissertation research study entitled *The Green School as Third Teacher.* You and your child are being contacted because you attend <insert school name>, a school that has been selected for this study due to the construction of a new and innovative school building.

The Green Building Literacy Survey

A survey will be used to understand the student experiences in the school building that are related to environmental issues. The purpose of this study is to identify the ways that the school architecture can support environmental education efforts in schools. Approximately 400 middle school children in five different schools will be part of this study.

On <date>, the survey will be integrated as an optional classroom activity for 6-8th grade students. We hope that you will be willing to allow your child to share his/her thoughts and experiences with us through this survey. The contents of the survey include questions about what students know and think about the environment, and also their attitude, knowledge and behaviors regarding greenness in the school building. Your child will have the opportunity to stop taking the survey at any time, and whether they participate or not, there is no impact on student grades. Students not participating in the survey will be engaged in homework activities. The survey is not expected to take the whole class period, thus your child will join the classroom activity when he/she has finished the survey. Students who take the survey will be entered into a raffle with a chance to win a $15 gift certificate to Barnes & Noble bookstore.

While your child may not directly benefit from participating in our study, we hope that this study will contribute to the improvement of environmental education efforts in your school community.

How will the information be used?

The researcher plans to publish the results of this dissertation study, but will not include any information that would identify you, your child or any other family member. To keep this information safe, all study data will be kept in a file and on a computer that is password-protected. To protect confidentiality, your child's real name and the names of any family members will not be used in any written copy of the discussion. For example, a report of the study results will be provided to <insert school name> administration; however, students will not be identified by name in this report.

The researcher will return to <schoo> in early 2012 to conduct a second survey. Thus, the data from your child will be kept for 2 years while the current project is active. After 2 years, your child's name will be removed from the file, and the remaining data will be kept for future green building research.

There are some reasons why people other than the researchers may need to see information your child provided as part of the study. This includes organizations responsible for making sure that the research is done safely and properly, including the University of Michigan.

Further Questions?

If you have questions about this research, including questions about the survey or the gift certificate raffle, you can contact Laura Smith, Ph.D. Candidate, University of Michigan, Department of Architecture and Urban Planning, 2223C Art + Architecture Building, Ann Arbor, MI 48104, (312)399-3918, laurbria@umich.edu.

If you have questions about your child's rights as a research participant, or wish to obtain information, ask questions or discuss any concerns about this study with someone other than the researcher, please contact the University of Michigan Health Sciences and Behavioral Sciences Institutional Review Board, 540 E Liberty St., Ste 202, Ann Arbor, MI 48104-2210, (734) 936-0933 **[or toll free, (866) 936-0933]**, irbhsbs@umich.edu.

Sincerely,
Laura Smith, PhD Candidate, University of Michigan
Department of Architecture and Urban Planning
2223C Art + Architecture Building, Ann Arbor. MI 48104

Parental Permission

By signing this document, you are agreeing to allow your child, -__________________________, to be part of the study entitled *The Green School as Third Teacher.* Your child's participation in this study is completely voluntary. If you allow your child to be part of the study, you may change your mind and withdraw your approval at any time. Your child may choose not to be part of the study, even if you agree, and may refuse to answer an interview question or stop participating at any time.

You will be given a copy of this document for your records and one copy will be kept with the study records. Be sure that the questions you have asked about the study have been answered and that you understand what your child will be asked to do. You may contact the researcher if you think of a question later.

I give my permission for my child to participate in this study.

_______________________________________ ______________________

Signature Date

Survey Student Assent Form

Green Building Survey Acceptance

I am interested in knowing more about what you know, think and do in your school building that relates to care for the environment. You will be given a survey in this class period. It is okay for you not to answer some of the questions or to say that you don't want to answer any more questions. If you are willing to take this survey, please print and sign your name below.

Participant (PRINT)

Participant Signature (and DATE)

Appendix C: Photography Project Consent Forms

Photovoice Project Parental Consent Form

Dear Parents,

Laura Smith, PhD candidate at the University of Michigan, College of Architecture and Urban Planning, invites your child to participate in a research study entitled *The Green School as Third Teacher.* You and your child are being contacted because you attend Redding School of the Arts (RSA), a school that has been selected for this study due to the construction of a new and innovative school building.

