Buildings as Teaching Tools:

A Case Study Analysis to Determine Best Practices that Teach Environmental Sustainability

Craig Schiller,

Vivian Loftness,
Azizan Aziz,
Erica Cochran

Carnegie Mellon University

Table of Contents

List of Tables

List of Figures

List of Appendixes

(Both Appendixes are attached separately in the Adobe Portfolio)

Acknowledgments

I would like to thank my advisors Vivian Loftness, Azizan Aziz, and Erica Cochran for the continued input and advice throughout my research. I would also like to thank Stephanie Barr for her contributions to the analysis of my case studies, her holistic research on green schools, and her collaboration with the Buildings that Teach Framework. A special thanks to Omar Clennon who helped me finalize the design of my Design Cards.

Finally, I would like to thank the building operators, designers, and educators who took the time to have an interview with me about their buildings. In particular, Dan Hellmuth, Sally Selby, Dr. Rocky Rowhedder, Mary Tod Winchester, Indigo Raffell, Dr. Alexandra von Meier, Dr. Lawrence Carlson, and Dr. Bill Wiecking were instrumental in my data collection process and the creation of my framework.

Cover page photo credits (from top to bottom):
HPA Energy Lab, Hawaiian Preparatory Academy: Hawaiian Preparatory Academy
Intelligent Workplace, Carnegie Mellon University: Craig Schiller
CCI Center, Conservation Consultants, Inc: Craig Schiller
Adam Joseph Lewis Center, Oberlin College: Craig Schiller

Executive Summary

This research is intended to help meet the growing demand for green schools that foster sustainability education by aggregating and cross-analyzing specific pedagogical strategies from buildings currently being used as teaching tools for sustainability. Over 350 specific teaching strategies were collected from 15 of the world's highest performing academic buildings using Anne Taylor's theoretical framework for linking architecture with sustainability education. These strategies were collected through interviews, literature reviews, web content, course curriculums, photographs, and site visits. This research also analyzed current educational theory that can be extended to the physical built environment, which was used to qualitatively analyze each pedagogical strategy.

To specifically focus the data collection process, 36 of the most important sustainability issues related to the built environment were also compiled for this research and used to organize the teaching strategies. Additionally, four thematic categories (*Multisensory, Outreach, Curricular, and Research*) were created to organize the strategies based on their different educational goal, method of knowledge transfer, and intended audience. Finally, the 368 teaching strategies were cross-analyzed to determine the most common overall pedagogical strategies currently used.

Educators, designers, and facility planners should use the information presented in this paper as a foundation for innovation in educational planning and design innovation. Also, the most common teaching strategies should be considered a benchmark for future buildings that teach. This list is not exhaustive, however, as the potential strategies for utilizing a building as a teaching tool is likely limitless. Therefore, all of the collected teaching strategies (over 350, attached in the Adobe Portfolio) are presented as individual design cards to display the pedagogical possibilities of buildings that teach and to inspire innovating strategies in the future.

Section I – Research Overview

Place, Pedagogy, and Sustainability Education

"It is paradoxical that buildings on college and university campuses, places of intellect, characteristically show so little thought, imagination, sense of place, ecological awareness, and relation to any larger pedagogical intent."
~ David Orr

Consider that people spend an average of 90% of our time in buildings that are responsible for 40% of all carbon dioxide emissions and, in the United States, consume 70% of our electricity of our nation's electricity (Torcellini, et al. 2006). China alone is predicted to use enough raw materials to create 220 billion square feet of new building space over the next three decades while 27,000 species are becoming extinct per year from habitat destruction alone (Elewa 2008, Yudelson 2008). These numbers are the tip of the iceberg that indicates we are experiencing an unprecedented, and potentially irreversible, degradation of our environmental and human health. So what if we could design high performing buildings that will not only address these environmental issues but also act as pedagogical tools that teach us how to live more sustainably? Could these buildings change our attitudes about sustainability and the built environment in a way that could affect our lives as well as positively change our community?

After all, it is without question that we will be requiring every future generation to live in a world with increasing environmental concerns and limits. In order for future generations to thrive in this new world, they will need a deep understanding of our societies' energy, water, and material uses and how they are connected to human health as well as the health of our planet. What better place to start cultivating this understanding then within the physical school structure where students will spend more than fourteen thousands hours of their lives? This is undoubtedly enough time for the school's setting, physical appearance, and overall design to influence the students (Deal and Peterson 2009).

In 1994 David Orr coined the term "Architecture as Pedagogy" to describe this concept, specifically the social and environmental lessons we can learn *from* our buildings. Rocky Rowhedder expanded on this idea by stating that buildings have tremendous pedagogical power, and it is up to our academic institutions to transform **it** into teaching tools for sustainability (Rohwedder 1998). Rowhedder also argues that creating sustainable buildings allows an institution to demonstrate civic responsibility and convey an important message to the students, that the educators are investing in the their future (Rohwedder 2004). In fact, research suggests that modeling sustainability within the school itself is one of the most effective ways to teach students about sustainability (Higgs and McMillan 2006).

For many reasons green buildings have caught hold in the education market, changing the landscape of learning environments. Beyond the innate benefits – financial savings to the district from reduced energy consumption and lower rates of absenteeism due to increase indoor environmental quality (Kats 2006), green schools offer an exciting context for environmental education and sustainable behaviors (Schiller, et al. 2012). Imagine generations of children who have been educated in academic buildings the address and teach these important environmental concepts (Orr 1994, 133):

- Learning to power civilization by current sunlight
- Reducing the amount to of materials, water and land use per capita
- Growing food and fiber sustainably
- Disinviting the concept of waste
- Preserving biological diversity
- Restoring ecologies ruined in the past century
- Rethinking the political basis for modern society
- Developing economies that can be sustained within the limits of nature
- Distributing wealth fairly within and between generations

By designing high performing teaching tools that address these issues, we can provide students with a 3D textbook for innovative solutions to environmental problems; a physical context in which students can learn how to live sustainability and gain hands on experience with a healthier built environment (Barr 2011, Deal and Peterson 2009, Orr 1994, Orr 1997, Schiller, et al. 2012, Stephen, et al. 2008, Taylor 2009).

Research Perspective

Unfortunately, the majority of literatures regarding buildings that teach have focused on the design features, specific technologies, influence on green building practices, and the importance to student health and performance (Janda and Meier 2005, Orr 1994, Orr 1997, Rohwedder 2004, Stephen, Lay and McCowan 2008). While there has been a tremendous amount of research on the physical environment and educational theory, there has been a minimal amount of work analyzing how these two fields interact with each other and how they can be combined. Additionally, no known research has been conducted cross-analyzing the specific strategies utilized in current buildings that are being used as a teaching tool.

To address the current gaps in research, elements of educational science need to be surveyed for facets that can be extrapolated to the built environment. A framework is also needed to collect, analyze, and organize specific strategies and technologies buildings are using to teach. In doing so, these strategies can be used by designers and educators to develop buildings that teach in a more holistic manner as well as innovate new pedagogical strategies. This research attempts to begin the aggregation of these specific teaching strategies, focused within current education science, to improve future buildings' ability to teach sustainability.

Utilizing the physical environment as a teaching tool is captured in Anne Taylor's *context-content-learning process* model, the theoretical framework for this research. Taylor describes three crucial elements for connecting the built, natural, and cultural environment with education: the physical setting being used to teach (*context),* what is being taught (*content),* and the specific strategies the buildings use to teach (*learning process).* This framework guided the focus and methods for this study (Taylor 2009).

Purpose

The objective of this study was to collect pedagogical strategies used by current buildings that are being used as teaching tools as well as to determine the most common and best-case strategies. A cross sectional analysis of the leading buildings that teach was created to support the compilation and future widespread implementation of these strategies to maximize their educational potential.

Research Question

This study was framed by the following research questions:

- How does education science and theory be extrapolated to the built environment?
- How specifically can the built environment be used to teach concepts on environmental sustainability?
- Can common pedagogical strategies be collected and analyzed, and if so what are the most common teach ing strategies?
- How can the built environment be designed and integrated into curriculum to maximize its pedagogical intent?

Section II – Combining How We Learn with Sustainability Education and the Built Environment

Summary

In order to ensure the protection of our natural resources and improve human health it is important to foster a 'deep' understanding of sustainability within our students. This deep understanding is the overall goal of buildings that teach and can be defined by a student's ability to (Light and Cox 2001, 49):

- Relate ideas to previous knowledge and experiences
- Look for patterns and underlying principles
- Check evidence and relate it to conclusions
- Examine logic and argument cautiously and critically
- Become actively interested in sustainability content

Sustainability is not a static field where facts or formulas can simply be memorized and applied. It is an interdisciplinary and dynamic field that requires a breadth of knowledge to be creatively applied to ever changing problems. Unfortunately, there is a disconnect between people's interest in sustainability and how they view the built environment. While on the environmental studies faculty at Oberlin College, Kathryn Janda pointed out that "the general population tends to treat buildings as static objects rather than dynamic systems" (Timpson, et al. 2006, 23)A deeper understanding of sustainability needs to be promoted in order to change this mindset and promote a more sustainable built environment. In order to accomplish this, the following pedagogical concepts and strategies (highlighted in this section) should be used to integrate the built environment with pedagogical strategies to teach sustainability.

1. Holistically planning a building that teaches to accommodate all types of intelligences.
2. Integrate environment and project-based learning to maximize the use of the built environment as a 3D textbook.
3. Use specific education strategies that enhance knowledge transfer and foster a deeper understanding:
   a. Use of contrast cases
   b. Incorporating multiple examples and transfer potential
   c. Contribute to others
   d. Teach in multiple contexts
   e. Make results readily available

Multiple Intelligences

In 1993 Harvard professor and psychologist, Howard Gardner, created the theory of multiple intelligences (MI theory) to broaden our understanding human intelligences. Rather than the traditional view of a singular intelligence, or IQ, Gardner argues that individuals have at least eight distinct and basic intelligences: Linguistic, Logical-Mathematical, Spatial, Bodily-Kinesthetic, Musical, Interpersonal, Intrapersonal, and Naturalist. The following table was compiled from Thomas Armstrong's book *Multiple Intelligences in the Classroom* and summarizes the defining characteristics and teaching strategies for each of the different intelligences.

Table 1 Compiled summary of the MI Theory from *Multiple Intelligences in the Classroom*

Intelligence	Core Components	Students with this intelligence love....	Instructional Strategies	Example Teaching Activities
Linguistic	sensitivity to the sounds, structure, meanings, and functions of words and language	reading, writing, telling stories, playing word games	read about it, write about it, talk about it, listen to it	lectures, discussions, word games, storytelling, choral reading, journal writing
Logical-Mathematical	sensitivity to, and capacity to discern, logical or numerical patterns; ability to handle long chains of reasoning	experimenting, questioning, figuring out logical puzzles, calculating	quantify it, think critically about it, put it in a logical framework, experiment with it	brainteasers, problem solving, science experiments, mental calculation, number games, critical thinking
Spatial	capacity to perceive the visual-spatial world accurately and to perform transformations on one's initial perceptions	designing, drawing, visualizing, doodling	see it, draw it, visualize it, color it, mind-map it	visual presentations, art activities, imagination games, mind-mapping, metaphor, visualization
Bodily-Kinesthetic	ability to control one's body movements and to handle objects skillfully	dancing, running, jumping, building, touching, gesturing	build it, act it out, touch it, get a 'gut feeling, of it, dance it	hands-on learning, drama, dance, sports that teach, tactile activates, relaxation exercises
Musical	ability to produce and appreciate rhythm, pitch, and timbre; appreciation of the forms of musical expressiveness	singing, whistling, humming, tapping feet and hands, listening	sing it, rap it, listen to it	rhythmic learnings, rapping, using songs that teach
Interpersonal	capacity to discern and respond appropriately to the moods, temperaments, motivations, and desires of other people	leading, organizing, relating, manipulating, mediating, partying	teach it, collaborate on it, interact with respect to it	cooperative learning, peer tutoring, community involvement, social gatherings, simulation
Intrapersonal	access to one's own "feeling" life and the ability to discriminate among one's emotions; knowledge of one's own strengths and weaknesses	setting goals, meditating, dreaming, planning, reflecting	connect it to your personal life, make choices with regard to it, reflect on it	individualized instruction, independent study, options in course of study, self-esteem building
Naturalist	expertise in distinguishing among members of a species; recognizing the existence of other neighboring species; and carting out the relations, formally or informally, among several species	playing with pets, gardening, investigating nature, raising animals, caring for planet earth	connect it to living things and natural phenomena	nature study, ecological awareness, care of animals

The multiple intelligence theory acts as both a framework and reminder that buildings should be designed to accommodate different learning styles. The physical environment itself is a non-traditional teaching tool that cannot teach in the standard 'lecture' format. Therefore there is tremendous potential to integrate the different intelligence into the built environment's pedagogy both passively (through design) and actively (through occupant engagement). By doing so, buildings that teach will increase their pedagogical potential through greater knowledge transfer to a broader audience. The following table provides passive and active examples of how the built environment can utilize the multiple intelligence theory to teach sustainability.

Table 2 Example of sustainability and the built environment can be integrated into multiple intelligences

Intelligence	Passive Example: Building Design	Active Example: Instructional Activity (Armstrong 2009, 70)
Linguistic	Provide interpretive signage about building and its systems	Talk about basic sustainability principles and how they relate to the built environment
Logical-Mathematical	Collect and display building data	Develop a hypothesis for a new invention or system that would improve your school
Spatial	Expose building systems	Design and draw a sustainable building
Bodily-Kinesthetic	Include a variety of tactile experiences both inside and outside the building	Build the sustainable building you designed
Musical	Incorporate sound and music into the building's functions	Study a musician who sings about, or advocates, environmental issues
Interpersonal	Provide social and group work space	Form a discussion group to discuss what sustainability means to you
Intrapersonal	Provide private spaces for reflection and study	Develop a self-study program to learn about your favorite aspect of green buildings (e.g. rain water harvesting, or renewable energy generation)
Naturalist	Plant multiple native species on the grounds, green roof, or green wall	Study the science behind green roofs and green walls, and how they benefit the built environment

Environment and Project-Based Learning

One of the most important pedagogical strategies that promotes education through the built environment is project-based learning, or environment-based learning. The concept calls for students to get out of the textbooks and to use the physical environment around them in their learning. Project-based instruction is an educational model in which students study, apply, and analyze real world problems with real-world applications (Railsback 2002).

This approach is particularly important when it comes to the complex and interdisciplinary topic of sustainability because it allows abstract concepts to quickly become real through examples in their immediate surroundings. It also requires students to direct their own learning, an important criteria in sustainability education (Timpson, et al. 2006). To successfully integrate the built environment and sustainability education, project-based learning projects should have the following ten criteria (Barr 2012; Lieberman and Hoody 1998; 1 NAAEE & NEETF 2001; Railsback 2002, 7):

Table 3 Criteria to integrate project-based learning with the built environment

1. Student centered, student directed
2. Break down traditional boundaries between disciplines
3. Contain content meaningful to students; directly observable in their environment
4. Real-world problems
5. Hands-on investigation and problem solving
6. Adaptable to different learning styles and individual students
7. Sensitive to local culture and culturally appropriate
8. Specific goals related to curriculum and school, district, or state standards
9. Connections among academic, life, and work skills
10. Develop knowledge, understanding, and appreciation for the environment, community, and natural surroundings

The purpose of environment-based learning in this context is to develop environmentally conscious students (S. K. Barr 2011) and can help create “thoughtful community leaders and participants and people who care about the people, creatures, and places around them” (NAAEE & NEETF 2001, 3) Another benefit, which can be a very influential justification for wide scale implementation, is that project based-learning improves a students overall academic performance (Ernst and Monroe 2004; Lieberman and Hoody 1998).

A large-scale study of 40 schools found that 92% of students who participated in project-based learning programs, academically outperformed their traditional counterparts and 100% of the students had improved behavior and attendance. This study analyzed schools that used Environment as the Integrating Context for learning (EIC) curriculums defined as “Using the school’s surroundings and community....as a framework for interdisciplinary, collaborative, student-centered, hands-on, and engaged learning” (Lieberman and Hoody 1998, 1). The following chart summarizes the study’s results from comprehensive standardized tests scores, GPAs, student attendance, and student behavior and attitude measures (Lieberman and Hoody 1998, 3):

Table 4 Improvement in students using environment-based learning

Assessment Area	Assessments Indicating EIC Students Perform Better than Traditional Students
Comprehensive Assessment	100%
Language Arts	100%
Math	71%
Science	75%
Social Studies	100%
Improved Student Behavior	100%
Improved Attendance	100%
Improved Attitudes	100%

Specific Pedagogical Strategies for Buildings that Teach

Contrast Cases

A green school’s design and features are only considered green when they are compared to a traditional school. It is the comparison and contrast that highlights the beneficial gains of an alternative design. As a result, it is important for buildings that teach to incorporate ‘contrasting cases’ into their pedagogy to distinguish what they are doing differently. Using contrasting, non-green examples of design features, technologies, or systems can increase occupants’ understanding of green alternatives by highlighting their advantages.

“Understanding when, where, and why to use new knowledge can be enhanced through the use of ‘contrasting cases’ a concept from the field of perceptual learning. Appropriately arranged contrasts can help people notice new features that previously escape their attention and learn which features are relevant or irrelevant to a particular concept”
~National Research Council 2000, 60

An example of using a contrasting case to increase knowledge about storm water management, is to design two different types of pavers in a parking lot. The majority of the lot should be a porous material to minimize runoff. However, at least one parking space should be constructed of traditional non-porous asphalt so students can compare the permeability and storm water advantages of the two material types. This will slightly decrease the parking lots ability absorb water, but will increase the knowledge students and visitors will gain about storm water management (National Research Council 2000; Timpson, et al. 2006).

Multiple Examples and Transfer Implications

Multiple studies have jointly concluded that the use of multiple examples enhances knowledge retention and transfer. Additionally, encouraging reflection and providing opportunities to apply new knowledge in additional contexts will also increase understanding (Anderson, Reder and Simon 1996). This is relevant for buildings that teach in two ways. First, the use of multiple examples can be embedded into the physical environment by designing multiple building systems or elements that have a similar function. Secondly, educational lessons from a green building or its individual systems can be extrapolated and transferred to nearly every academic subject, particularly in a k-12 environment (Wieking 2011).

The use of multiple example can be applied to the design of a building that teaches by incorporating multiple and redundant systems or technologies. For instance, a building could contain several different types of glazing, rather than uniform glazing. Additionally, a building could have multiple types of photovoltaic panels, or the same type from multiple manufactures. In both examples, a building increases its pedagogy by using 'multiple examples' of the same technology and demonstrating different solutions to the same problem. This is different than using 'contrasting cases' because 'multiple examples' have a similar function. It is the subtle differences in how they achieve their function that increase knowledge. (National Research Council 2000)

Providing students with the opportunity to transfer knowledge into new settings, and helping them reflect on the potential implications of that transfer, enhances learning (National Research Council 2000). An excellent example of how knowledge from a green building can be extracted and transferred to solve new problems is the School of the Future Competition from the Council of Educational Facility Planers International (CEFPI). In this design contest, students are asked to transfer what they have learned about green schools, into their own school they design themselves. This provides the students with an opportunity to reflect on their green school knowledge and apply it to solve a new problem: to design a new school, which will "enhance learning, conserves resources, be environmentally responsive and engage the surrounding community. (CEFPI 2012)"

Contributing to Others

A connection to other students and community members can be particularly motivating for learners of all ages. Projects that provide a feeling of positive contribution, or that have strong social consequences, will motivate students to become more engaged and passionate about what they are learning, which increases student academic success (Brewster and Fager 2000). Motivation increases when students can easily see the impact of what they are learning on their own school or local community, which they can relate to more than global issues (Timpson, et al. 2006). There are numerous curricular examples of projects and activities that are traditionally used inside the classroom to encourage contributions to others. These include group work, students tutoring one another, and students giving presentations to outside audiences (National Research Council 2000).

There are also some non-traditional strategies that empower students through community engagement and contributions within their school. These strategies include students helping to maintain the school building and grounds, such as sorting recyclables and sustaining a garden (Wuerth 2012). Additionally, students can actively engage their community by giving tours of their school. In both examples, the students gain a sense of pride and ownership of their building because they can experience first hand the impact their actions have (Timpson, et al. 2006; Wieking 2011).-

Teaching in Multiple Contexts

When subjects and specific concepts are taught in multiple contexts, which demonstrate the breadth of application, students are more likely to abstract relevant concepts and develop a more holistic understanding. This is particularly important to sustainability, which requires a holistic understanding of the interconnected nature between our actions and their consequences. By including examples from multiple contexts, learners are more likely to extract general principles, which can be used to solve new 'what-if' problems. Using multiple contexts can also enhance problem solving by asking learners to create solutions to a class of related problems, rather than a single problem(National Research Council 2000).

The subject of solar radiation is a good example of how teaching in multiple contexts can be integrated into the built environment. In this simple example, a school can physically teach about solar radiation using a photovoltaic panel, a solar water heater, and a solar oven. Students can learn how solar radiation can be converted into electrons to create electricity; how a fluid can absorb and convert it to heat for future use; and how it can be collected to cook food. By combining the general principles from these three uses, students will enhance their learning by gaining a more holistic understanding of solar radiation and its potential in the built environment (National Research Council 2000).

Teaching in multiple contexts can also extend to multiple subject matters. In fact, there is an abundance of opportunities in the built environment for this kind of knowledge transfer because many green building systems can be integrated into a variety of subject areas. For example, a photovoltaic array can be studied in a physics course while data from the array can be used in business or statistics course. By applying knowledge about the photovoltaic array in multiple contexts, students will gain a greater understanding of how the photovoltaic array functions and its benefits.

Make Results Readily Available

The connection between building systems, their energy or material life-cycles, and environmental impact would be lost unless the buildings provided feedback of its performance or the performance of individual systems. Unfortunately, buildings are commonly viewed as static objects whose environmental impacts are rarely understood, a trend that buildings that teach aim to reverse. If students and building occupants can't see or interact with their building's performance, how can they understand the environmental impact of their actions? Receiving feedback or experiencing change is a driving motivational factor for modifying behavior.

Buildings that teach should make changes in performance and operations easily visible, so occupants can see how the building functions and how their behavior can effect performance. Pliny Fisk III, a green builder, advocate and researcher, wrote, "buildings might be designed to *mimic* or *illuminate* these life-cycle events…causing humans to experience resources flows and cycles, understand resource dependencies…and adapt behavior accordingly" (Fisk III 2008, 308). He continues to argue that buildings should be designed to increase occupant's awareness to the surrounding resources by providing rapid feedback and information.

An excellent example of providing feedback is a building that displays real-time data of resource consumption and production. Oberlin College experimented with this idea by installing sensors in campus dormitories to monitor resource energy and water consumption. Researchers found that students who could easily see how their actions affected the building's energy performance reduced their energy consumption 32-55% during a dorm-dorm energy competition (Petersen, et al. 2007). In a separate study the same research team concluded that "real-time feedback on the environmental performance of campus buildings can and has been used as a mechanism for engaging, educating, motivating and empowering the student body" (Petersen, et al. 2007, 1). In this case, the feedback was in the form of real-time data displayed on websites and informational kiosks. However, the specific teaching strategy is quite simple and extends far beyond high-tech data sensors: buildings that provide feedback will influence occupant behavior.

Section III – The Research Framework

To uniformly evaluate each case study, a process was developed aligning with Anne Taylor's *context-content-learning process* framework. Taylor described three crucial elements for connecting the built, natural, and cultural environment with education: the physical setting being where education occurs (*context),* what is being taught (*content),* and the specific strategies the building uses to teach (*learning process).* In order for a consistent analysis of each case study, a spreadsheet was created for each building that contained analysis prompts for the three aspects of the framework.

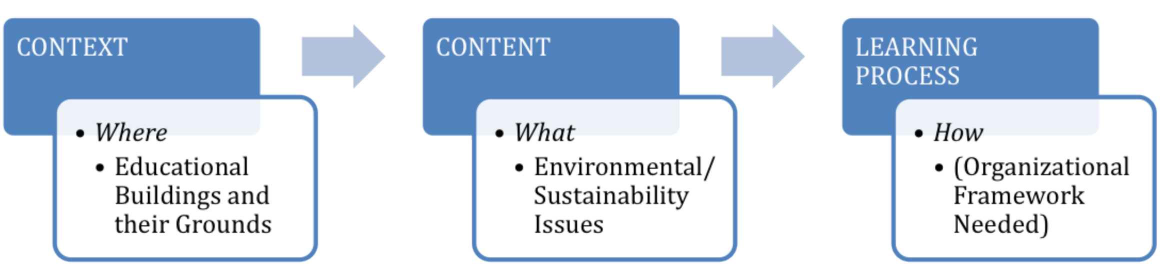

Figure 1 Preliminary flowchart of the theoretical framework

Context

Understanding the physical design attributes of the building is essential to understanding the learning context. For each case study, detailed attributes were collected including design strategies, specific technologies, site details, and operational practices. This information organized into the LEED Rating System's categories, allowing data to be correlated with *content* topics.

Content

To focus this research on sustainability issues and education, a catalog was created of 36 sustainability topics relating to the built environment(Table 2). These issues were selected from current literature, LEED criteria, and in collaboration with the Center for Building Performance and Diagnostics. This catalogue focused both the type of teaching strategies collected to those specifically relating to sustainability and the built environment. The catalog is organized to align with the LEED Rating System categories for audience familiarity and to directly correlate to *context*. Though these categories were connected to teaching strategies and environmental issues within a larger research project, this paper specifically analyzes the frequency of teaching strategies independently from the *content* taught.

Table 5 Catalog of the most important sustainability topics relating to the built environment

Site	Water	Energy		Materials	Indoor Environmental Quality
Ecosystem Site Selection	Conservation	Total Performance		Conservation	Natural Ventilation
Walkability	Storm Water	Conservation	Enclosure	Regional Materials	Low Material Outgassing
			HVAC		
			Lighting		
			Process Loads		
Native Landscaping	Grey Water	Passive Systems	Daylighting	Renewable Materials	Limit Indoor Chemicals
			Solar Heating		
			Natural Ventilation		
			Cooling		
Agriculture	Black Water	Renewable Energy		Re-Use, Recycled Content & Recyclability	Occupant Comfort
Outdoor Classroom	Zero Net Water	Energy Cascades		Operational Recycling	Views & Daylight
Ecosystem Restoration		Environmental Footprint		Cradle to Cradle	
		Zero Net Energy		Zero Net Waste	

Learning Process

Development of the MOCR Framework

As seen in Figure 1, early on in the data collection process it became clear that an organizational framework was needed to provide structure and manage the large volume of teaching strategies. Moreover, preliminary background research and case study analysis revealed several commonly used pedagogical themes and approaches. Therefore, four thematic categories (*Multisensory, Outreach, Curricular, and Research*) were created based on different educational goals, method of knowledge transfer, and intended audience of each strategy. These categories, called the MOCR Framework and are summarized in Figure 2, were validated through literature reviews, interviews, and external reviews by educators, building operators, architects, and sustainability and building professionals including:

- Vivian Loftness, Architect and Building Science Professor at Carnegie Mellon University
- Azizan Aziz, Architect and Building Science Professor at Carnegie Mellon University
- Erica Cochran, Architect and Building Science Professor at Carnegie Mellon University
- Daniel Hellmuth, Principle Architect at Hellmuth & Bicknese Architecture
- Rocky Rowhedder, Environmental Studies Professor at Sonoma State University
- Sally Selby, Principle at Sidwell Friends School
- Mary Tod Winchester, Vice President of Administration at the Chesapeake Bay Foundation
- Indigo Raffel, Environmental Educator at the Conservation Center Inc.
- Stephanie Barr, Green Schools Specialist at the Institute for the Built Environment

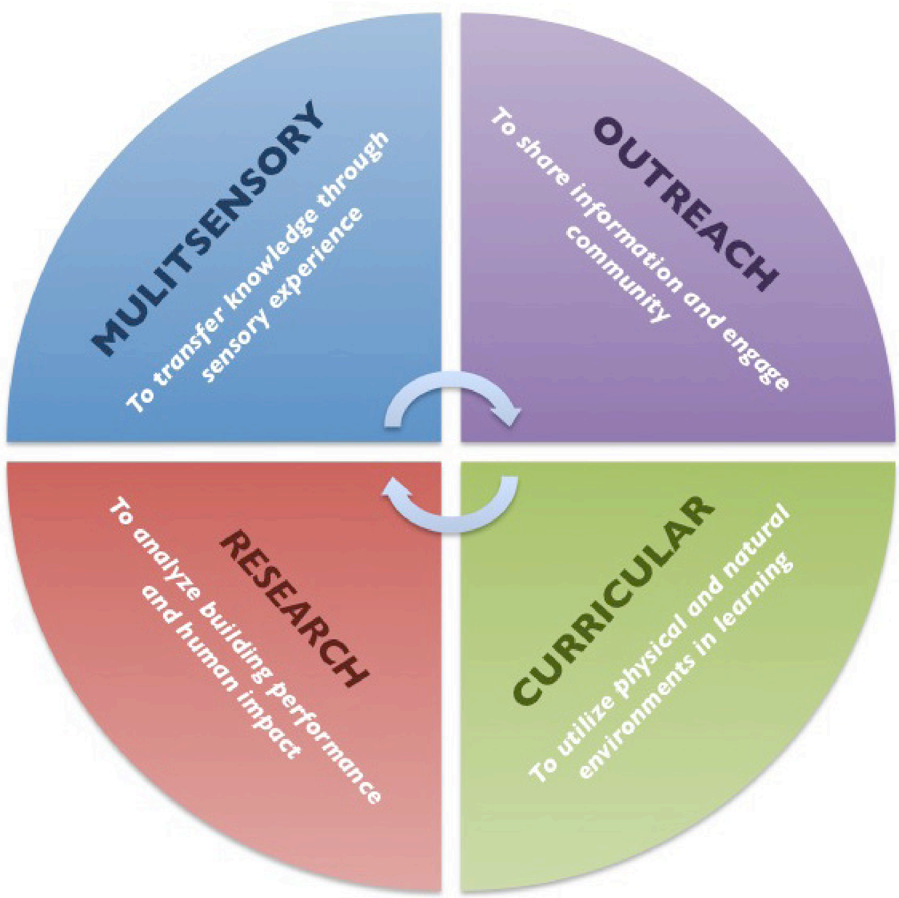

Figure 2 The MOCR framework

Consequently, the final theoretical framework that was used throughout the data collection process can be seen in Figure 3.

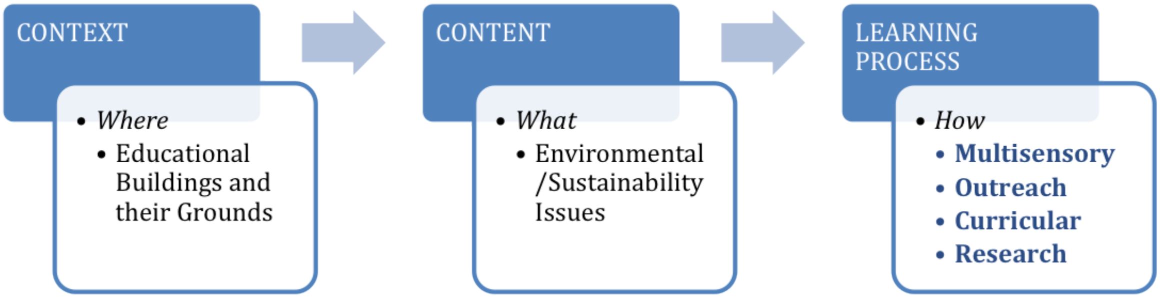

Figure 3 Final flowchart of the theoretical framework

Multisensory

The teaching strategies in this category seek to transfer knowledge through sensory experiences of the building and its grounds. These strategies influence the occupants overall experience through tactile interaction, sight, smell, and sound to create a positive and inspiring association with green design. Many interviewees stated that this sensory experience was one of the most important and intentional goals of their building's sustainable design. For example, the primary teaching strategy at the CCI Center is to bring visitors into the center so they can simply experience a green building (Raffel 2011). Similarly, the focus of the Environmental Technology Center, is to provide a positive impression; "let people experience the place first, then have a chance to seek out what it is" (Rohwedder, Questions on the Pedogogy of Place of the ETC 2011).

This sensory experience can be achieved subtly, such as having spaces entirely daylit and naturally ventilated, or in a more pronounced manner with exposed and accessible buildings system. Regardless of the pedagogical method used, the general goal for *multisensory* strategies is to provide a passive connection and transparency between building's sustainable design and the occupants. In doing so the building itself can become a three-dimensional textbook and a physical representation of the organization's sustainably goals (Orr 1994, Taylor 2009).

Outreach

The teaching strategies in this category communicate information about the building as well as engage the community. These strategies are designed to broaden the audience that is educated about the building's sustainable design and systems to include community members, students, educators and industry professionals. The *Outreach* category broadly encompasses a variety of multimedia and community engagement strategies such as interpretive signage, designated websites about the building, real-time data displays, and educational tours. An example of how *Outreach* strategies can increase a building's audience is the website for the Adam Joseph Lewis Center which receives around 70,000 visits a year, 25% of which are international (Petersen, et al. 2007). Another example is the Philip Merrill Environmental Center, which has given educational tours to tens of thousands of visitors since it opened. These strategies are essential to help proliferate education about a sustainable built environment because one green building cannot define a movement; the green lessons of that building must diffuse into the community (Janda and Meier 2005).

Community engagement strategies are another important aspect of the *Outreach* teaching category. The symbiotic relationship of community collaboration is a fundamental aspect of integrating sustainability into educational institutions and philosophy (Cortese 1999, Ogrodnik 2011). This collaboration can be achieved through community volunteering, which is a primary teaching strategy of both the Chicago Center for Green Technology and the Phipps Conservatory. In both cases, the institution relies on community volunteers to provide building information, give tours, and help maintain the building's gardens (Ogrodnik 2011).

Curricular

This teaching category seeks to incorporate the built environment into students' education by integrating the building's sustainable design and individual systems as subject matter for coursework. Similar to the *Outreach* category, the strategies within the *Curricular* category are uniquely customized by individual educators to be integrated with their own lesson plans as well as adhere to their specific education standards and goals. One of the most successful ways to do this, in terms of improved knowledge retention for the students (National Research Council 2000), is get away from the textbook and include hands-on lessons (called project or environment based learning) that focus on the built environment.

Sidwell Friends Middle School does an excellent job integrating the built into curriculum and provides an illustrative example. Students in biology class study the building's green roof, which is planted with native plant species, to experience first hand what a local ecosystems works. In this case students are using part of the school building as a substituting for a biology textbook. They are also learning that the built environment can support local insect and bird species by providing habitat. These students are actively engaged in hands-on learning that fosters and supports sustainability. Pedagogical examples such as this are some of the most important ways a building can educate students about sustainability (Carlson 2012, Rohwedder, Questions on the Pedogogy of Place of the ETC 2011, Stephen, Lay and McCowan 2008, Selby 2011, S. K. Barr 2011, Wieking 2011).

Research

This teaching category seeks to analyze and verify the building's design, technologies, performance, and impact on occupants. Unlike the previous pedagogical categories, which focus on green building education, the goal of *Research* strategies is to professionally advance the green building industry. This is achieved by providing evidence and documentation of the building's overall performance as well as the performance of individual systems (Loftness 2011). Data sensors and monitoring, post occupancy evaluations, and PhD dissertations are all *Research* strategies because they critically analyze the performance of the building, a specific technology within the building, or the buildings overall effect on the occupants.

Making building data easily accessible is also an important *research* strategy because it allows 3rd party institutions, such as the Department of Energy, to critically evaluate the buildings design. The building can also be researched by k-12 students, which connects scientific inquiry with sustainability education and advocacy. (Bennett, Humphrey and Kerlin 2012, Wieking 2011, Selby 2011). Regardless of who conducts the research, incorporating *Research* strategies into buildings that teach is essential for the prolific growth of the industry because it provides a necessary outlet for green building validation (Fisk 2011, Loftness 2011, Orr 1994, Wieking 2011).

Section IV – Data Collection and Case Studies

Case Studies

This study utilized case study analysis in order to examine the methods and strategies of green buildings used as teaching tools. The study sample consisted of 15 cases meeting the following criteria:

1. Critically recognized for either their progressive sustainable or educational design
2. Availability of information on the case's facility design and educational programming
3. Described as a building that teaches, learning lab, living lab, 3D textbook, or vessel for green building advocacy and research, within the building's mission statement

Buildings meeting these criteria were found through a variety of methods including literature reviews, web searches, sustainable design awards, education awards, and conferences. Additionally, recommendations from industry professionals identified buildings they which were considered *leading* examples. The buildings collected and used as case studies are listed in Appendix A.