A photo project and interview will be used to understand the student experiences in the school building that are related to environmental issues. The purpose of this study is to identify the ways that the school architecture can support informal environmental education. This study will take place from May 2-6, 2011 at RSA as an alternative activity during Physical Education. Research activities will occur again in the 2011-12 school year.

What will happen if my child participates?

If your child is involved in the study, he/she will take part in a participatory photography project with other youth. This small group of middle school students will learn: (1) how to take photographs and analyze their content, and (2) how to mount photographs for display. Over the course of the project's four days, your child will take pictures of what "environmental sustainability" means to him/her in this school community, develop captions for the photos, and discuss them with the group. Whether participating in the activity or not, there will be no impact to student grades for involvement in this project. Participating students will receive a water bottle and bookmark as gratitude for their participation.

After the photo exercise is finished, the researcher will conduct brief interviews with students who agree to an interview. Your child could be interviewed about topics such as previous experience with environmental issues, attitudes about the school building, and knowledge about particular school building features. The interview is expected to take 20 minutes, and will be audiotaped. Agreeing to the interview and audio taping is not required for your child to be part of the study.

While your child may not directly benefit from participating in our study, we hope that this study will contribute to the improvement of environmental education efforts in your school community.

How will the information be used?

The researcher plans to publish the results of this study, but will not include any information that would identify you, your child or any other family member. To keep this information safe, the audiotape of your child's interview will be placed in a locked file cabinet until a written word-for-word copy of the discussion has been created. As soon as this process is complete, the tapes will be destroyed. The researchers will enter study data on a computer that is password-protected. To protect confidentiality, your child's real name and the names of any family members will not be used in the written copy of the discussion. The photographs taken by students may be included in the dissertation , future publications, and could potentially be put on display at the school; however, no photos of identifiable individuals will be used for these purposes.

The researcher will return to RSA in the academic year 2011-12 to conduct a second Photovoice project in the new building. Thus, the data from your child will be kept for 2 years while the current project is active. After 2 years, your child's name will be removed from the file, and the remaining data will be kept for future green building research.

There are some reasons why people other than the researchers may need to see information your child provided as part of the study. This includes organizations responsible for making sure that the research is done safely and properly, including the University of Michigan. Additionally, a report of the study results will be provided to RSA administration; however, students will not be identified by name in this report.

Further Questions?

If you have questions about this research, including questions about process logistics or about your child's token gifts for participating, you can contact Laura Smith, Ph.D. Candidate, University of Michigan, Department of Architecture and Urban Planning, 2223C Art + Architecture Building, Ann Arbor, MI 48104, (312)399-3918, laurbria@umich.edu.

If you have questions about your child's rights as a research participant, or wish to obtain information, ask questions or discuss any concerns about this study with someone other than the researcher, please contact the University of Michigan Health Sciences and Behavioral Sciences Institutional Review Board, 540 E Liberty St., Ste 202, Ann Arbor, MI 48104-2210, (734) 936-0933 **[or toll free, (866) 936-0933]**, irbhsbs@umich.edu.

Sincerely,
Laura Smith, PhD Candidate, University of Michigan
Department of Architecture and Urban Planning
2223C Art + Architecture Building, Ann Arbor, MI 48104

Parental Permission

By signing this document, you are agreeing to allow your child, -_______________________, to be part of the study entitled *The Green School as Third Teacher*. Your child's participation in this study is completely voluntary. If you allow your child to be part of the study, you may change your mind and withdraw your approval at any time. Your child may choose not to be part of the study, even if you agree, and may refuse to answer an interview question or stop participating at any time.

You will be given a copy of this document for your records and one copy will be kept with the study records. Be sure that the questions you have asked about the study have been answered and that you understand what your child will be asked to do. You may contact the researcher if you think of a question later.

I give my permission for my child to participate in this study.

_______________________________________ ______________________

Signature Date

I give my permission for my child to be interviewed.

____

Initials

I give my permission for the interview with my child to be audiotaped.

____

Initials

Photovoice Project Student Acceptance Form

Participant Name____

Phone Number:____

Email Address:____

This Photovoice project is a research activity in which participants will be contributing a voice to school community issues through the use of photography. Participants will work around the theme of environmental sustainability, and the full participation of all participants will be valuable to the completion of the project. <u>However, even if you sign this form, know that it is ok for you to stop the project at any time</u>. Your participation is completely voluntary, and will have no effect on your grades. You do not need to be in photos taken by your peers unless you want to be. If you participate in this project until the end, you will receive a water bottle and bookmark as a thank you.