Table 6 Overview of case studies

Building Name		Institution	Location	Building Type	Year Completed	Green Achievement
1	Adam Joseph Lewis Center	Oberlin College	Oberlin, OH	Higher Education	2000	Comparable to LEED Platinum
2	Advanced Green Builder Demonstration	Center for Maximum Potential Building Systems	Austin, TX	Nonprofit	1995	Zero Energy, Zero Water
3	Beamish-Monroe Hall	Queen's University	Kingston, ON Canada	Higher Education	2004	
4	Center for Interactive Research on Sustainability	University of British Colombia	Vancouver, BC Canada	Higher Education	2012	Living Building Challenge, LEED Platinum
5	Chicago Center for Green Technology	Chicago's Department of Environment	Chicago, IL	Government	2003: renovation	LEED Platinum
6	The CCI Center	Conservation Consultants Inc.	Pittsburgh, PA	Nonprofit	1998: renovation	LEED Gold
7	Environmental Technology Center	Sonoma State University	Rohnert Park, CA	Higher Education	2001	Zero Energy
8	Environmental Living Learning Center	Northland College	Ashland, WI	Higher Education	1998	Comparable to LEED Certified
9	HPA Energy Lab	Hawaiian Preparatory Academy	Waimea, HI	K-12	2010	Living Building Challenge, LEED Platinum

10	Integrated Teaching and Learning Laboratory	University of Colorado	Boulder, CO	Higher Education	1997	
11	Intelligent Workplace	Center for Building Performance and Diagnostics, Carnegie Mellon University	Pittsburgh, PA	Higher Education	1997	50% Primary Energy Reduction
12	Living Learning Center	Washington University in St. Louis	Eureka, MO	Higher Education + K-12	2009	Living Building
13	Philip Merrill Environmental Center	Chesapeake Bay Foundation	Annapolis, MD	Nonprofit	2000	LEED Platinum
14	Phipps Conservatory	Phipps Conservatory	Pittsburgh, PA	Nonprofit	2012: addition	Addition: Living Building, LEED Platinum, SITES Certification
15	Sidwell Friends Green Middle School	Sidwell Friends School	Washington, DC	K-12	2006	LEED Platinum

Data Collection

In total, 368 specific teaching strategies were collected from the case studies using the theoretical framework shown in Figure 3. First, detailed information about the building's design, including specific systems, were collected and organized into one of the categories in Table 5. This information represents the *context* portion of the theoretical framework, the physical place where learning occurs. Next, information about what specifically was being taught was collected and organized into the same categories in Table 5. This represents the *content* portion of the theoretical framework. Finally, the *context* and *content* information was qualitatively interpreted and extrapolated into individual teaching strategies organized into the MOCR Framework. Each of these specific teaching strategies represents one particular way a building is being used to teach a sustainability topic. The number of teaching strategies collected per case study can be seen in Figure 4 (the entirety of the data collected from each case study can be found Appendixes 1-15 in the Portfolio).

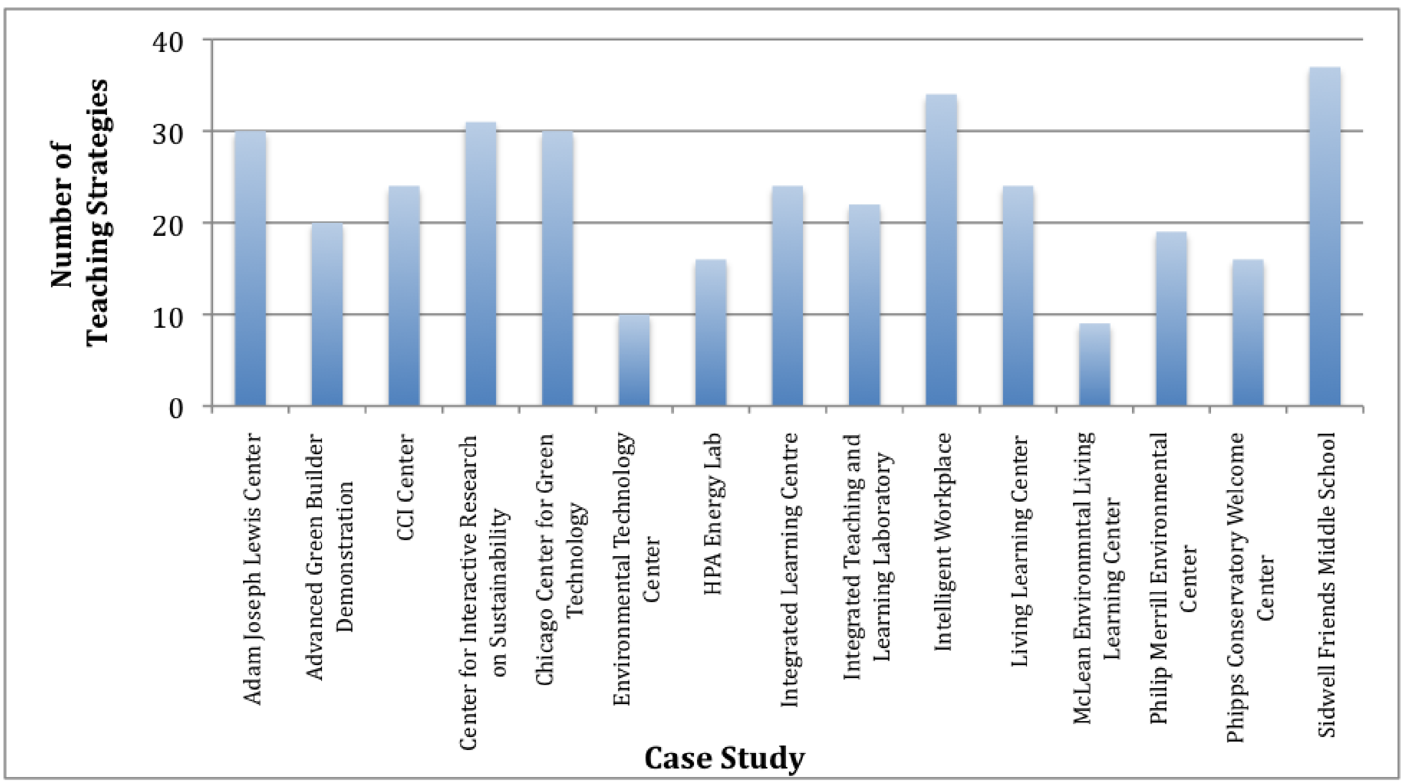

Figure 4 Number of teaching strategies for each case study

All data and information was collected in the same manner for each case study. This data was collected through interviews, literature reviews, web content, course curriculums, and photographs. Interviews were conducted for each case study with a member of the project team, educator, or professional associated with the building. Each interview was administered using open-ended questions focusing on the methods and strategies the building is using to act as a teaching tool. Additionally, first hand data was obtained from site visits of several of the buildings (7 of the 15 buildings were visited). Validation of data was achieved through triangulation of multiple sources. Figure 5 organizes the amount of data collected by *content*, the sustainability issue being taught, organized into LEED categories. Figure 6 organizes the a same data organized into the thematic teaching categories in the MOCR Framework (Multisensory, Outreach, Curricular, Research).

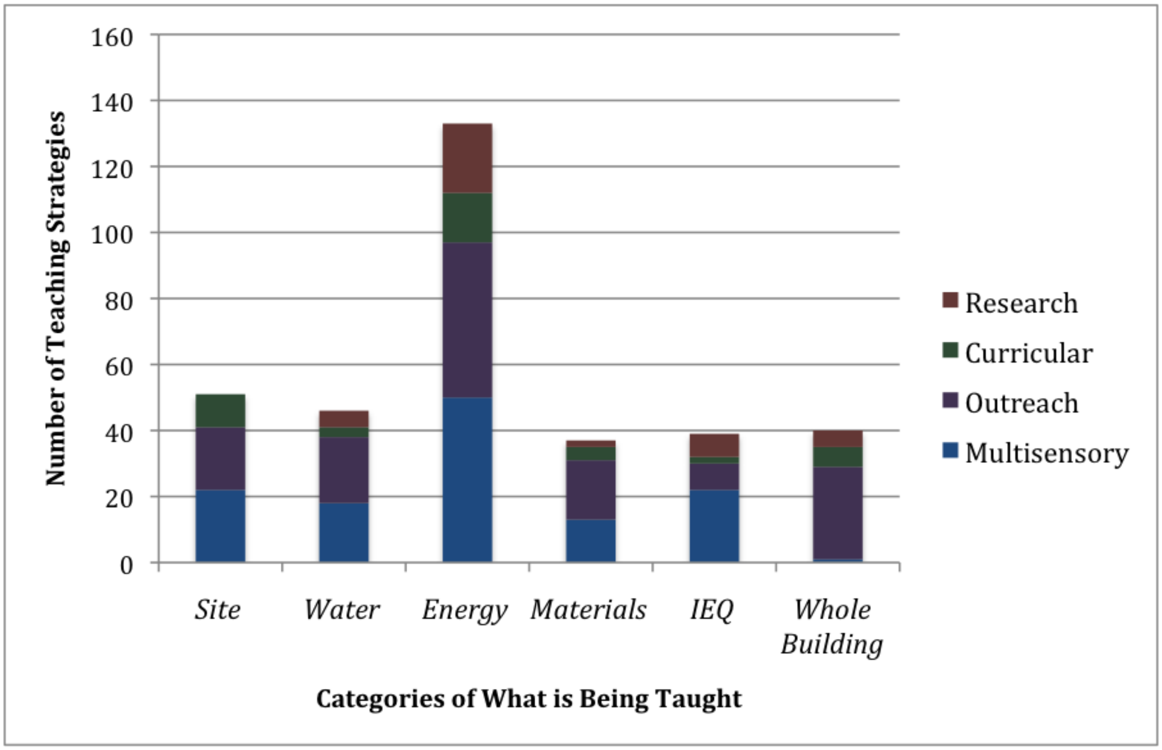

Figure 5 Number of teaching strategies for each category in LEED

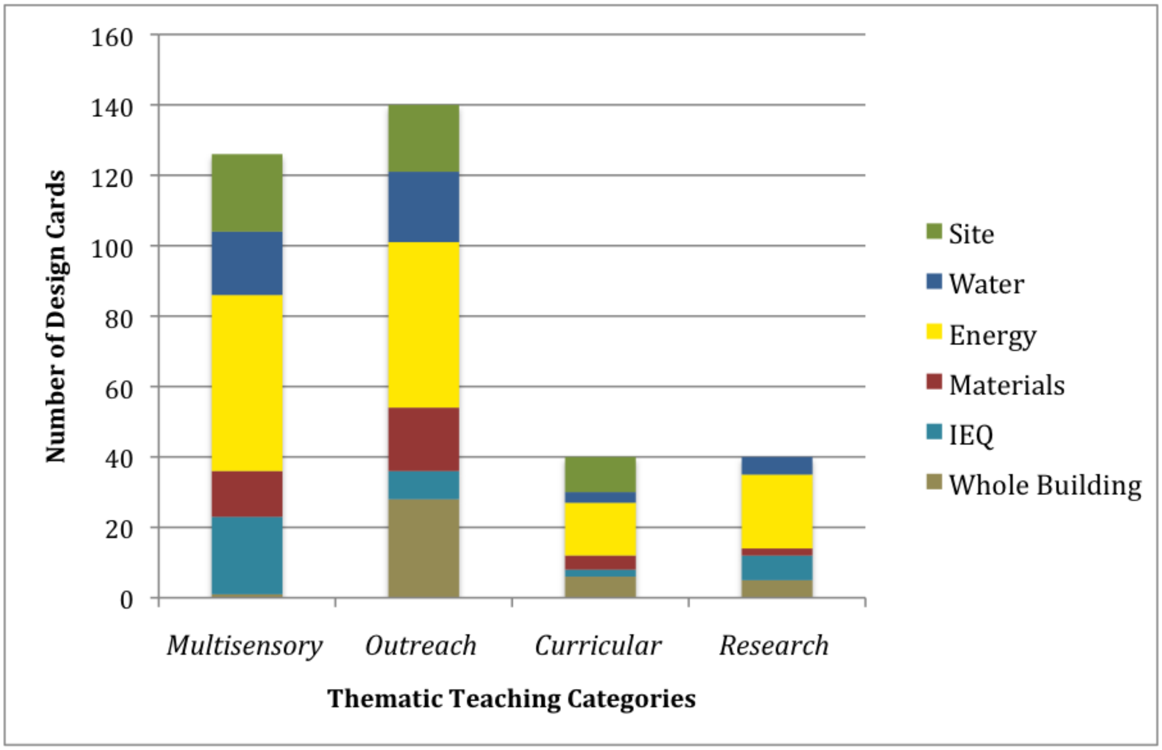

Figure 6 Number of teaching strategies for each category in the MOCR Framework

Presenting the Teaching Strategies

Design Cards

Because of the large volume of collected teaching strategies, and to accommodate future additions, each teaching strategies is presented as an individual design card. Each card contains an image of the particular teaching strategy as well as the following information from the *context-content-learning process* framework (Figure 7):

- *Context:* On the top of each card is the name of the building in which the teaching example was taken from. Also listed is the parent organization of the buildings and its location.
- *Content:* The sustainability issues being taught, listed in Table 5, are listed on the top of the design card. The issues are color coordinated based on the general LEED Category they fall into, which is listed on the top left of each card.
- *Learning Process:* How this particular strategy educates its particular sustainability issues (*content*) is explained in the main body of the design card. Key words are highlighted to emphasize their importance.

Additionally, the primary color of each card is coded with the MOCR framework: *Multisensory*-**blue**, *Outreach*-**purple**, *Curricular*-**green,** and *Research*-**red**. The color-coding of both the MOCR Framework and the sustainability issues being taught, allows the design cards to be quickly organized by the user, as diagramed in Figure 8. For example, you can easily organize all the examples that teach about water be finding the design cards with a blue top (highlighted in Figure 7). By organizing the design cards in a grid-like fashion (Figure 8), you can clearly identify the different levels of complexity in which a building can teach a particular sustainability issue, as well as gain a more holistic understanding of how buildings can teach. All of the design cards can be found in the Portfolio organized by *context* and *content*.

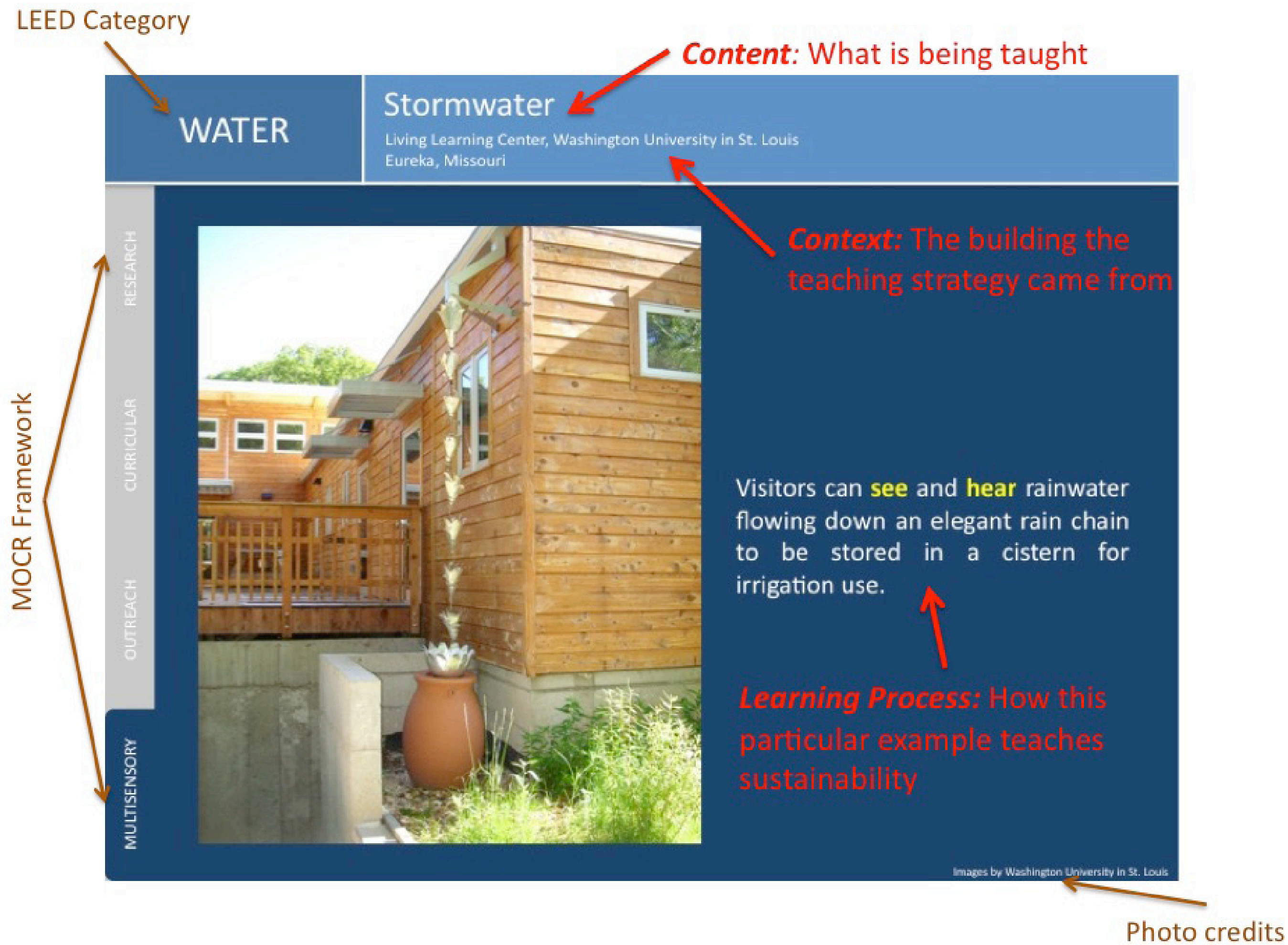

Figure 7 Example of the final Design Card

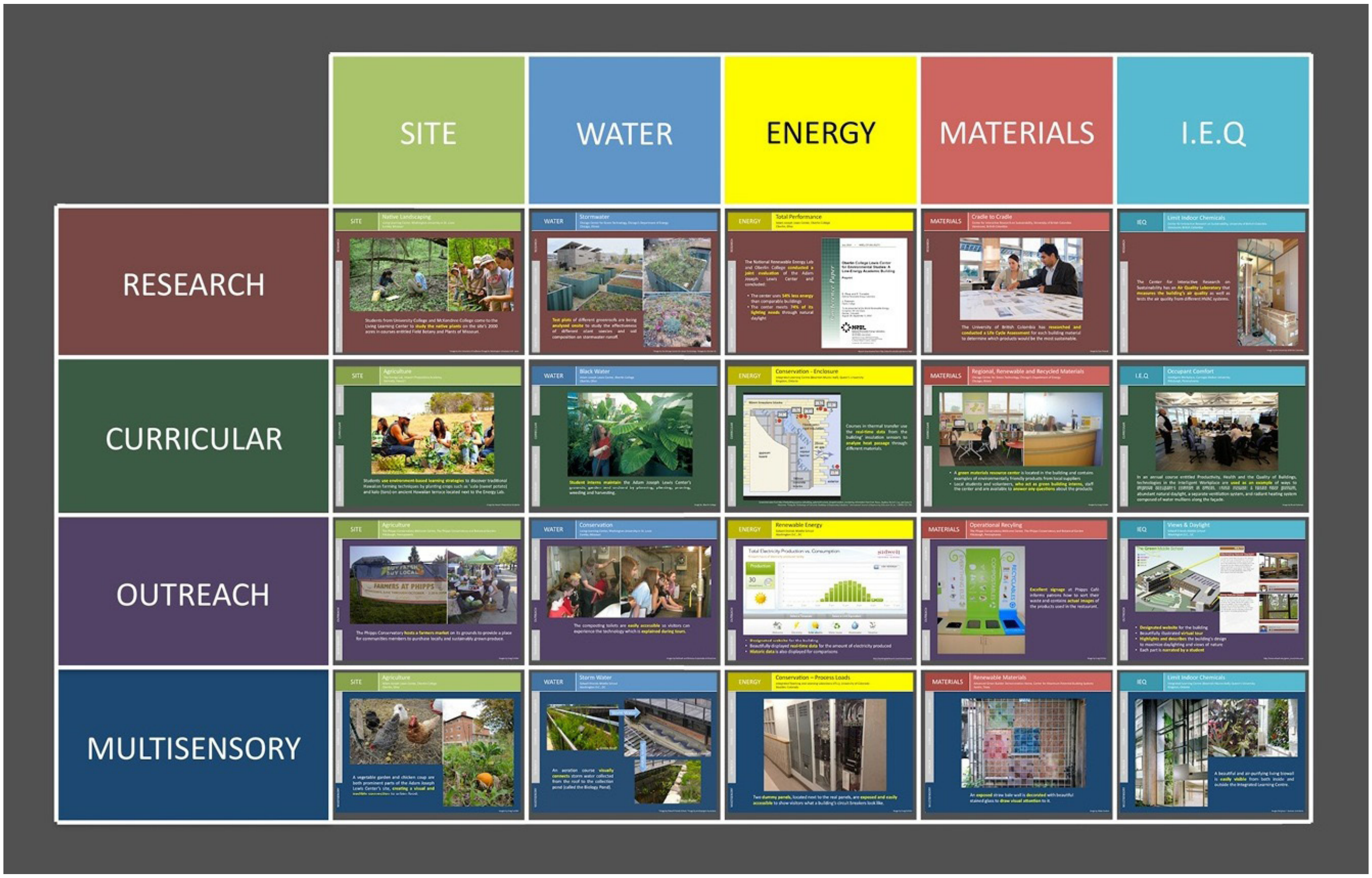

Figure 8 Example of how to use the Design Cards

Website

A website (www.buildtoteach.com) was also created to provide an accessible way to access the design cards. This allows interested parties to easily learn how other buildings are being used to teach. A comment section under each strategy and is intended to spark discussion and provide feedback from industry professionals and individual with first hand experience with the buildings. The strategies displayed in this website are organized using the MOCR framework and are identical to the design cards.

Section V – Analysis and Results

Results Overview

A cross sectional analysis of all case studies revealed general effectiveness findings, as well as the most commonly used teaching strategies within each of the four teaching categories. The overall effectiveness of the different types of teaching strategies were qualitatively analyzed and the findings highlighted in Figure 8. Additionally, specific strategies were quantitatively analyzed for frequency of use, independent of effectiveness. The most common teaching strategies are presented in Figure 9, Figure 10, Figure 11 and Figure 12. In addition to the most common strategies, two infrequent and innovative strategies are also presented to display a breadth of potential innovations within buildings that teach. The data collection process revealed a multitude of innovative teaching strategies and the strategies presented represent only a small sample. The effectiveness of each teaching strategy was not specifically analyzed, rather the innovative strategies were chosen qualitatively based on their variety and ingenuity.

Teaching Strategy Integration and Hierarchy

The following *qualitative* findings represent the beliefs of many of the professionals who have collaborated with this research as well as the interviewee participants. However, these results need more *quantitative* data to support their claims and should be viewed as preliminary *qualitative* findings.

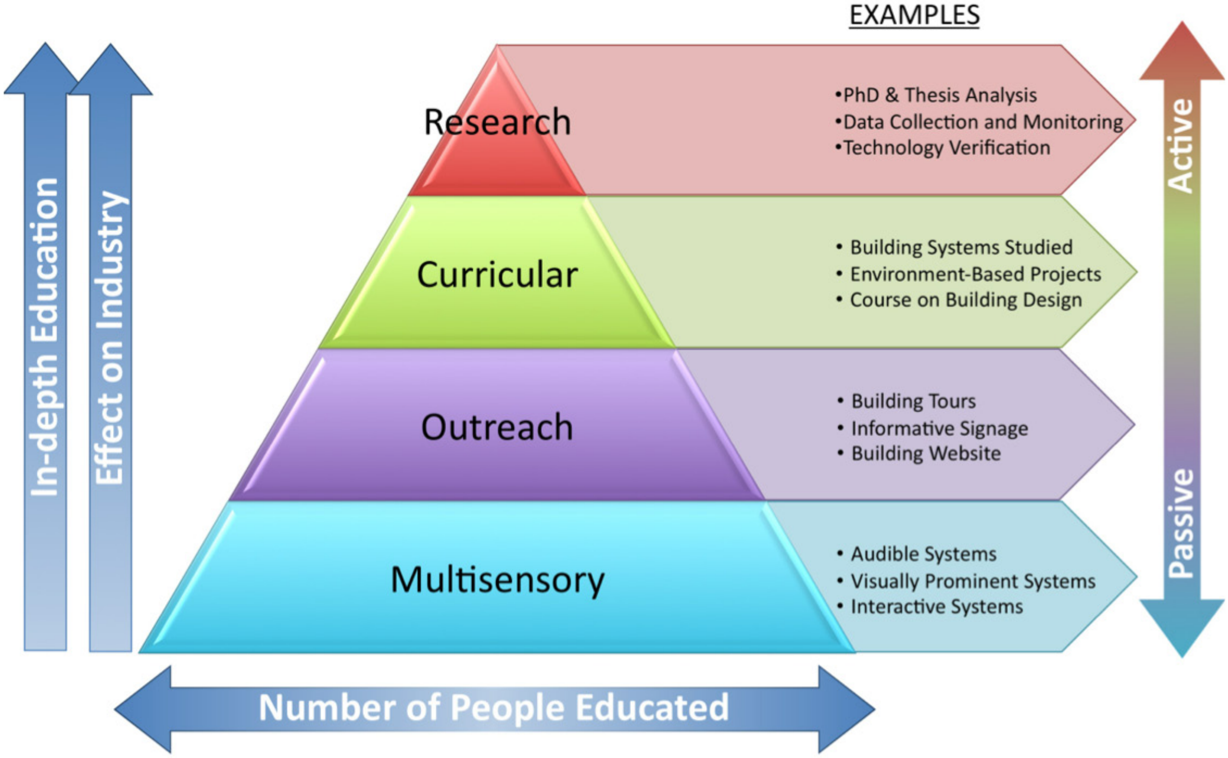

Figure 9 Preliminary qualitative analysis of the benefits of different teaching strategies

Multisensory

Multisensory teaching strategies are important because they superficially connect aspects of the built environment with the largest possible audience. These strategies also help supplement learning by providing a connection to often abstract or behind-scenes-processes. Unlike the other teaching categories, the multisensory category is primarily influenced by the building's design team and is often conceived early in the building's conceptual stage. Additionally, to successfully integrate these strategies into the building the design team needs to have distinct pedagogical goals clearly laid out. In doing so, project teams can specifically design multisensory strategies to both catch the attention of visitors (usually through visual or audible means) as well as create a level of transparency between the building's performance, specific functions, and the occupants. However, these strategies are superficial because they only *trigger* interest; ultimately they rely on other pedagogical strategies, or the visitors' personal interest, to establish a deeper connection to sustainability and the built environment (Rohwedder 2011).

A good example of a superficial multisensory connection is having a large wind turbine predominantly displayed on the front lawn of a building. Designers on the project team made the conscious decision to place the wind turbine on the front lawn to specifically attract attention and trigger the interest from both students and community members. The wind turbine acts as a visual signal to all passersby that renewable energy is being produced at this particular building. However, this wind turbine is considered superficial because it simply generates interest or acts as a real world example. It does not provide any specific information or in-depth learning, additional teaching strategies such as informative signage or courses on renewable energy are needed to increase learning. Conversely, without the wind turbine, there would be significantly less interest in renewable energy in the first place, rendering the turbine important teaching strategy. The community also wouldn't have a working real-world example of this particular technology, which increases knowledge transfer and retention (National Research Council 2000).

Outreach

Outreach strategies provide a higher level of knowledge transfer than multisensory strategies because they involve verbal or written descriptions often through tours, signage, or websites. These strategies are often in conjunction with multisensory strategies to provide supplemental explanations and information about the physical environment. The benefit of these strategies is that they are relatively simple compared to course-work or research, allowing them to reach a broad audience up to tens of thousands of people each year (Petersen, et al. 2007, Winchester 2011). However, these strategies have to be actively sought out by parties interested in that particular building. This means that if a building is relatively unknown, industry professionals or community members wouldn't know to access its website or take a tour. Outreach strategies are also fairly static: tours are often given using an unchanged script, websites are seldom updated, and signs rarely replaced.

Therefore, outreach strategies are the next tier above multisensory in terms of knowledge retention and transfer. These strategies also require active engagement or participation, so they reach a smaller audience than the completely passive multisensory strategies. But, they do provide specific information about the building or its particular systems; which industry professionals can transfer to other buildings, their affect on the green building industry is greater.

Curricular

Curricular teaching strategies specifically study aspects of the building's design, systems, and site through curriculum content which includes a variety of educational programming ranging from short term lesson plans to entire courses that study the building's high-performing design. Environment-based learning projects, which study the building's physical environment or use it as an example, intimately rely in multisensory strategies to maximize their pedagogical potential. However, these strategies act relatively independently from outreach strategies, which provide static explanations intended for a different non-student audience. Curricular strategies increase knowledge transfer and retention by providing structured interaction and analysis, creating a more thorough education. At a higher educational level, this can also have a much larger effect on the industry since future professionals are being learning from existing high-performing examples. The downside to curricular strategies is that the number of students who are educated is limited because students need to be enrolled to participate.

Almost all of the curricular strategies are facilitated by educational professionals and are therefore completely independently from the initial design process. The exception is if students are involved in the design process, which is a short term and non-repeatable curricular project. This can be very educational, but the most successful curricular examples are championed by passionate educational staff to ensure the building is consistently being used in various curriculum (S. K. Barr 2011). This itself can be very difficult to maintain due to the cyclical nature of students' interest (Bensch 2000).

Research

Research strategies encourage the analysis of specific technologies or design elements within a building. This can be achieved through performance monitoring, data analysis, or technology testing. Regardless of which particular method, the outcome has the greatest effect on the green building industry compared to any of the other teaching categories. This is because the result is a verification of anticipated performance results, or an investigation to any discrepancies between the two. Research strategies also foster the highest level of education due to the specialization and time required. At a higher education level, research specifically involving a building that teaches can result in or master's thesis PhD dissertation. This specialization also means that the fewest number of people are educated at this level.

The majority of research strategies rely on data monitored and collected through sensors located throughout the building. Many of these sensors can be added after the building is completed, but structural and insulation sensors need to be installed during construction. Therefore project teams need to be involved with the research goals of a particularly building early in the design process. Similarly, design teams need to be involved early on if modular technologies or multiples systems with the same function are going to be installed. Finally, the building's organization needs to have long-term research interests and capabilities, including dedicated staff and funding, for in-depth research to be successful.

The Most Common Teaching Strategies

The following *quantitative* findings represent the most common teaching strategies utilized by all of the case studies based on frequency of use only. These results need more data to *quantitatively* compare their respective effectiveness.

Multisensory

Most Common Strategies: As shown in Figure 9, the most common multisensory teaching strategy, used by 100 percent of the case studies, was the use of **visibly prominent systems**, building elements intentionally designed to be observed by occupants. **Outdoor classrooms** are used in 60 percent of the case studies to create an indoor-outdoor connection to foster students' understanding and compassion for the natural world. **Exposed and accessible systems** are also incorporated into 60 percent of the case studies to help visitors understand how the building's systems are constructed and operated. They also provide an opportunity for visitors to see building systems that are usually behind the scenes and inaccessible, such as mechanical rooms or wall insulation. Nearly half of the case studies (47 percent) contain **interactive components**, which provide visitors with a tactile experience, allowing them to manipulate the building components. In the same way, 40 percent of the case studies have systems that **display change,** such as the impact of occupants of energy and water use, effectively communicating the interaction of the building, the natural environment, and the occupants.

Innovative Strategies: Several cases contained an accessible **green roof with extensive native vegetation** providing a sensory experience that connects ecosystems and wildlife with the built environment. Sidwell Friends Green Middle School integrated **wind chimes in their natural ventilation shafts**. This innovative solution allowed students to hear when their building' passive ventilation strategy was activated.

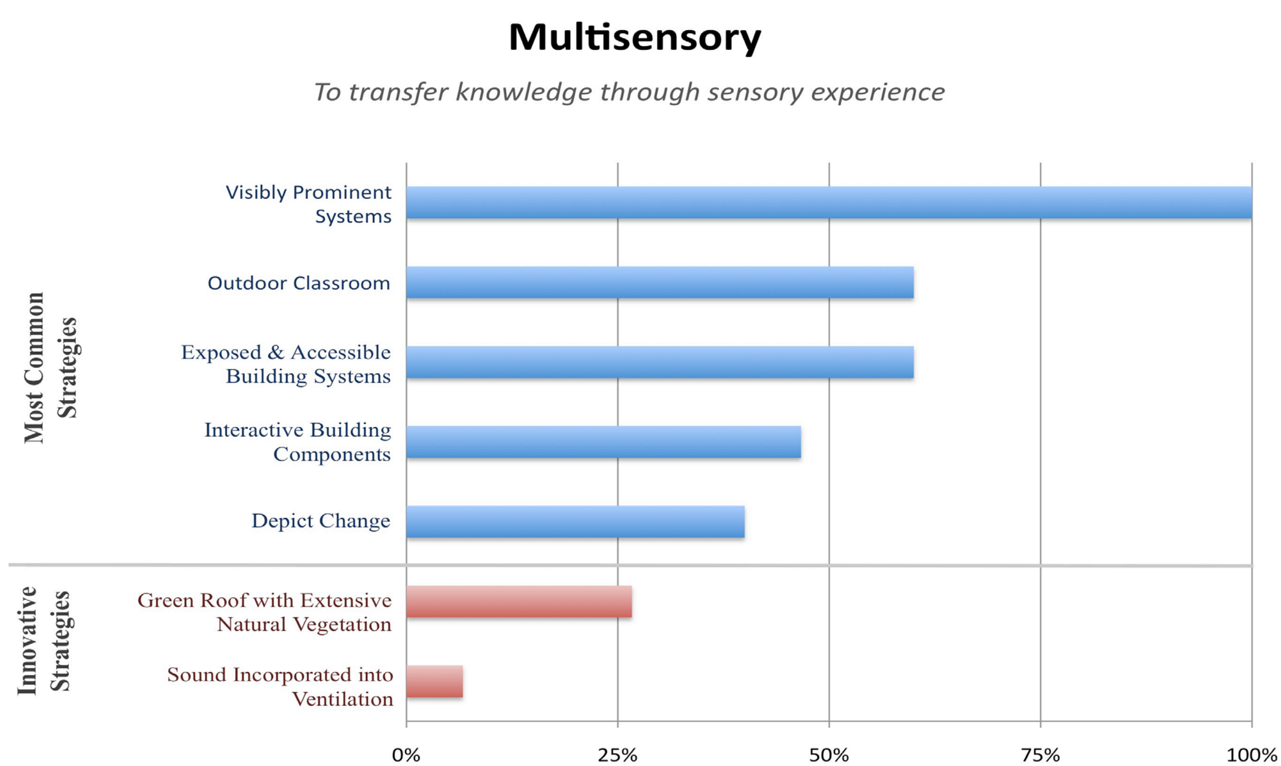

Figure 10 The most common *Multisensory* teaching strategies

Outreach

Most Common Strategies: As shown in Figure 10, **tours** of a building are the most common outreach strategy, utilized in 100 percent of the case studies. Tours provided an excellent opportunity for visitors to learn about the building and ask questions. Several case studies catered tours to different audiences, often offering a general tour for school groups and a detailed tour for industry professionals. Similarly, the tours of several case studies were given by volunteers or students, which were noted by interviewees as instilling a sense of ownership in tour guides. **Interpretive signs** were used to showcase building features in 67 percent of case studies and allowed visitors to connect the information with their surroundings. A **website** was hosted by 60 percent of the case studies to provide detailed information on the building's design, purpose, technologies, and live performance data. Websites allowed a larger audience to learn about the building. Over half of the case studies (60 percent), contain a **flexible meeting space**, open to members of the surrounding community. These spaces were noted as being powerful teaching tools as they connected the building **with diverse audiences**, even those not necessarily interested in the environment or green building. In addition, 60 percent of the case studies hosted **community events and programs** focused on sustainability, such as green building courses or an ecology lecture series, creating a community-learning center for the environment and green building.

Innovative Strategies: Both Sidwell Friends Green Middle School and the Environmental Technology Center (ETC) list all of the building' materials and manufactures on their website. The ETC also includes the local contractors who installed their materials and building systems. The Chicago Center for Green Technology has a resource room, staffed by volunteers, that acts as a library for green building materials from local suppliers. These teaching strategies connect interested parties with the tools and resources to replicate the successes of these cases.

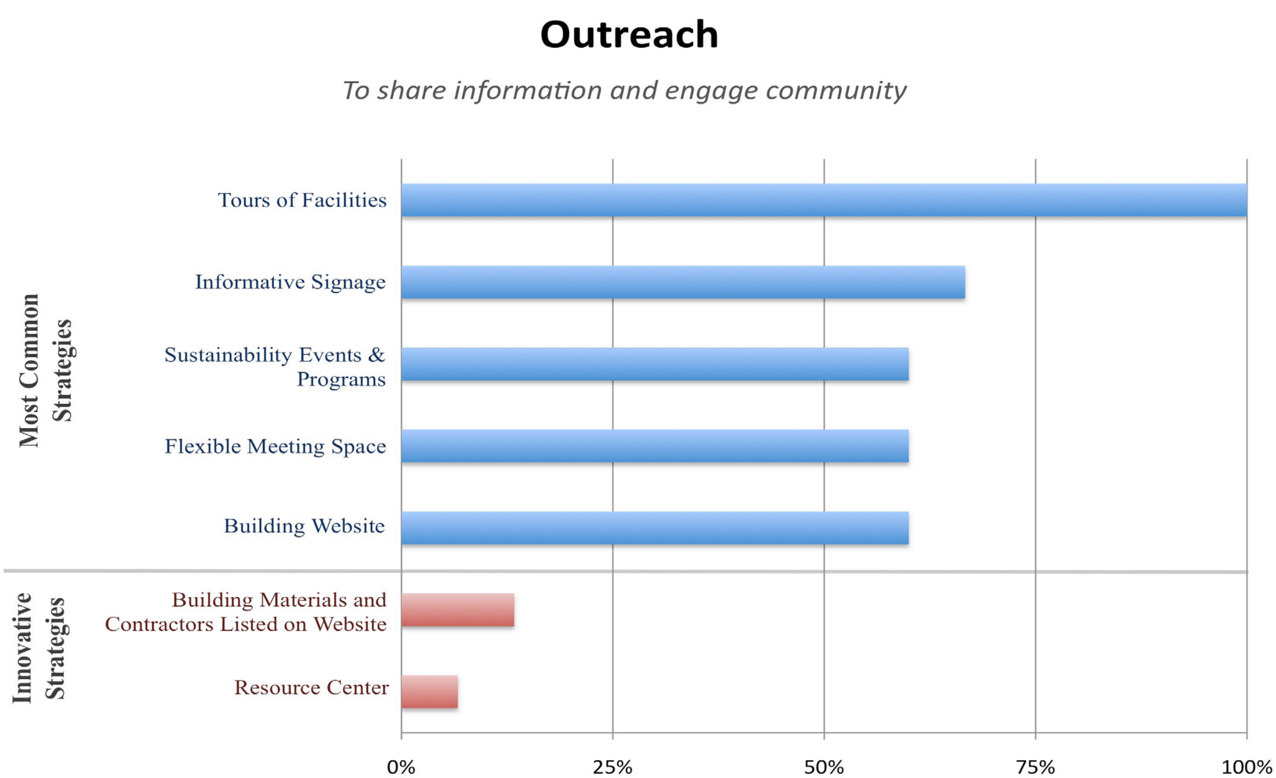

Figure 11 The most common *Outreach* teaching strategies

Curricular

Most Common Strategies: As shown in Figure 11, **environment based projects** were the most common curricular teaching strategy, used by 87 percent of the case studies. These projects utilized the built environment for hands on learning and research for classes in the building. The second most common curricular teaching strategy (used by 73 percent of the case studies) was the **study of the building's systems**. In this strategy, students study one of the building's systems (such as the HVAC system or renewable energy system) to learn how it functions and how it was designed. Similarly, in a majority of case studies (60 percent), students **study the building's site** to learn how ecosystems interact with the built environment. In 47 percent of case studies, the curricular programs went beyond teaching how the building's systems operate and had **students maintain the facilities**. This strategy provides students with the opportunity to put what they learned into practice, improving knowledge transfer. Finally, 40 percent of the case studies had an entire **course on the building's design**, educating students on the design philosophy, technical specifications, benefits, and potential challenges of building green.