After taking photographs, the researcher would like to interview you about the photos you took. Additionally, these interviews will be audio taped. If you do not wish to be interviewed or audio recorded, you can still take part the Photovoice Project.

We ask that you be able to adhere to the guidelines below.

- You will attend the group meetings.
- You will respect other participants' work.
- You will complete the individual photo assignment.
- You will allow the 6 photos and captions of your choosing to be displayed with other participants' work in publication or in a display in your school building.

I agree to be part of this study ______________________________________

Photovoice Participant Signature (and DATE)

I agree to be interviewed as part of this study ____________

Initials

I agree to be audio taped as part of this study ____________

Initials

Thank you for sharing your time and your voice!

Student Photo Release Form

TO WHOM IT MAY CONCERN:

I hereby grant full permission to Laura Smith, to use, reproduce, publish, distribute, or exhibit my photograph for official purposes, such as information, training, education, and communication.

Without limitation as to time, I hereby waive all rights for compensation in connection with the use of my photograph or in connection with the material in which it will appear, in whole or edited form, so long as the Laura Smith uses the material only for official purposes, such as information, training, education, and health communication.

Note: If the person is under the age of 18, a parent or guardian must sign this consent form.

____

Print name here

____________________________	____________________________________
Signature	Signature of parent or guardian (if necessary)
____________________________	____________________________________
Address	Address
____________________________	____________________________________
Date	Date

Appendix D: Survey Category Development

To develop final categories for Green Building Literacy Survey (GBLS) questions, the survey questions were first subject to a series of factor and reliability analyses. For the factor analyses, Principle Axis Factoring was the extraction method with Varimax rotation. Cronbach's Alpha values were used for the reliability analyses. Questions were grouped into a priori categories (based on conceptualizations discussed in Chapters 3 and 4), and then each group of questions underwent Principle Axis Factoring, where items with factor loadings <0.4 were removed[37] and no double loadings occurred. Thus, the survey items in Table D-1 are those that loaded on the same factor with loadings greater than or equal to 0.4. Reliability analyses were then used with the remaining items in the group to test the internal consistency of each group. As Table D-1 shows, all groups are within an acceptable range (near or above 0.7) with the Cronbach's Alpha to proceed with analyses. While 0.7 is typically regarded as the lower limit for reliability analyses, an alpha of 0.6 and above is acceptable for exploratory studies (Hair, Anderson, Tatham, & Black, 1998), which is certainly the case in terms of studying green building literacy. There were numerous survey questions that were dropped at this stage of the analysis due to low factor loadings. Within the environmentally responsible behavior (ERB) category, the scale items that measured transit and lighting behaviors were not strong enough to include in the final category. Transit questions asked about how frequently students arrive at school via alternative modes of transit (walking/biking or bus/carpool). As noted previously, all five schools are in suburban locations where car transit is likely the most convenient method. Additionally, transit choices likely reflect choices made by parents rather than the students themselves, which may explain why these scale items do not play a significant role in this grouping of items. Also within the ERB category, there were two questions measuring behavior turning off lights at home and school. This question was not maintained for home behaviors, but just barely made the cut-off for inclusion in School behaviors.

[37] Questions that had factor loadings that could be rounded up to 0.4 were maintained.