Innovative Strategies: Three of the case studies **involved with the design of the building**. These students helped outline the project goals and design criteria, gaining real world design experience. Another unique example is the use of **art students to create the interpretive signage**. Both the CCI Center and the Philip Merrill Center collaborated with art students from local universities to create informative signage about these buildings.

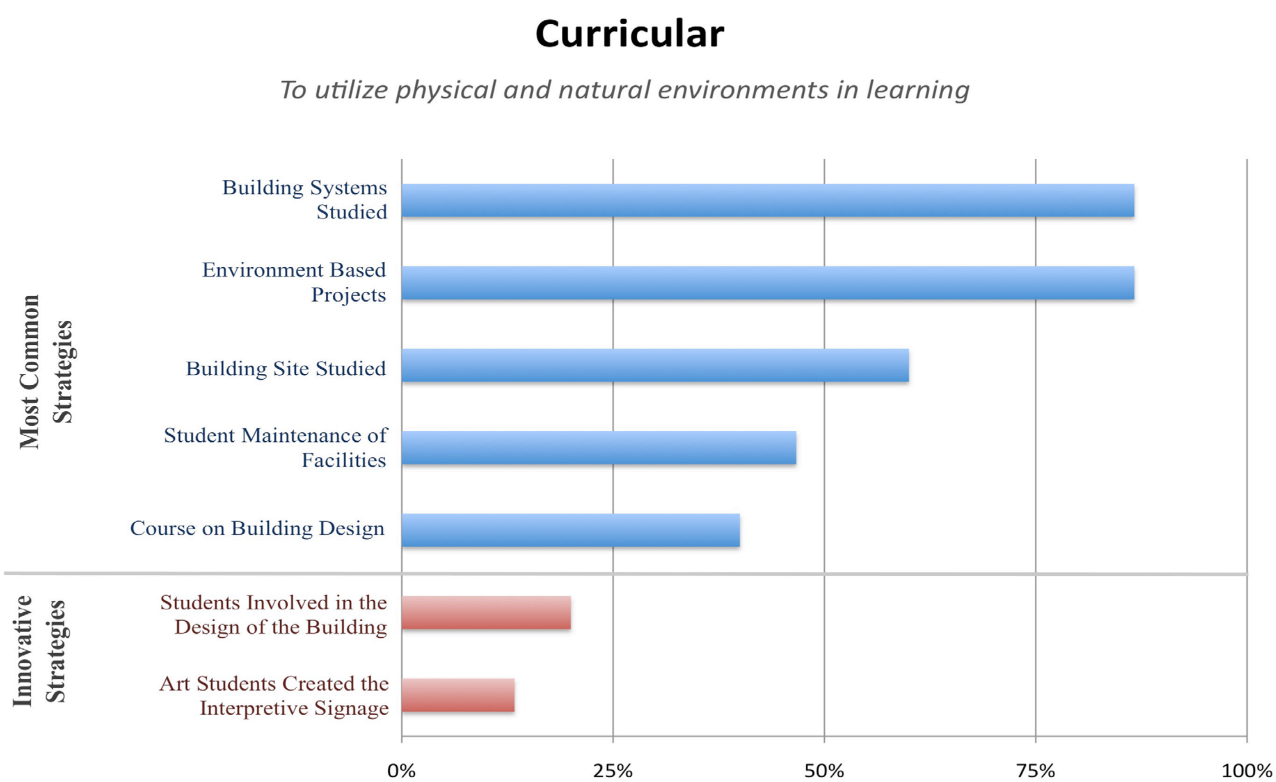

Figure 12 The most common *Curricular* teaching strategies

Research

Most Common Strategies: As shown in Figure 12, **analyzing the building's performance** was the most common research teaching strategy used by 80 percent of the case studies. Analysis was conducted by a variety of individuals and organizations including professors, PhD candidates, and third party research institutions, such as the Department of Energy. This whole-building analysis was noted as essential for the verification and advocacy of green building practices. The second most common strategy (used by 73 percent of the case studies) was the incorporation **data sensors to monitor** the building's systems. This strategy was essential for accurate analysis of the building's performance. **Multiple or redundant technologies** were used in 47 percent to the case studies, allowing the performance of several types of technologies to be analyzed and compared. The evaluation of building **occupants** was studied in 40 percent of the case studies. Post occupancy evolution and the continual study of occupant behavior in the built environment were noted as important research topics for the advocacy of green building. Lastly, **modular technologies** were used in 33 percent of the case studies. These plug-and-play technologies can be quickly swapped for 'upgraded' versions, allowing new technologies to be easily tested.

Innovative Strategies: A few of the case studies have **published academic papers on the building's use as a teaching tool**. These papers are necessary to expand the industries knowledge on the importance and effect of buildings that teach. Another unique teaching strategy was the use of **experimental mockups** of the building's site, such as Solar Decathlon homes or green roof test plots. These mockups allowed the hosting organization to monitor and experiment on sustainable design prototypes.

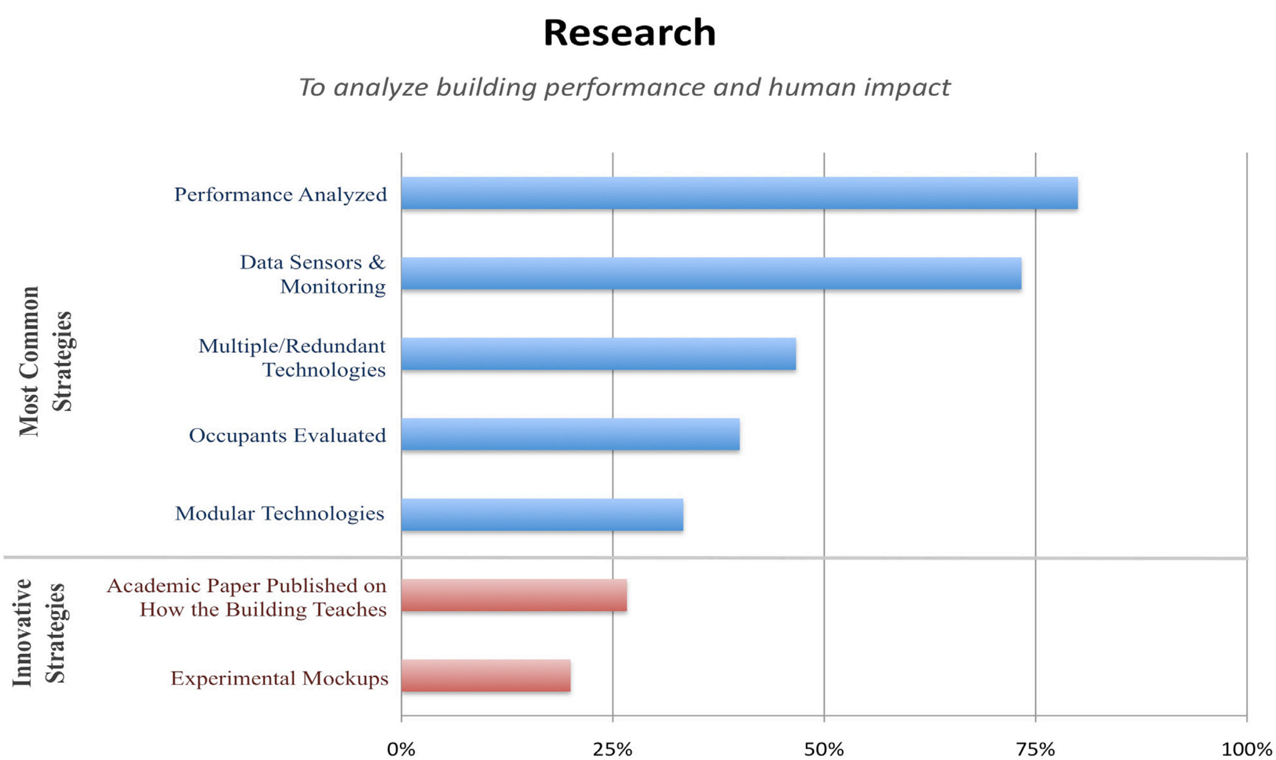

Figure 13 The most common *Research* teaching strategies

Conclusions

The types of teaching strategies each case study used were dependent on the overall mission of the organization. Each case study harnessed teaching strategies in the categories (*multisensory, outreach, curricular, research)* that best aligned with the mission of their organization. For example, the Intelligent Workplace was created as a research-intensive living laboratory and therefore focused on teaching strategies in the *research* category. The CCI Center focused on *outreach* teaching strategies because it was founded as a green building demonstration project by an outreach and education organization.

Though one teaching category may be more heavily utilized by an organization, the use of teaching strategies from all 4 categories creates a holistic pedagogical approach and maximizes the educational value of a building. This was illustrated in all cases and was supported by the literature and the interview responses. In fact, many interviewees stated they would like to use additional teaching strategies to increase and diversify the teaching value of their building but were limited by resources.

Educators, designers, and facility planners should use the information presented in this paper as a foundation for innovation in educational planning and design. Also, the most common teaching strategies should be considered a benchmark for future buildings that teach. However, this list is not exhaustive, as the potential strategies for utilizing a building as a teaching tool is likely limitless, the unique examples presented should be seen as evidence for breadth of pedagogical possibilities and are meant to inspire other innovative teaching strategies.

To collect and present additional teaching strategies, a website (www.buildtoteach.com) has been created based on this research and the ongoing work of Craig Schiller. The goal of the website is to provide interested stakeholders with specific examples of *how* buildings are being used to teach and *what* they are teaching. This website aims to combine the *context, content* and *learning process*es from the framework presented in this paper.

Limitations

This paper did not attempt to quantify the success of the presented teaching strategies. The presented strategies were chosen based on the frequency of use and are independent of what was being taught (*content*). While numerous interviewees described the success and implications of the strategies they used, as this was not a focus of data collection the data was limited and inconclusive. Additionally, several case study buildings were completed very recently and their intended teaching strategies have not been fully developed or implemented. Finally, while each building had abundant information available, access to this information (such as course and curriculum details) was dependent on the cooperation of each interviewee and their organization.

Future Work

The focus of this research was to collect individual strategies being used by current buildings that teach. The affect of these strategies were not analyzed or determined. Many of the building operators, designers, and educators claimed their buildings had abundant and clear influence to their students and communities. These benefits need to be clearly documented in order to gain wider acceptance for these high performance demonstration buildings, which usually have an additional upfront cost.

Currently there has not been a holistic qualitative study to determine if students that spend time in 'buildings that teach' perform better academically or have a greater understanding of sustainability. There is however, one study in progress between Eastern Kentucky University, Northern Kentucky University and the Kenton County School District to determine if a green school, which is used as a living laboratory improves students test scores and attitudes (Bennett, Humphrey and Kerlin 2012). This 6-year study represents an important first step to determine if buildings that teach have a quantifiable holistic and positive influence on their students and communities. Additional research is needed to quantify the sphere of influence (if any) these buildings have, which could be used as powerful evidence to advocate for the wide scale implementation of these buildings.

Furthermore, this research has ignored many of the aspects of the holistic culture of a green school, a focus of Stephanie Barr, and a researcher at the Institute for the Built Environment at Colorado State University. By combining our research we created a more compressive framework for combining school culture with educational programming and the school facility. This framework (Figure 13) needs to be elaborated on with more case studies and research.

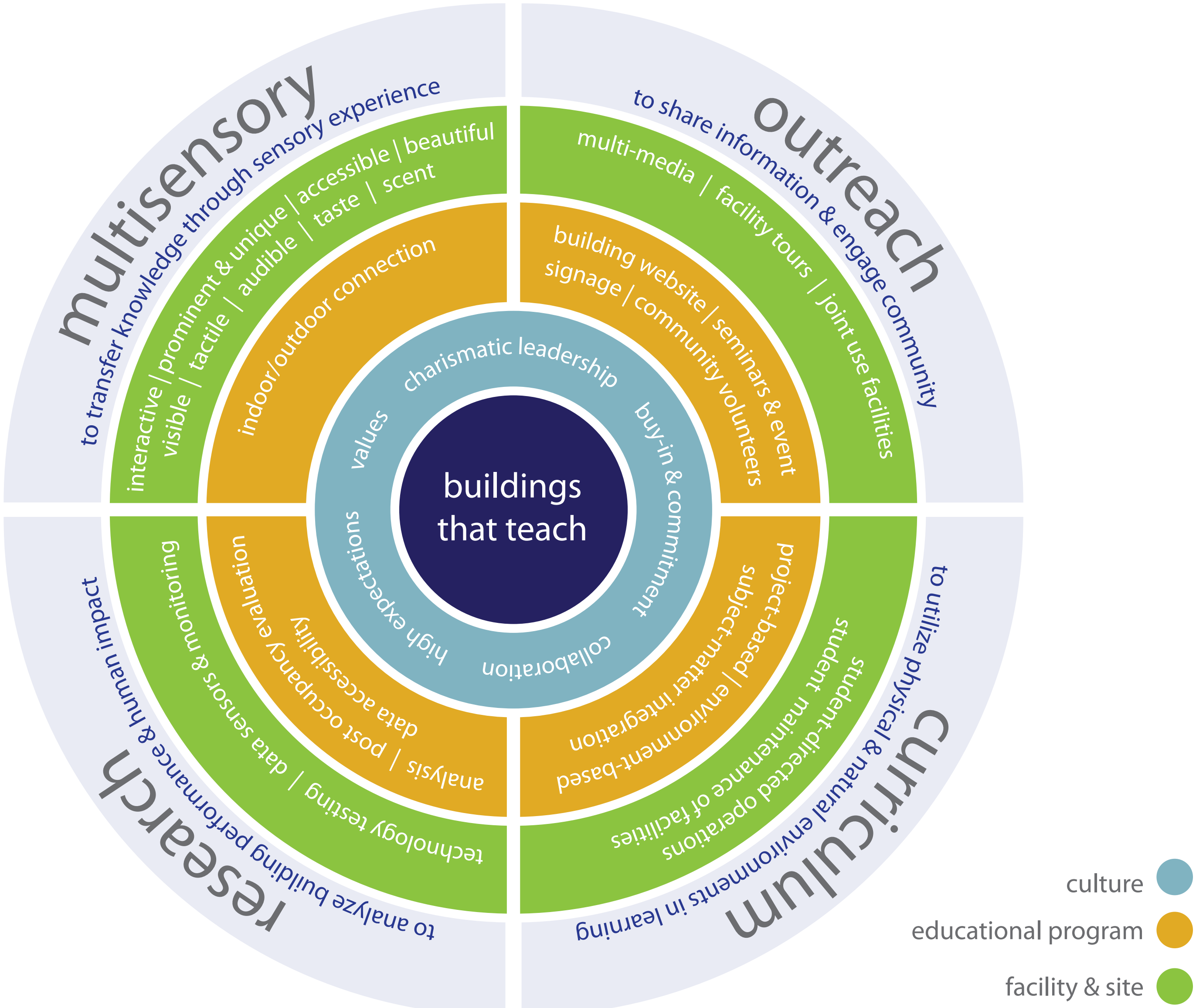

Figure 14 The Buildings that Teach Framework

Works Cited

1. Anderson, John R., Lynne M. Reder, and Herbert A. Simon. "Situated Learning and Education." 1996.
2. Armstrong, Thomas. *Multiple Intelligences in the Classroom.* Alexandria, Virginia: ASCD, 2009.
3. Barr, Stephanie, interview by Craig Schiller. *Combining Project-Based Learning and the Built Environment* Fort Collins, CO, (2012, 17- January).
4. Barr, Stephanie Kay. *Green Schools that Teach: Identifying Attributes of Whole-School Sustainability.* Thesis, Fort Collins: Colorado State University, 2011.
5. Barr, Stephanie, Katharine Leigh, and Brian Dunbar. "Green Schools that Teach: Whole-School Sustainability." *Greenbuild Conference Proceedings.* Toronto: US Green Building Council, 2011. 3-September.
6. Bennett, Billy, Dwayne Humphrey, and Steve Kerlin. "Curriculum and Professional Development in a Green School Learning Laboratory." *Conference Presentation.* Denver: National Green Schools Conference, 2012, 27-29- February.
7. Bensch, Ingo. *Northland College's Environmental Living and Learning Center.* Program Evaluation, Madison: Energy Center of Wisconsin, 2000.
8. Brewster, Cori, and Jennifer Fager. *Increasing Student Engagement and Motivation: From Time-on-Task to Homework.* Booklet, Portland: Northwest Regional Education Laboratory, 2000.
9. Carlson, Lawrence E., interview by Craig Schiller. *What was the vision for the ITLL and how is it used as a teaching tool?* (2012, 18-May).
10. Carlson, Steven W. "Performance Monitoring of a Sustainable Residence Hall at Northalnd College." *Energy Center of Wisconsin.* 2000. http://www.ecw.org/resource_detail.php?resultid=235 (accessed 2011, 29-7).
11. CEFPI. *School of the Future Design Competition.* 2012. http://www.cefpi.org/i4a/pages/index.cfm?pageid=3550 (accessed 2012, 9-April).
12. Cortese, Anthony D. *Education for Sustainability: The university as a Model of Sustainability.* Organization Publication, Second Nature, Second Nature, 1999.
13. Deal, Terrence E., and Kent D. Peterson. *Shaping School Culture: Pitfalls, Paradoxes, & Promises.* San Fransico, CA: Jossey-Bass, 2009.
14. Elewa, Ashraf M.T. *Mass Extinction.* Berlin: Springer, 2008.
15. Ernst, Julie, and Martha Monroe. "The effects of environment-based education on students' critical thinking skills and disposition towards critical thinking ." *Environmental Educational Research*, 2004: 507-522.
16. Fisk III, Pliny. "The Greening of the Brain." In *Biophilic Design*, by Stephen R. Kellert, Judith H. Heerwagen and Martin L. Mador, 307-313. Hoboken, New Jersey: John Wiley & Sons, Inc, 2008.
17. Fisk, Pliny, interview by Craig Schiller. *Questions and Tour of the Advanced Green Demonstration Home* (2011, 3-July).
18. Hellmuth, Daniel F, and Neil Myers. "The Living Learning Center: "One of the Greenest Buildings in the World"." Chicago: School & College Building Expo, 2011, 14-March.
19. Higgs, Amy Lyons, and Victoria M McMillan. "Teaching Through Modeling: Four Schools' Experiences in Sustainability Education." *The Journal of Environmental Education* 38, no. 1 (2006): 39-53.
20. Janda, Kathryn, and Alexandra von Meier. "Theory, Practice, Proof: Learning from Buildings that Teach." In *Sustainable Architecture: Cultures and natures in Europe and North America*, by Simon Guy and Steven A. Moore, 31-50. New York: Spoon Press, 2005.
21. Kats, Gregory. *Greening America's Schools: Costs and Benefits.* Capital E, 2006.
22. Kellert, Stephen R., Nicole M. Ardoin, and Ali Senauer. *Overview of Bringing Buildings to Life.* Draft, Yale and Stanford Universities, 2009.
23. Lawrence, Carlson E., and Jacquelyn F. Sullivan. "Hands-on Engineering: Learning by Doing in the Integrated Teaching and Learning Program." *International Journal of Engineering Education*, 1999: 20-31.
24. Lay, David, interview by Craig Schiller. *Interview about the Beamish-Munro Hall and how its being used as a teaching tool* (2011, 1- December).
25. Lieberman, Gerald A., and Linda L. Hoody. *(Executive Summary) Closing the Achievement Gap: using the Environment as an Integrating Context for Learning.* State Education and Environment Roundtable, Poway: Science Wizards, 1998.
26. Light, Greg, and Roy Cox. *Learning & Teaching in Higher Education.* Thousand Oaks: SAGE Publications Inc, 2001.

27. Loftness, Vivian, interview by Craig Schiller. *Questions about the IW and how it teaches.* (2011, 8th-July).
28. National Research Council. *How People Learn: Brain, Mind, Experience and School.* Washington, D.C: National Academy Press, 2000.
29. Obama, Barack. *Weekly Address: Strengthening the American Education System.* White House. Washington D.C., 2011, 24-September.
30. Ogrodnik, Kelly, interview by Craig Schiller. *How is the Phipps used to teach sustainability?* (2011, 17-August).
31. Orr, David. "Architecture as Pedagogy." In *Earth in Mind: On Education, Environment and the Human Prospect*, by David Orr, 112-117. Washington DC: Island Press, 1994.
32. Orr, David. "Architecture as Pedagogy II." *Conservation Biology* 11, no. 3 (1997): 597-600.
33. Orr, David. "Architecture as Pedagogy II." *Conservation Biology* 11, no. 3 (1997): 597-600.
34. Petersen, John E., Vladislav Shunturov, Kathryn Janda, Gavin Platt, and Kate Weinberger. "Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives." *International Journal of Sustainability*, 2007: 16-33.
35. Petersen, John, Michael E. Murray, Gavin Platt, and Vladislav Shunturov. "Using Buildings to Teach Environmental Stewardship: Real-time Display of Environmental Performance as a Mechanism for Education, Motivating and Empowering the Student Body." *Greening the Campus VI.* Munice: Ball State University, 2007.
36. Raffel, Indigo, interview by Craig Schiller. *How is the CCI Center used as a teaching tool?* (2011, 22-August).
37. Railsback, Jennifer. *Project-Based Instruction: Creating Excitement for Learning.* Northwest Regional Educational Laboratory, 2002.
38. Reis, Michael. "University Buildings that Educate: The Ecology of Design." *Environmental Design + Construction.* 2001, 22-February. http://www.edcmag.com/Articles/Feature_Article/9e737b7338697010VgnVCM100000f932a8c0____ (accessed 2011, 6-February).
39. Renee, Stephen, David S. Lay, and James D. Mccowan. "Using the Technology of University Buildings in Engineering Education." *International Journal of Engineering Education* 24, no. 3 (2008): 521-528.
40. Rohwedder, Rocky, interview by Craig Schiller. *Questions on the Pedagogy of Place of the ETC* (2011, 28-April).
41. Rohwedder, Rock. "The Pedagogy of Place and Campus Sustainability." *Symposium on Academic Planning in College and University Environmental Programs.* Washington D.C.: North American Association for Environmental Education, 1998. 1-8.
42. Rohwedder, Rock. "The Pedagogy of Place and Campus Sustainability." *Symposium on Academic Planning in College and University Environmental Programs.* Washington D.C.: North American Association for Environmental Education, 1998. 1-8.
43. Rohwedder, Rocky. "The Pedagogy of Place: The Environmental Technology Center at Sonoma State University." In *Higher Education and the Challenge of Sustainability: Problematic, Promise and Practice*, by Peter Blaze Corcoran and Arjen E.J. Wals, 293-304. Kluwer Academic Publishers, 2004.
44. Schiller, Craig, Stephanie Barr, Vivian Loftness, Azizan Aziz, and Erica Cochran. "Buildings as Teaching Tools: Strategies to Maximize the Pedagogical Potential of a Sustainably Built Environment." *The 9th Greening of the Campus Conference.* Muncii: Ball State University, 2012.
45. Selby, Sally, interview by Craig Schiller. *Questions about Sidwell Friend's Green Middle School* (2011, 13-June).
46. Stephen, Renee, David S. Lay, and James D. McCowan. "Using Technology of University Buildings in Engineering Education." *International Journal of Engineering Education* 24, no. 3 (2008): 521-528.
47. Taylor, Anne. *Linking Architecture and Education: Sustainable Design for Learning Environments.* Albuquerque: University of New Mexico Press, 2009.
48. Taylor, Anne. *Linking Architecture and Education: Sustainable Design of Learning Environments.* Albuquerque: University of New Mexico Press, 2008.
49. The North American Association for Environmental Education & The National Environmental & Training Foundation (NAAEE & NEETF) . *Using Environment-Based Education to Advance Learning Skills and Character Development.* Report, Washington D.C: NAAEE & NEETF, 2001.
50. Timpson, William M., Brian Dunbar, Gailmarie Kimmel, Brett Bruyere, Peter Newman, and Hillary Mizia. *147 Practical Tips for Teaching Sustainability.* Madison, WI: Atwood Publishing, 2006.
51. Torcellini, P., S. Pless, M. Deru, and D. Crawley. *Zero Energy Buildings: A Critical Look at the Definition.*

Appendix A

	Building Name	Abbreviation	Institution	Location	Building Type	Year Completed
1	**Adam Joseph Lewis Center**	AJLC	Oberlin College	Oberlin, OH	Higher Education	2000
2	**Advanced Green Builder Demonstration**	AGBD	Center for Maximum Potential Building Systems	Austin, TX	Nonprofit	1995
3	**CCI Center**	CCI	Conservation Consultants Inc.	Pittsburgh, PA	Nonprofit Headquarters	1998: renovation and addition to a 1910 building
4	**Center for Interactive Research on Sustainability**	CIRS	University of British Colombia	Vancouver, BC Canada	Higher Education	2012
5	**Chicago Center for Green Technology**	CCGT	Chicago's Department of Environment	Chicago, IL	Government	2003: renovation of a 1953 building
6	**Energy Lab**	Energy Lab	Hawaiian Preparatory Academy	Waimea, HI	K-12	2010
7	**Environmental Technology Center**	ETC	Sonoma State University	Rohnert Park, CA	Higher Education	2001
8	**Integrated Learning Centre**	IL Centre	Queen's University	Kingston, ON Canada	Higher Education	2004
9	**Integrated Teaching and Learning Laboratory**	ITLL	University of Colorado	Boulder, CO	Higher Education	1997
10	**Intelligent Workplace**	IW	Center for Building Performance and Diagnostics, Carnegie Mellon University	Pittsburgh, PA	Higher Education	1997
11	**Living Learning Center**	LLC	Washington University in St. Louis	Eureka, MO	Higher Education + K-12	2009
12	**McLean Environmental Living Learning Center**	ELLC	Northland College	Ashland, WI	Higher Education	1998
13	**Philip Merrill Environmental Center**	Philip Merrill	Chesapeake Bay Foundation	Annapolis, MD	Nonprofit Headquarters	2000
14	**Sidwell Friends Green Middle School**	Sidwell	Sidwell Friends School	Washington, DC	K-12	2006
15	**The Phipps Conservatory Welcome Center**	Phipps	The Phipps Conservatory and Botanical Garden	Pittsburgh, PA	Interpretive Center	2012: addition added to a 1893 building

	Building Name	Green Achievement	escription from Organization (if availabl	S.F.	Architect
1	**Adam Joseph Lewis Center**	Would be LEED Platinum*	"a building and landscape that would cause no ugliness, human or ecological, somewhere else or at some later time."	13,600	William McDonough
2	**Advanced Green Builder Demonstration**	Zero Energy, Zero Water	"a demonstration structure featuring numerous sustainable building techniques"		Pliny Fisk III
3	**CCI Center**	LEED Gold	"a resource hub to highlight the benefits of environmentally sound green building practices...a living laboratory showing people working in harmony with the built environment."	2,300*	
4	**Center for Interactive Research on Sustainability**	Living Building Challenge, LEED Platinum	a model for sustainable buildings and a place where young people will change the paradigm of thinking to a world of sustained abundance	61,085	Perkins + Will
5	**Chicago Center for Green Technology**	LEED Platinum	"the most comprehensive green design educational resource in the Midwest"	40,000	TKA + Partners
6	**Energy Lab**	Living Building Challenge, LEED Platinum		6,112	Flansburgh Architects
7	**Environmental Technology Center**	Zero Energy	"A Building that Teaches"	2,200	AIM Associates
8	**Integrated Learning Centre**		"a Live Building"	80,000	Bregman + Hamann Architects
9	**Integrated Teaching and Learning Laboratory**		"Building as a Learning Tool"	34,000	Klipp Colussy Jenks Dubois Architects
10	**Intelligent Workplace**	50% Primary Energy Reduction	"Living Laboratory"	6,000	
11	**Living Learning Center**	Living Building	"Environmental Research and Education Center"	3,000	Hellmuth + Bicknese
12	**McLean Environmental Living Learning Center**	Would be LEED Certified*		40,000	
13	**Philip Merrill Environmental Center**	LEED Platinum		3,200	Smith Group JJR
14	**Sidwell Friends Green Middle School**	LEED Platinum		72,200	KieranTimberlake Associates
15	**The Phipps Conservatory Welcome Center**	Welcome Center: LEED Certified. Expansion: Living Building, LEED Platinum, SITES Certification	"a revolutionary demonstration model of a variety of alterative, renewable energy strategies and devices and a teaching tool..."	11,000	IKM, Inc.

*Constructed before LEED Rating System

*Addition

Appendix B

Adam Joseph Lewis Center

Adam Joseph Lewis Center Oberlin College			11997		LEARNING PROCESS			
ENVIRONMENTAL ISSUES			DESCRIPTION OF BUILDING TECHNOLOGY	EDUCATION	MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE	Ecosystem Site Selection							
	Walkability							
	Native Landscaping			O: Lists all the native spices on the buildings designated website. C: Student plan, plant, prune, weed and harvest the landscape		●	●	
	Agriculture		50 pear and apple trees are planted on site as well as a permaculture garden to demonstrate urban agriculutre[3]	M: The orchard is a prominent part of the buildings grounds. M: There is a vegetable garden and chicken coup that makes up a large section of the building's 'backyard' C: Students interns plant and maintain the orchard and garden, take care of the chickens, and compost landscaping and food scrapes for fertilizer	●●		●	
	Outdoor Classroom							
	Ecosystem Restoration		A sample of ecosystems native to Ohio were planted and constructed on site including small hardwood forests, and wetalnds.[3]	O: Detailed description of the ecosystems native to Ohio and how several of them (wetland, forest and dry land) were re-created on the building's site		●		
WATER	Conservation			O: The website provides real-time data on the buildings water use		●		
	Stormwater		All the storm water from the building is funneled into a constructed pond	M: The stormwater retention pond is a visibly prominant part of the buildings landscape.	●			
	Grey Water							
	Black Water		Living machine can handle 2000 gallons a day of water	M: The easily accessible living machine allows students to see the process and experience its no-smell M: the living machine is prominently part of the buildings design O: online webcam of the living machine O: Detailed description of each part of the black water system including tank statistics and a Wastewater 101 and a FAQ section C: Students monitor and maintain the living machine. R: "In Spring of 2004 students Jonathan Beckhardt, Ellen Kunz, and Trever Walter investigated the possibility of importing wastewater from other campus buildings to the Center's Living Machine. Their report, presented to facilities planners in May 2004, has laid the groundwork for expansion of the system."	●●	●	●	●
	Zero Net Water							
ENERGY	Total Performance			O: there is a small animated video on the buildings website describing how it consumes and produces electricity O: Total performance of electricity and water ensues available on the buildings dashboard O: dashboard kiosk in lobby. R: The buildings energy performance has been heavily researched by leading organizations such as the NREL		●●●		●
	Conservation	Enclosure	R values: Roof 35, Walls 21, triple pane R-7 windows.	O: website section describes the importance of a tight envelope and lists the R-values for the roof and walls compared to a conventional building		●		
		HVAC	Separate heating, cooling and ventilation systems. Closed loop geothermal wells (24 at 240 feet) keep circulating water at 30-105 degrees consistently. Radiant floor slab in atrium. Individual water source heat pumps in each space exchange heat from with that space with the circulating water. A heat recovery unit recovers 50-60% of energy. HVAC commissioning before occupancy.1	O: Geothermal Wells are thoroughly described in its own section under Heating, Cooling & Air Quality. The function of the geothermal wells and the heat pumps are thoroughly described O: Real time data on the geothermal system on the website dashboard		●●		
		Lighting	Lights have efficient fixtures, dimmers, and occupancy sensors (t8 and CFL bulbs)[3]	O: lighting has its own brief section under the energy category of the buildings website		○		
		Process Loads						
	Passive Systems	Daylighting	Shading eaves over Southside windows and trellis along east façade. Classes and public spaces positioned along the south facade1 Sundial that racks solar seasons.	M: Large south facing glass façade prominently lights the atrium and interior spaces and heats in the winter	●			
		Solar Heating	East west axis for solar orientation	O: Passive systems have a paragraph on the buildings webpage under Heating, Cooling & Air Quality which describe the use of southern glass and thermal mass		○		
		Natural Ventilation	Orientation into prevailing breezes and operable windows1 Fresh air is introduced low and exhausted high via clerestory windows in the atrium for passive air ciruclation1					
		Cooling						
	Renewable Energy		3700 so, about 69,000 kwh/year1 Rated maximum output 60kW, with a realized maximum output of 45kw3 An additional 100kw system was added above the parking lot in 2006 and has since been a net exporter of electricty4	M: There is a small tracking pv panel in front of the building O: Real time data about the renewable energy system is located on the buildings website	●	●		
	Energy Cascades							
	Environmental Footprint		LCA analysis was done for several of the products including the PV system	O: A Life Cycle Analysis is its own section on the website and describes the importance of products being net environmentally beneficial. R: A research study was conducted on the LCA of the PV system and its payback according to different currencies		●		●
	Zero Net Energy							
MATERIALS	Conservation							
	Regional Materials		Local brick and concrete were used[1]	O: local products are listed in the Materials section of the website		●		
	Renewable Materials							
	Recycled Content & Recyclability & Reuse		Carpeting is leased so it can be recycled by the manufacturer into new carpet. Raised floor is also leased. Steel framing aluminum in the windows, roof, curtain walls, and tile and bathroom partitions are all recycled materials.1					
	Operational Recycling							
	Cradle to Cradle		All wood is FSC.[1]	O: FSC wood is mentioned on the website very briefly and doesn't go into detail on what FSC entails		○		
	Zero Net Waste							
INDOOR ENVIRONMENTAL QUALITY	Natural Ventilation		All occupied spaces supplied with 100% fresh outside air[3] every 4 hours on average[3]	O: A section entitled Indoor Air Quality describes the importance of natural ventilation to flush out co2 and toxins and the ERV to make it efficient.		○		
	Low Material Outgassing			O: Low material VOC is mentioned briefly on the website		○		
	Limit Indoor Chemicals							
	Occupant Comfort			M: the atrium is extremely comfortable due to its abundant daylight, plants, and fountain.	●			
	Views & Daylight			M: All the offices and classrooms have natural views and natural daylight.	●			
WHOLE BUILDING			C: There is an annual course entitled "Practicum in Ecological Design of the Adam Joseph Lewis Center" that studies the buildings design philosophy and technology R: The national renewable energy lab used the AJLC as a case study to highlight the buildings design and sustainable features.				●	●

1. Petersen, John, Michael E. Murray, Gavin Platt, and Vladislav Shunturov. "Using Buildings to Teach Environmental Stewardship: Real-time Display of Environmental Performance as a Mechanism for Education, Motivating and Empowering the Student Body." Greening the Campus VI. Muncie: Ball State University, 2007.
2. Reis, Michael. "University Buildings that Educate: The Ecology of Design." Environmental Design + Construction. 2001, 22-2. http://www.edcmag.com/Articles/Feature_Article/9e737b7338697010VgnVCM100000f932a8c0____ (accessed 2011, 6-2).
3. "Highlighting High Performance: Adam Joseph Lewis Center for Environmental Studies." National Renewable Energy Lab. November 2002. www.nrel.gov/docs/fy03osti/31516.pdf (accessed March 11, 2011).