Table D-1. Green Building Literacy Survey categories

Category Name and Survey Items	No. Items	Alpha	Mean	(SD)
Green Building Knowledge Score	4*	**0.71**	**30.9**	(10.72)
Write-in Green Building Features				
Multiple Choice Questions				
Green Building Feature Photos Short Answer Questions				
Green Building Fill-in-the-Blank Questions				
Home Behaviors	4	**0.63**	**3.12**	(0.84)
General ERA at home				
Talk with parents about environmental problems				
Recycle at home				
Compost at home				
School Behaviors	6	**0.71**	**3.11**	(0.79)
General ERA at school				
Help others at school conduct ERB's				
Turn off lights at school				
Recycle at school				
Compost at school				
Pick up litter on school grounds				
Behavioral Willingness	4	**0.67**	**3.68**	(0.86)
Less water when brushing teach				
Less water when bathing				
Walk more to reduce air pollution				
Use dimmer light bulbs				
Supportive Environment	5	**0.84**	**3.00**	(0.94)
ERA opportunities at school				
Building helps me learn				
Building helps me act				
Teachers help me act				
Peers help me act				
Environmental Sensitivity (ES)	4	**0.66**	**3.03**	(0.75)
My Environmental Sensitivity				
My Family's Environmental Sensitivity				
Watch programs or read about nature/environment				
Teacher or youth leader role model for ES				
Environmental Education (EE) Opportunities	4	**0.67**	**2.55**	(0.88)
Environmental education classroom activities				
Environmental education out-of-class activities				
Green building classroom activities				
Green building out-of-class activities				
Environmental Conditions	3	**0.61**	**3.58**	(0.88)
Satisfaction with Lighting in School Building				
General Satisfaction with school building				
Connected to Nature inside school building				

*The Green Building Knowledge Score is comprised of 30 test questions grouped into four sub-categories. With the exception of this knowledge category, all other categories included survey questions measured on a 5-point scale, where 1=low and 5 =high.

Interestingly, numerous survey questions in the categories of behavioral willingness and environmental conditions were dropped from the ultimate groupings due to reversed question wording on the survey instrument (*e.g.*, “I am willing” versus “I am **not** willing”). Anecdotally, numerous middle school teachers noted that students were confused by the double negatives in the willingness section. Therefore, some of this student confusion could have led to unreliable measures from survey items that were worded negatively. The questions were reverse coded to move in the same direction as the positively worded questions. However, in factor analyses, these negative questions were clearly loading on separate factors. They have thus been dropped from analysis moving forward.

Green Building Knowledge Test Preparation for Analysis

The green building knowledge test (Parts I and II of the GBLS) required a different set of data checks compared to likert-style survey questions. The test had four sections including write-in, multiple choice, photo identification, and fill-in-the-blank questions that were summed together to measure Green building knowledge (GBK). Prior to summation, select Classical Test Theory procedures were used to determine knowledge test items to keep/omit (Crocker & Algina, 2008). The statistical procedures for used for knowledge test questions are reported in Table D-2 and include:

- **Percentages:** The first trend to observe in knowledge questions is the frequency of correct versus incorrect answers provided by students. In this study, the following criterion were used: a question is too easy if >80% of students answer correctly, and too hard if <20% answer incorrectly. All questions but one (the “sun” multiple choice question) fell into this range.[38]

[38] Note that some multi-part questions were combined. For example, in the photo identification exercise students easily identified the name of the feature (*e.g.*, solar panel) but had more difficulty identifying the environmental benefit (*e.g.*, reducing the use of fossil fuel energy sources). In the example given, 94% of students named the solar panel, but only 24% received perfect points for identifying the benefits. If we average these two numbers, the resultant percentage falls within the acceptable range for keeping both questions.

Table D-2. Green building knowledge test item-by-item analysis

	% Correct	% Incorrect	Correlation w/GBK	Relia-bility
Feature Write-in				**0.82**
Feature 1	**37.3**	8.8	0.44	
Feature 2	**36.3**	14	0.53	
Feature 3	**28**	28.6	0.54	
Feature 4	18.6	48.9	0.55	
Multiple Choice				**0.38**
Stormwater	**76.9**	11.8	0.23	
RenewableEnergy	**76.4**	14.8	0.29	
AirQuality	**62.4**	33.8	0.30	
NativePlant	**37.1**	40.6	0.40	
Sun	**9.5**	60.7	0.14	
Compost	**68.7**	20.8	0.30	
RoofMaterial	**72.4**	12.8	0.27	
Photo ID				**0.67**
Bike Name	**89.7**	10.0	0.30	
Bike Benefit	**71.6**	19.8	0.39	
Facuet Name	**62.9**	35.1	0.45	
Faucet Benefit	**52.4**	39.1	0.48	
Solar Name	**94.2**	5.3	0.36	
Solar Benefit	**24.5**	24.3	0.49	
Wind Name	**84.5**	10.3	0.40	
Wind Benefit	**23.3**	24.1	0.52	
Fill-in				**0.79**
Bldg Material	**31.9**	15.3	0.59	
Local Material	**65**	33.6	0.59	
Kwh	**31.8**	52.1	0.40	
Garden	**50.4**	33.1	0.53	
Reduce Water A	**26.3**	43.4	0.49	
Reduce Water B	**9.3**	61.4	0.45	
Plants Absorb	**48.6**	40.4	0.52	
Problem of	**49.9**	47.6	0.54	
Windows Impact	**53.9**	37.6	0.65	
Windows because	**51.1**	40.9	0.66	

- **Correlations:** The next trend to examine is whether or not scores for each question correlated with the overall Green building knowledge (GBK) scores. The result is a series of point biseral correlation coefficients, where a coefficient greater than 0.20 is generally acceptable (Crocker & Algina, 2008, pp. 317-327). All knowledge questions except one (again the "sun" multiple choice question) had a correlation value greater than 0.20.

- **Factor analyses:** A 30-item analysis shows that the whole group reliably measures GBK with an alpha of 0.83; however, reliability analyses are sensitive to the number of items, and the high number of items makes the use of reliability analyses questionable here. Factor analysis was conducted on the knowledge items, but the resultant categories failed to make theoretical sense. In Table B-2, the reliability analyses for each question type (multiple choice, photo identification, etc.) are shown, indicating that if students performed a certain way on one question type (e.g., a fill-in-the blank question) they tended to perform the same way on all questions of that type. Multiple choice questions has a low internal consistency (alpha=0.38), meaning that content understanding likely drove performance on this section versus academic abilities, such as the ability to create acceptable written responses (a requirement for all sections except the multiple choice section).

Based on these analyses, there was only one question that was eliminated from the test (highlighted in gray in Table D-2). That question was the "sun" multiple choice question that asked students about the appropriate direction to face solar panels on a building in the U.S. This question was eliminated based on a low correct response rate (only 9.5% of students answered correctly) and the low correlation with GBK (Pearson correlation value=0.14).

The final step in the process was to create a GBK score for each student. After the process of question elimination (explained above) was complete, the scores for each of the four sections were summed into one total GBK score that was then used in the analysis.

Appendix E: Photography Project Data Analyses

There were numerous types of data that resulted from the photography project that was part of the data collection effort in this study. Those data types are: 1) a complete set of photos taken by students on campus, 2) a photo board with edited down images where each image has a 1-2 sentence written description, and 3) interview data for a subset of students in the project. For the analyses included here, only data type #2 was used, though the researcher was able to begin analysis with a mind toward the full collection of experiences with students.

The photography analyses presented here engaged an approach to the data that was more quantitative than qualitative in that the final data representations were numeric. However, the analytical process involved a series of data coding that incorporated student photographs and writing to assign categories to each photo, and thus relied on researcher interpretation of the data.

For the most part, the task of coding was a straightforward one, especially where student photographs and text aligned. Figure E-1 shows two examples of Arts School post-move student photos that were easily categorized based on a clear match between photo content and what the student wrote. Other photographs were more difficult to categorize quickly, and required researcher interpretation of the written text, and sometimes researcher knowledge of the school building, to categorize the photograph. Figure E-2 shows two examples of photos that exemplify instances where categorization was slightly more difficult. The photograph by Student 11 is a good example of researcher categorizing based not just on the photo and text, but also having seen the way these reusable cans are used during the site visit to this school. Finally, there were photographs on student photo boards that could not be placed into categories, typically due to vague photo content and written descriptions. Figure E-3 shows two examples of photos that eluded categorization.

"I chose this picture because some ride bikes instead of using cars witch saves the environment" (Student 10)

"This picture shows our open hallways which cut down the cost of lighting. I also shows the corner of the art room where children create eco-friendly art!" (Student 31)

Figure E-1. Easy to categorize photographs

"I took this picture because that even in the crack you have to pick up trash." (Student 18)

"This shows they reuse these cans." (Student 11)