● (red)	Design Card
● (black)	Image needed to create Design Card
○	Teaching strategy but insufficient for Design Card

Advanced Green Builder Demonstration Home

Advanced Green Builder Demonstration Home Center for Maximum Potential Building Systems				1995	LEARNING PROCESS			
ENVIRONMENTAL ISSUES			DESCRIPTION OF BUILDING TECHNOLOGY	REASONS FOR INCLUSTION	MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE		Ecosystem Site Selection						
		Walkability						
		Native Landscaping	Native landscapoing is abundent on the site and integrated into the buiding in shading trellises and ivy is used throughout the building.	M: Native landcaping is abundent throughout the buildings site	●			
		Agriculture						
		Outdoor Classroom	There is a large shaded area that is used as an outdoor classroom year roudn	M: the outdoor classroom space is shaded and coooled with large fans creating an indoor-outdoor connection year round	●			
		Ecosystem Restoration	The building acts as a host for native species to grow, creating its own ecosystem. A bat tower is built onsite to porvie habitat for a local species of bat.	M: The buildign is specifically to act as an ecosystem by providing habitat for native plants. M: the bat tower is a unique way to provie native habitat for species.	●●			
WATER		Conservation	The building uses zero water composting toilets.	M: the outdoor compositng toielts provide a unique outdoor bathroom experience withere vistors can learn compoisting toilets have no smell.	●			
		Stormwater	Rain water catchment system provides 10% of the domestic water needs. This is done through a large attached cistern and a pond catches excess water.	M: a rain water catchmen cistern is on site but hidden by natrual vegitation R: studies by Texas A&M as well as the AGBDH deterimed that a standard home can provide all of its water needs (in central and east texas) by capturing rainwater from the roof with the use of water conserving fixtures and reycling and reuse techniques.	○			●
		Grey Water						
		Black Water	All black and grey water on site is treated through a biological 'low-pressure dosing system". This systems treates all wastewater to be re-used for plant and animal production.					
		Zero Net Water						
ENERGY		Total Performance						
	Conservation	Enclosure	The entire AGBDH is designed modularly so it can easliy grow with the needs of the home. The is done through rebar grid that can easily accomidate a vareity of prefab panesl. Insulated CMUs are used made from recyced fly ash.[1]	M: exposed enclosure allows the buildign to be easily expanded in the future.	●			
		HVAC	The pond onsite acts as a heat sink for the heat pump.					
		Lighting						
		Process Loads						
	Passive Systems	Daylighting						
		Solar Heating	South facing roof absorbs heat in the water for the heat pump.	M: the solar hot water heaters are promintantly loacted in the front of the buidings to make theam easily accessible and vislble.	●			
		Natural Ventilation						
		Cooling	Open floor plan, thermal mass, and extensive vegitaion help cool the building. Also there is a large shaded outdoor area with large fans. The north facing roof					
		Renewable Energy						
		Energy Cascades						
		Environmental Footprint	All the materials were chosen based off a life cycle assesment procedure framework (or ladder) to determine the enviromental impacts of each stage in the material or products life.[1]	O: the LCA ladder used in the building is posted on flyiers outside the center. O: the unique LCA ladder was publshed ina book R: The materials in the builder were heavily researched for their overall life cycel assesment. A visual LCA framework was created during this research R: A report on carbon diaxide intensity was published based off the LCA material work of the AGBDH		●●		○●
		Zero Net Energy						
MATERIAL		Conservation	The AGBDH replaces Portland cement (a large contributor to global warming) with coal fly ash, a by product of electircal generation. This fly ash is used in the CMUs					
		Regional Materials	Reliance on environmentally conscious regional materials and by-products[1]	M: the sustainble mateirals used throughout the building are on display so visitors learn about the different products				
		Renewable Materials	Straw bale construction is used as insulation in parts of the building. The majority of the interior and furniture is made from renewable products such as wood.	M: the sustainble mateirals used throughout the building are on display so visitors learn about the different products M: Renewable products are prominatnly visible throught the interior. M: A strawbale wall is exposed on the interor and clad with stained glass to draw attention to it.	●●●●●			
		Recycled Content & Recyclability	No virgin wood products, or Portland cement. Reycled rbar is the main structural support. The building re-uses a variety of items for interior decorations such as reclamed chees graters as light shades.	M: the sustainble mateirals used throughout the building are on display so visitors learn about the different products M: rebarb is exposed on the interior and exterior of the building. M: Reclaimed cheese graders are used as light shades.				
		Operational Recycling						
		Cradle to Cradle						
		Zero Net Waste						
INDOOR ENVIRONMENTAL QUALITY		Natural Ventilation	Operable windows and an open floor plan allow natural ventilaion to be abundent throughout the home.	M: operable windows are abudent throuhout the building	●			
		Low Material Outgassing						
		Limit Indoor Chemicals						
		Occupant Comfort	Natural vegitation is abundent through out the home, including an outdoor kitchen area.	M: An outdoor kitchen area provids a unique natural experince for occupants. M: natural vegitation is abundent on the site of the building, providing shade and cooling throuh evapotranspiratin.	●●			
		Views & Daylight						
WHOLE BUILDING			O: A montly open house is held at the center to educate community members about the buildngs sustainabe design features. Food and drink are served. O: A section of a book published by the orgnaization is desgnignated to the buildings design process and features			●●		

1. Fisk III, Pliny, and Gail Vittori. Center for Maximum Potential Building Systems; 35 Years of Serious Commotion. Austin: Center for Maximum Potential Building Systems, 2009.
2. Fisk III, Pliny, and Gail Vittori. The Texas "Recycled Content". Advanced Green Building Demonstration Home Project. Paper, Austin: Center for Maximum Potential Building Systems, 1993.
3. Fisk III, Pliny, interview by Craig Schiller. Questions and Tour of the Advanced Green Demonstration Home (7 3, 2011).

● (red)	Design Card
●	Image needed to create Design Card
○	Teaching strategy but insufficient for Design Card

CCI Center

CCI Center **Conservation Consultants Inc.**	1998			LEARNING PROCESS			
ENVIRONMENTAL ISSUES		DESCRIPTION OF BUILDING TECHNOLOGY	EDUCATION	MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE	**Ecosystem Site Selection**	Current building as an adaptive reuse of an existing building from 1910 in a heavily developed neighborhood					
	Walkability	The building is in a mix use neighborhood with a walk score of 91					
	Native Landscaping		Native Landscaping on the green roof.				
	Agriculture	Several planting containers on the roof grow some food such as peppers, basil, and tomatoes.	The rooftop deck has planter gardens growing food.	●			
	Outdoor Classroom	Outdoor meeting and recreation space on the roof and 1st floor garden space. Tours and classes are taken on the green roof.	M: There is an outdoor space with tables they created along side the building. There is also a roof top deck with tables for employees to use.	●			
	Ecosystem Restoration	The property next to the conference room was obtained and converted to a garden and outdoor space.[1]					
WATER	**Conservation**	Low flow toilets, faucets, and shower heads.[1]	O: Simple water conservation methods low flow shower heads & water displacement devices) are demonstrated in an interactive display in the lobby.		●		
	Stormwater	Rain water collection and irrigation system.[1]	M: There is a highly visible rain barrel collecting rainwater, it unaesthetic however. A beautiful and accessible green roof reduces storm water run off.	○●	●		●
	Grey Water						
	Black Water						
	Zero Net Water						
ENERGY	**Total Performance**						
	Conservation: **Enclosure**	Insulation amount exceed codes: AirkKrete R-19 walls and R-19 dense pack cellulose walls. R-72 dense pack cellulose attic. R-6 gas-filled windows.1	M: Part of the building has a cutout section displaying the wall's insulation. M: A display shows the different types of loose fill insulation	●●			
	Conservation: **HVAC**	Separate ventilation system with heat recovery, efficient gas fired heating and AC. Exposed ductwork eliminates transmission losses, floor distribution with diffusers, conference room has a radiant floor hearting system.1	M: The mechanical room is behind double glass doors in the lobby of the building, easily accessible and visible. M: The radiant floor control system is prominently displayed along the wall of the room where the system is installed. M+O: A	●●●	○		
	Conservation: **Lighting**	T8 fluorescent lamps with direct/indirect fixtures.[1]	O: An interactive display allows visitors to turn on and various types of light bulbs to see their respective brightness.		●		
	Conservation: **Process Loads**						
	Passive Systems: **Daylighting**	Extensive daylighting via large windows on the south and east facades as well as clerestory windows. Prominent PV panels are used as shading devices.					
	Passive Systems: **Solar Heating**	Exposed thermal mass on the interior in the form of brick walls and concrete floors. [1]					
	Passive Systems: **Natural Ventilation**	Operable windows, full building design with a central atrium with operable skylights and clerestory windows.	M: All windows are operable and there is a ventilation shaft that connects the second floor with clerestory windows.	○			
	Passive Systems: **Cooling**						
	Renewable Energy	2.5 KW PV system,	M: An interactive PV display is put in front of the building that allows visitors to turn on a light, fan, or buzzer. There are several volt and amp meters to track the flow of electric. M: Prominently displayed PV panels along south façade as awnings and on roof M: A PV panel is on display in the lobby of the building. O: There is an interactive kiosk in main lobby that displays the amount of renewable energy being produced. O: Pictures of the PV instillation and detailed product specifications displayed in signage. R: The amount of renewable energy produced from the PV array is collected by a Fronius data logger	●●●	●●		○
	Energy Cascades						
	Environmental Footprint						
	Zero Net Energy						
MATERIALS	**Conservation**	Re-used much of the existing building including the interior and exterior brick, wood floors and metal ceilings.[1]					
	Regional Materials						
	Renewable Materials	Use of AgriBoard (composed of waste agricultural wheat straw and osb)[1]					
	Re-Use, Recycled Content & Recyclability	Re-used insulation from previous building, lumber from previous building was re-used as framing material, shelving and cabinets, and interior trim. Reclaimed doors and glass lights from Clearview Project Services. Juice containers converted into rain water containers. Refurbished file cabinets, tables and chairs,					
	Operational Recycling	Community recycling center on site.[2] Recycling, composting and vermiculite encouraged onsite.[1]	O: The building acts as a community recycling center by having recepticals for cell phones, compact fluorescents, alkaline batteries, and ink toner and cartridges.		●		
	Cradle to Cradle						
	Zero Net Waste						
INDOOR ENVIRONMENTAL QUALITY	**Natural Ventilation**		M: All windows are operable and there is a ventilation shaft that connects the second floor with clerestory windows.	○			
	Low Material Outgassing	Low VOC water based paint, citrus based wood finishes[1] Asbestos and formaldehyde free wood substitute siding [1]					
	Limit Indoor Chemicals	Non-toxic cleaning materials[1]					
	Occupant Comfort						
	Views & Daylight		M: the main office space is completely daylight	●			
Whole Building		O: Tours are regularly given to students, industry professional and community members. However the majority of the tour groups are 4th-8th grade students O: The is a large sign in the buildings that describes all of the sustainable design features. C: CCI has 4 beautifully illustrated signs displayed through out the building that describe the different environmental components. The four signs are themed, Earth, Water, Fire, Air, and were created by the Environmental Graphics class at the Art Institute of Pittsburgh.			○●	●	

1. Conservation Consultants Inc. "CCI Center: Green Building Materials and Techniques used through out CCI." CCI.

2. 30. Raffel, Indigo, interview by Craig Schiller. How is the CCI Center used as a teaching tool? (2011, 22-8)

●	Design Card
●	Image needed to create Design Card
○	Teaching strategy but insufficient for Design Card

Center for Interactive Research on Sustainablity

Center for Interactive Research on Sustainability University of British Colombia 2011				LEARNING PROCESS			
ENVIRONMENTAL ISSUES		DESCRIPTION OF BUILDING TECHNOLOGY	EDUCATION	MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE	**Ecosystem Site Selection**	Site was selected to be prominent: A location on campus to maximize the exposure and achievements of the CIRS building. LEED Sustainable Site credits were achieved for site selection, development density, and reduced site distrubance.10					
	Walkability	Building was constructed adjacent to the campuses "Sustainability Street" a popular pedestrian path.	M: Bike racks line the front entrance	●			
	Native Landscaping	100% of plantings will be native/adaptive speaces.[10]	M: Highly visible and prominent Living wall planted with native landscaping. M: Highly visible green roof planted with native specs providing a new ecosystem. O: O: The website has an illistrate diagram of the native landscaping with detailed information including system diagram, system description, benefits, and lessons learned	●●	●		
	Agriculture						
	Outdoor Classroom						
	Ecosystem Restoration	The constructed landscape is a natural and functional system that brings habitat to an urban area. Also for the LBC, a habitat of equal size to the buildings site, had to be permenently created elsewhere.	M: Highly visible green roof planted with native specs providing a new ecosystem	○			
WATER	**Conservation**						
	Stormwater	All the water that falls on the roof is collected. 1,226,000 Liters of rainwater can be harvested throughout the year. This water is filtered and disinfected onsite and then distributed through the building.7 Storm water is filtered, treated with UV light and chlorine, pH adjusted, then and held in a treated water tank for domestic use.8 Zero storm water output from site.10	M: Storm water flows from the living roof overflows into the rain garden and bioswale, creating a visual and audible process. O: The website has an illustrate diagram of the stormwater system with detailed information including system diagram, system description, benefits, and lessons learned	●	●		
	Grey water	2,300 Liters of water can be purified per day1 and is filtered by the Solar Aquatic System3. 100% of all water reclaimed water at CIRS comes from the building and the campus sewer system and is treated and re-used on site. The Solar Aquatic System is located in an isolated glass walled room and is highly visible. It treats the waste water in a manner that mimics natural purification processes. The water is used for irrigation and toilet flushing throughout the building.8	O: The website has an illustrate diagram of the reclaimed water system with detailed information including system diagram, system description, benefits, and lessons learned	●	●		
	Black water	2,300 Liters of water can be purified per day1 and is filtered by the Solar Aquatic System3. 100% of all water reclaimed water at CIRS comes from the building and the campus sewer system and is treated and re-used on site. The Solar Aquatic System is located in an isolated glass walled room and is highly visible. It treats the waste water in a manner that mimics natural purification processes. The water is used for irrigation and toilet flushing throughout the building.8	M: The Solar Aquatic Treatment System is located in a highly visible, isolated glass walled room adjacent to the "Sustainability Street", the pedestrian path that runs through the site.				
	Zero Net Water	The CIRS building is entirely self-sufficient, all water used comes from rain water collation and is stored in a 100-cubic meter cistern under the building stores (107,000 L)					
ENERGY	**Total Performance**	Energy Modeling was done by Stantec Consulting suing eQUEST v3.61 and DOE2.2e. It projected 63% energy savings relative to reference building. Modeling also showed that the amount of energy sent back to EOS building was greater than that accepted from EOS making CIRS net energy positive. 6	O: a beautifully illustrated diagram of the buildings energy systems can be found on the buildings designated website O: Real time data of the building can be found on the buildings website, but its not all active yet. R: A designated building technician is fully employed to give building data to researchers and optimize building performance		○●		●
	Conservation — **Enclosure**	The living wall is located on the Western façade and provides seasonal shading and dynamic color changes.	R: The building has 3 different types of glazing (electric currant, triple pane curtain wall and a filled unit (??). The are in the process of testing the electric currant glazing to analyze effectiveness				●
	Conservation — **HVAC**	Two air handling units are used, one for the auditorium only, one for the rest of the building. The auditorium handler heats and cools, the rest of the building is only heated. Both heat through displacement venlation.[5]					
	Conservation — **Lighting**	The lighting energy consumption was modeled to be 15.7 kw/h/m2 which is 56% less than the reference case of 36kw/h/m2. T5 and LED lights are utilized4 Daylighting dimmer sensors, motion sensors.3	O: The website has an illustrate diagram of the daylighting system with detailed information including system diagram, system description, benefits, and lessons learned R: Energy consumption from lighting was modeled to be 15.7 kw/h/m2 which is 56% less than the reference case of 36kw/h/m2,		●		●
	Conservation — **Process Loads**						
	Passive Systems — **Daylighting**	Designed to be 100% daylight. Living wall seasonally shades/allows more daylight. Narrow floor plate maximizes daylight penetration. Pv panel awnings shade south facade3					
	Passive Systems — **Solar Heating**						
	Passive Systems — **Natural Ventilation**	The central atrium acts as a thermal chimney and the buildings narrow footprint maximize natural ventilation.[5]	O: The website has an illustrate diagram of the natural ventilation system with detailed information including system diagram, system description, benefits, and lessons learned	●			
	Passive Systems — **Cooling**						
	Renewable Energy	40 sq meters of evacuated tubes on roof provides 15,400 kwh/yr. 25 kw PV array (22,148 kwh/yr) on roof and window sunshades, provides less than 10% of building electrical needs.	M: Renewable energy panels act as shading devices creating visibly prominent and dynamic shadows	●			
	Energy Cascades	Heat recovery unit recovers waste energy from ventilation exhaust from the neighboring Earth and Ocean Sciences building. This heat is run through a heat pump and any excess is returned back The EOS building to heat it. The amount of energy gathered from EOS is greater than the total energy consumed at CIRS. Ground source geothermal pumps supplement the heat pumps. A heat recovery system captures internal building waste heat and pre-heats the DHW. 6	O: The website has an illustrate diagram of the energy exchange system with detailed information including system diagram, system description, benefits, and lessons learned		●		
	Environmental Footprint	The building sequesters more carbon that it emitted during construction.2 600 tons of C02 are sequestered within the wood structure.1 Campus energy reduced by 275 Megawatt-hours each year due to CIRS building, and campus CO2 emissions are reduced 150 tons per year.1					
	Zero Net Energy	The model projects that the amount of energy used by CIRS (including the EOS heat recovery system) to total 613,540 equivalent kilowatt-hours per year (ekWhr/yr). The energy model results also showed the amount of energy in the heat that can be accepted back by EOS to be 622,070 ekWh/yr making CIRS net-positive in energy performance.. the total projected savings to the overall campus energy consumption is 1,036,780 ekWh/yr.[6]					
MATERIALS	**Conservation**						
	Regional Materials	For the Living Building Challenge, all materials and services must come from regional sources, with eh distance depending on the product (denser materials=closer)	O: The website has detailed information about the buildings materials including system diagram, system description, benefits, and lessons learned				
	Renewable Materials	The primary structural material is wood (half locally harvested from pine beetle infested forests, half FSC certified). A design guideline for the project is to 'highlight' sustainable materials.	M: Abundant use of Wood as the primary structural material.	●	●		
	Re-Use, Recycled Content & Recyclability	For the Living Building Challenge, all materials must be durable and designed for re-use or deconstruction.					
	Operational Recycling						
	Cradle to Cradle / Life Cycle Assessment	One of the project goals was to conduct a LCA fall building assemblies and products for embodied energy, greenhouse gases, and minimize CO2 during consturciton.50% of the wood used was FSC certified, the other half was locally sourced.	C: The university has a LCA course and uses the CIRS building as a case study in their curriculum. R: Life Cycle Assessments were conducted for building products and assemblies.			●	●
	Zero Net Waste	For the Living Building Challenge, the building must reduce or eliminate waste during construction and operation, and design for durability, re=use, and recyclability of all materials.					
INDOOR ENVIRONMENTAL QUALITY	**Natural Ventilation**	Operable windows in the regularly inhabited spaces and the building is designed to maximized cross ventilation. Displacement ventilation with adjustable vents for personal control.	O: The website has an illustrate diagram of the natural ventilation system with detailed information including system diagram, system description, benefits, and lessons learned R: a graduate student in the Sustainable Building Science Program studies pollutants in Natural Ventilation and natural ventilation effectiveness CIRS		●		●
	Low Material Outgassing						
	Limit Indoor Chemicals		R: The building houses an Air Quality Laboratory that tests the building's air quality. It also has a mock hospital room and tests contained dispersal in different HVAC systems				●
	Occupant Comfort		R: UBC Graduate students have been conducting research on the building inhabitants to determine their satisfaction with their work environment, including: thermal comfort, acoustics, and air quality.9				●
	Views & Daylight	The building is organized around a Greenroof courtyard and all offices have abundant daylight and views	M: All offices have daylight and views, most have views of the Greenroof	●			
WHOLE BUILDING		M:100 weeks of construction were documented by a professional photographer and available on the buildings designated website. O: The building has a beautifully designed and holistic website dedicated to current research and information on building systems. O: Tours are given by either professors or undergrad students depending on the age level of the group. O. The building houses the Sustainability Education Resource Center which informs students how to incorporate sustainability into their own studies and lives. It also provides information on sustainability programs, initiatives, volunteer opportunities, and current research. It is a sustainability HUB. O: CIRS hosts sustainability networking events for students. O: CIRS hosts lecture events given by leading sustainability authors from around the world (list on website) C: The CIRS center currently houses 6-8 grad students in the Sustainable Building Science Program who study the buildings design, systems and performance. R:The CIRS center currently houses 6-8 grad students in the Sustainable Building Science Program who research the buildings design, systems and performance		●	●●●●●	●	●

1

●	Design Card
●	Image needed to create Design Card
○	Teaching strategy but insufficient for Design Card

1. University of British Colombia. Building Overview. 11 2. 2011. http://cirs.ubc.ca/building/building-overview (accessed 1 4. 2012).
2. University of British Colombia. UBC Centre for Interactive Research on Sustainability. 11 18, 2010. http://www.youtube.com/watch?v=ZL-47Vc1kHg&feature=relmfu (accessed 1 4, 2012).