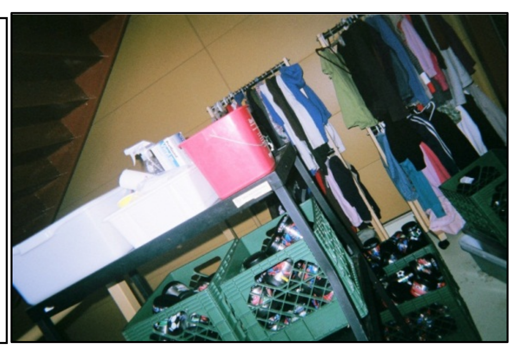

Figure E-2. Categorizing photographs by using written text

"I chose the photo because it is a good example of preserving items." (Student 30)	
"This structure made me look at the whole building more closely and I liked it. :D" (Student 15)	

Figure E-3. Photographs that could not be categorized

Appendix F: Study Limitations

The limitations in this study are those common in social science research projects of this scale and scope and in school settings where barriers to access abound. The study limitations are summarized below in two sections. The first section discusses limitations for the survey research, and the second for the photography project.

Survey Research Limitations

The first limitation to consider is the sampling bias that resulted from the way students were recruited into the study. The schools in this study were carefully selected for their campus buildings having or not having the architectural intent to be a teaching tool for environmental issues. Once the Teaching Green School Buildings in three different U.S. cities were selected and each agreed to participate, comparison schools were sought in each geographic location. Letters were sent to three to six potential comparison schools in each region. However, comparison schools ended up being difficult to recruit, and as a consequence, the researcher decided to include two comparison schools that agreed to participate despite differences between schools that potentially challenge comparison (these differences are discussed at length in Chapter 5). Therefore, there is neither a random sample of schools included in this study nor an ideal set of comparison schools. Likewise, there may be some bias in the sample of students within each school who participated in the study. The survey instrument was administered during regular class time for all middle school students in each school. However, the requirement to obtain parental consent meant that only the students who returned consent forms could be included in the analyses. Of all the consent forms returned, only 1 out of 400 returned with a parent denying permission for their child to participate. The reasons for not returning consent forms is unknown, though it is assumed that many students simply forgot or did not prioritize this task. Students in all schools were offered the chance to win a bookstore gift certificate for returning the consent form. Thus, students who did return forms may have had mixed motivations – from wanting to please teachers to having a chance to win the lottery.

The timing of the survey administration across schools presents several potential limitations. The second concern is that data was collected with the Arts School ten days before the end of their school year. The researcher noticed end-of-year anticipation amongst students during the site visit, and the teachers at the school confirmed that students were losing focus as each day moved students closer to summer vacation. Art School student performance on the knowledge test may have been negatively impacted by the timing of the data collection.

Two other potential study limitations relate to the way that outcome variables were measured. First, the outcome variable of Green building knowledge was quantified based on a 29-item test that included both quantitative and qualitative questions. As discussed in Chapter 4, the qualitative test questions presented a challenge for conversion into numeric codes. Without the resources to involve a second rater, the principal investigator devised a method by which to assign numeric codes that involved an iterative process and being blind as to the survey participant. A second potential limitation in the outcome variables is that School behaviors were measured with self-reported data versus direct observation.

A final concern is that the fairly low number of students in the study (n = 399) resulted in moderate to low statistical power in the analytical models presented. Running the same regression models with more statistical power may identify significant predictors that did not emerge in the current study. In particular, variables deemed borderline predictors in this study may shift into significance in a study with more observations.

Photography Documentation Research Limitations

The photography project was not as central to the analyses as was the GBLS. Yet, it is worth noting several of the key limitations of the photography data collection method.

A first concern is that the sample of students in the photography project is self-selected. There are several potential biases. The first is that students interested in the visual arts or photography specifically were likely to join given the nature of the project. The same could be said for students already interested in sustainability. Another circumstance is that the project was scheduled into the school day during physical education. It is possible that students who don't care for gym chose to join the project.

Another concern is that it was difficult to manage the project given an average of 30 students and the vibrant sociality of middle school students. Despite the researcher's emphasis on doing one's own work, students had a tendency to explore their campus taking pictures in small groups. Thus, there was certainly a contamination of ideas among students in a way impossible to determine where an idea first started (*e.g.*, the idea to photograph a class pet, which then emerges in six different students' photo sets). Because of this phenomenon, the researcher enacted several strict rules on the last day of the project, including assigning seats to split friends and a reminder that this is a scientific process where *individual* student viewpoints are sought. Measures such as these lend to photo boards that were uniquely assembled by each student, though some residual peer influence may have still guided student choices.

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