3. University of British Colombia. The Building. http://cirs.ubc.ca/building (accessed 1 4, 2012).

4. University of British Colombia. *Lighting.* http://cirs.ubc.ca/building/building-manual/lighting (accessed 1 5, 2012).
5. University of British Colombia. Ventilation. http://cirs.ubc.ca/building/building-manual/ventilation (accessed 1 5, 2012).
6. University of British Colombia. (n.d.). Energy Systems. Retrieved 2 21. 2012. from http://cirs.ubc.ca/sites/cirs.ubc.ca/files/11_EnergySystems_2.pdf
7. University of British Colombia. (2011). Rainwater System. Retrieved 2 22. 2012. from http://cirs.ubc.ca/sites/cirs.ubc.ca/files/12_Rainwater.pdf
8. University of British Colombia. (2011). Reclaimed Water System. Retrieved 2 22. 2012. from http://cirs.ubc.ca/sites/cirs.ubc.ca/files/13_Reclaimed%20Water_0.pdf

9. http://cirs.ubc.ca/community/CIRS-inhabitants
10. University of British Colombia. (2011). Landscape. Retrieved 2 22. 2012. from http://cirs.ubc.ca/sites/cirs.ubc.ca/files/14_Landscape.pdf

Chicago Center for Green Technology

Chicago Center for Green Technology The Chicago Department of Environment 2003					LEARNING PROCESS			
ENVIRONMENTAL ISSUES			DESCRIPTION OF BUILDING TECHNOLOGY	EDUCATION	MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE	**Ecosystem Site Selection**		Brownfield site remediated by the city, formerly a construction material recycler[2]	Tour concentrates on the buildings history and the renovation on a brownfield site				
	Walkability		Bike storage, showers, and changing facilities on site. Within 1/2 mile of Metra station and 1/4 miles of two bus lines. Showers and bike racks are provided on site.[2]	M: Bike racks are the first thing you see before you enter the building. O: Signs for carpool and electric vehicle parking only are in the parking lot to promote alternative types of transportation	●	●		
	Native Landscaping		Native plants were selected for the buildings 160,000 site and green roofs. There are also several green walls planted with native plants.	M: The native landscaped site is a beautiful contrast to Chicago's urban environment. M: Beautiful green walls are prominently located on the outside of the building O: There is a beautiful museum style sign that explains how native landscaping provides habitant for animals and insects. O: All native plants species planted at the building are listed on the buildings website4	●●	●●		
	Agriculture		There are several small raised planter beds with vegetables and flowers on site.	M: Small but colorful raised garden beds draw visible attention to common and recognizable food plants.	●			
	Outdoor Classroom		The storm water pond and constructed wetland around the site are beautifully landscaped.					
	Ecosystem Restoration		Restored wetlands on sight to manage storm water by slowing the flow of rainwater so pollutants can settle and be filtered by plants.2	ME: The native landscaped site is a beautiful contrast to Chicago's urban environment. O: There is a beautiful museum style sign that explains how native landscaping provides habitant for animals and insects..	●	●		
WATER	**Conservation**		All water fixtures are low flow. Native plants used onsite to reduce irrigation needs[2]	O: A beautifully illustrated sign shows all of the water conservation and improvement strategies the Center uses.		●		
	Stormwater		Green roof system, 4 rainwater cisterns (12000 gallons total) capture water for irrigation use. Bioswales, native plants in a constructed wetlands slow rainwater before it enters the sewers or ground. 2 Also there is an extensive vegetated roof.	M: Multiple types of porous pavers (gravel and open grid pavement) are used on sight, teaching in multiple contexts M: an extensive Greenroof can be seen from the easily accessible room M: The rain water cisterns are highly visible outside the building. O: A sign describes the different strategies the center uses to manage storm water and its importance in Chicago. R: There are multiple Greenroof test beds on the buildings site testing different plant compositions and their affect on stormwater run off.	●●●	●		●
	Grey Water							
	Black Water							
	Zero Net Water							
ENERGY	**Total Performance**		The building outperforms ASHRAE 90.1 by 40% with annual energy savings expected at $29,000 per year.[2]					
	Conservation	**Enclosure**	White painted roof (the parts that aren't covered by green roof or solar pv)					
		HVAC	28 Geothermal wells (200ft) under the constructed wetlands.[2]					
		Lighting	Daylighting design offsets the need for electrical lighting by 24%[2]					
		Process Loads						
	Passive Systems	**Daylighting**	Daylighting strategies offset electrical lighting needs by 24%2 Solar panels along the south façade act as shading devices.					
		Solar Heating						
		Natural Ventilation						
		Cooling						
	Renewable Energy		Solar Panels provide 20% of buildings elctricy[2] there are 4 solar arrays at the center including a 32.4 kWh array outside the building.	M Several of the solar arrays, awning and outside, are very visible. O: There is a beautifully illustrated sign inside the buildings entryway that explains the different renewable energy solutions the buildings is using. O: there is a small sign outside that explains how the awnings are solar panels. C: students from local universities study the solar array on the CCGT roof which is easily accessible	●	●○	●	
	Energy Cascades							
	Environmental Footprint							
	Zero Net Energy							
MATERIALS	**Conservation**		100% of the original building's shell was retained, 84 percent of all construction waste was diverted from the landfill[2]	O: A beautifully illustrated sign in the buildings entranceway illustrates how the building conserves materials through building re-use and recycled and renewable products.		●		
	Regional Materials		Over 50% of building materials were manufactured or assembled within 300 miles.	O: Material manufactures and contact information for some 'featured' materials are listed on the website[4]				
	Renewable Materials		The Elevator runs on canola oil instead of petrochemical-based oil.	M: There are multiple renewable flooring materials used on the resource center to show the diversity of options. O: A material resources center is located in the building has examples of green products from local suppliers and has computers for visitors do research materials. C: Volunteers staff the resources center and answer any green material questions visitors may have.	●	●●	●	
	Recycled Content & Recyclability		36% of all materials have recycled content including: drywall, cellulose insulation, linoleum, ceiling tiles, rubber flooring, gravel, fill materials, steel, tile, and MDF board2	O: There is a small museum style exhibit that shows what recycled materials are being used in the building and what their previous materials were.				
	Operational Recycling		A recycling center is located within the building and occupant participation is encouraged.	O: There is a recycling center located within the building for community members. O: The center is a drop off site for hard to recycle materials such as batteries		●●		
	Cradle to Cradle							
	Zero Net Waste							
INDOOR ENVIRONMENTAL QUALITY	**Natural Ventilation**							
	Low Material Outgassing							
	Limit Indoor Chemicals		No CFC or HCFC are used. The Elevator runs on canola oil instead of petrochemical based oil, which isn't toxic when it leads (all hydraulic oil leaks). There is a large 'stomp-off' mat at the entrance of the building to reduce outdoor pollution being	M: There is very visible 'stomp-off' mat at the entrance which is 'overstated' to be noticed by visitors.	●			
	Occupant Comfort			O: A sign in the buildings entrance way highlights some of the strategies the building uses to improve indoor air quality including reducing vehicle use		●		
	Views & Daylight			M: All of the offices have views of the native landscaping	●			
WHOLE BUILDING			The building regularly gives tours to community members and schools. There are signs throughout the building that allow visitors to have a self guided tour. Also most of the buildings systems are exposed to allow visitors see how the building functions, these include,			●●●		

1. City of Chicago. History of the Chicago Center for Green Technology. 2010. http://www.cityofchicago.org/city/en/depts/doe/supp info/history of the chicagocenterforgreentechnology.html (accessed 2011, 15-6).
2. U.S. Department of Energy. Chicago Center for Green Technology. 4 22, 2003. http://eere.buildinggreen.com/overview.cfm?projectid=97 (accessed 6 20, 2011).
3. Hanson, Katie, interview by Craig Schiller. Questions about the CCGT (2011. 22-6).
4. Chicago Department of Transportation. *Chicago Center for Green Technology.* http://www.chicagogreentech.org/ (accessed 5 15, 2012)

●	Design Card
●	Image needed to create Design Card
○	Teaching strategy but insufficient for Design Card

Environmental Technology Center

Environmental Technology Center
Sonoma State University 2001

ENVIRONMENTAL ISSUES			DESCRIPTION OF BUILDING TECHNOLOGY	REASONS FOR INCLUSION	LEARNING PROCESS: MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE	**Ecosystem Site Selection**		Previously a parking lot that was eventually turned into and educational agricultural area and then the ETC[3]			○		
	Walkability							
	Native Landscaping		Entire site is planted with native species[5]	O: The ETC hosts a sustainable landscapes certification program bringing in community members to experience the building. CO: Students of the sustainable landscape certification program use the buildings site as an example of sustains practices.	○			
	Agriculture		There is a large vegetable garden and apple orchard that surround the building	M: The organic garden is visibly dominate surrounding the building O: The ETC hosts a sustainable landscapes certification program bringing in community members to experience the building. CO: Students of the sustainable landscape certification program use the buildings site as an example of sustains practices.	🔴	🔴	🔴	
	Outdoor Classroom							
	Ecosystem Restoration		Replanted the site because of its damaged state previous to the ETC[5]	O: The ETC hosts a sustainable landscapes certification program bringing in community members to experience the building. CO: Students of the sustainable landscape certification program use the buildings site as an example of sustains practices.				
WATER	**Conservation**		Waterless urinals and water efficient (drip irrigation) systems.[5]					
	Stormwater		Underground piping implemented for the future possibility of rain water harvesting. Bioswale on site.[5]			○		
	Grey Water							
	Black Water							
	Zero Net Water							
ENERGY	**Total Performance**		The ETC is ZERO ENERGY BUILDING and was modeled using Energy 10[3]	O: The building is used as a meeting space for the California sub committee on energy due to its zero energy status.2 C: The buildings energy performance is studied in an energy management course on campus.		🔴	●	
	Conservation	**Enclosure**	Lots of thermal mass of different varieties and Low-e fiberglass windows	M: Several different types of thermal mass that can be seen and felt. C: The different types of thermal mass are used for thermodynamic measurements in one of the course on energy management. Students see how heat flows through the different materials3	●		●	
		HVAC	Radiant floor system					
		Lighting	High-efficiently t-5 Lights[1]	C: A class on energy management and energy efficiency learns about high-performance lighting fixtures and ballasts and uses lights in the buildings as an example.			●	
		Process Loads						
	Passive Systems	**Daylighting**	East-west axis, clerestory windows and light colored surfaces for refelction5 Simulation was done for daylighting in a helidon to verify the design could achieve 50 foot candles in the seminar room on an overcast day1	C: The passive cooling, heating and natural ventilation and daylighting systems are studied in an a passive solar design course3				
		Solar Heating	4 different types of thermal mass including rammed earth walls and two kinds of CMUs[3]	C: The passive cooling, heating and natural ventilation and daylighting systems are studied in an a passive solar design course3 C: A thermal energy management course studies how heat is transferred through the various types of thermal mass				
		Natural Ventilation	Extensive ventilation modeling in a wind tunnel was conducted to ensure the buildings shape would maximize natural ventilation.	M: Prominent ventilation ducts and the shape of the building to create stack ventilation C: The passive cooling, heating and natural ventilation and daylighting systems are studied in an a passive solar design course3	🔴		🔴 ●	
		Cooling	Cooling is done naturally with the uses of operable windows, thermal mass, ceiling fans, and seasonal shading devices.	M: Building is a consistent temperature of 70 year round despite drastic heat waves C: The passive cooling, heating and natural ventilation and daylighting systems are studied in an a passive solar design course3				
	Renewable Energy				○		○	
	Energy Cascades							
	Environmental Footprint							
	Zero Net Energy		Between 2001-2003 the ETC was monitored to have produced an average of 946 kwh more than it used					
MATERIALS	**Conservation**		Durable steel roofing with extended life span[3]					
	Regional Materials		The majority of the materials and contractors were sourced from within the area.[3]	O: All of the materials used in the building and their contractors are listed on the buildings designated website.		🔴		
	Renewable Materials		Cellulose insulation and seaweed acoustical panels[4]					
	Recycled Content & Recyclability		Recycled plastic lumber trellises, recycled auto glass tiles[4] Concrete made from 8% rice all ash and 43% fly ash[5]					
	Operational Recycling							
	Cradle to Cradle		FSC wood used throughout the building					
	Zero Net Waste							
INDOOR ENVIRONMENTAL QUALITY	**Natural Ventilation**		Building was tested in a wind tunnel to maximize natural ventilation[3]	M: the building has a prominently visible passive ventilation shaft that gives occupants the feeling of a fresh and healthy environment.	🔴			
	Low Material Outgassing		Formaldehyde-free acoustical wall and ceiling panels[4] Non-solvent based adhesives and water based wood finishes[2]					
	Limit Indoor Chemicals							
	Occupant Comfort		Occupants can individually control temperature via individual operable windows[3]	M: The entire building is a constant comfortable temperature year round (even in California's hot climate) due to the thermal mass and natural ventilation systems.	🔴			
	Views & Daylight							

1. AIM Associates. AIM Projects: Environmental Technology Center. 4 3, 2011. http://www.aimgreen.com/projects/projects-etc.html (accessed 4 3, 2011).
2. Janda, Kathryn, and Alexandra von Meier. "Theory, Practice, Proof: Learning from Buildings that Teach." In Sustainable Architecture: Cultures and natures in Europe and North America, by Simon Guy and Steven A. Moore, 31-50. New York: Spoon Press, 2005.
3. Rohwedder, Rocky, interview by Craig Schiller. Questions on the Pedagogy of Place of the ETC (4 28, 2011).
4. Rowdier, Rocky. "The Pedagogy of Place and Campus Sustainability." Symposium on Academic Planning in College and University Environmental Programs. Washington D.C.: North American Association for Environmental Education, 1998. 1-8.
5. U.S. Department of Energy. Environmental Tech. Center, Sonoma State. 10 14, 2008. http://eere.buildinggreen.com/overview.cfm?projectid=247 (accessed 4 1, 2011).

🔴	Design Card
●	Image needed to create Design Card
○	Teaching strategy but insufficient for Design Card

HPA Energy Lab

HPA Energy Lab Hawaiian Prepatory Academy		2010		LEARNING PROCESS			
ENVIRONMENTAL ISSUES		DESCRIPTION OF BUILDING TECHNOLOGY	EDUCATION	MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE	**Ecosystem Site Selection**						
	Walkability						
	Native Landscaping	Native Hawaiian plants will be reintroduced on site.[3]					
	Agriculture	Traditional Hawaiian crops such as taro and sweet potato are being grown and harvested	C: Students use project-based learning techniques to learn about traditional Hawaiian farming techniques by planting crops such as 'uala (sweet potato) and kalo (taro). This planting is to help restore the ancient Hawai'ian terrace adjacent to the Energy Lab.3			●	
	Outdoor Classroom	Two outdoor classrooms, on incorporated into building design, the other is a aquaculture and thermal culture farm located on site.2	M: There an outdoor classroom designed into the building and with overhead shading and thermal mass to keep it comfortable year round. M: There is a second outdoor classroom, an outdoor aquaculture and thermal culture farm, located a little bit away from the building, it is currently being constructed.	● ○			
	Ecosystem Restoration	As part of the LBC ecosystem replacement, a piece of land was purchased in Oregon as a conservation offset. Restoration projects are being done on the 216 acres to bring back native Hawaiian species. Also, the site around the Energy Lab was used by traditional Hawaiians as farming terraces					
WATER	**Conservation**	Duel flush toilets in every bathroom[3].	O: the website describes has a picture of the duel flush toilet.		○		
	Storm Water	All rain water is collected and purified on site. 1 inch of rain equals 380 gallon of water collected.1 The Freshwater catchment system is monitored with sensors for volume (accurate to the thickness of a sheet of paper) and temperature.	M: The Freshwater Catchment System is easily accessible below the buildings deck. R: The data from the catchment system is visible on the touch screen kiosk and online to analyze the performance of the system.	●			●
	Grey Water						
	Black Water						
	Zero Net Water	Zero Energy from building. All rain water is collected, and purified on site. 1 inch of rain equals 380 gallon of water collected.1					
ENERGY	**Total Performance**	The entire building uses about 1800 watts, including all servers, cameras, water pump and purification system.[2] Energy data is put online so it can be used by researches around the world.	O: Live data kiosk in center of building provides feedback for the buildings energy, lighting and water systems. R: Building data is sorted and accessible online and is being used by researches around the world to study the performance of a living building.		●		•
	Conservation: Enclosure						
	Conservation: HVAC	The CO2 and temp sensors determine when the fans and windows open to cool. Last resort for cooling is the air conditioners which are actually heat pumps. Radiant cooling system is used at night to cool the building and computers. Water	M: The radiant cooling system tank is easily accessible below the deck. M: Steel piping instead of PVC is prominently visible throughout the building.	○○			
	Conservation: Lighting		O: Kiosk in building controls all lighting within the building.		●		
	Conservation: Process Loads	The buildings total energy consumption, including process loads is 1800 watts. The computers in the center are laptops to keep the wattage down. All electronics are tagged with their electrical consumption. There is a master switch that shuts off all power outlets.1	M; a second switch shuts off all the power strips. O: Everything that is plugged in has a tag attached to it showing the watts the device consumes. . C: there is a scavenger hunt into the building to find the electrical products with that consume the least and most amount of energy. Students also learning about the energy consumption of the building and how the process loads are minimized through efficient products R: A student is studying a nearby hotel's process loads, using the HPA's energy monitoring software. They hooked ups sensors at the hotel.	•	•	●	●
	Passive Systems: Daylighting						
	Passive Systems: Solar Heating						
	Passive Systems: Natural Ventilation	Building is shaped like an airfoil to ventilate rooms passively and naturally.[1]					
	Passive Systems: Cooling						
	Renewable Energy	24kw of solar energy systems, which include 3 different types of solar panels, one of which as an inverter built into them which increases efficiently. The Energy Lab uses 20-25% of the energy they produce, providing $2000 a month of excess energy to the rest of the campus. In the process of instantly a Pump Storage Hydro systems, that will pump water 1800 ft up in elevation and a generator will collect the energy during off peak hours.1 Biofuel crops will soon be grown on the buildings site to provide fuel for energy labs vehicles system.3	M: The solar panels are designed to also act as shading devise, making them visibly prominent. O:The energy lab has 3 different types of solar panels on sight, which is used to educate community members on which type of pv has a better ROI for that region3. O: The energy lab's website briefly describes size and types of pv panels used.	●	● ○		
	Energy Cascades	Copper heat pumps are located under the laptop that controls the building, keeping the wattage down and the water in the rain water cistern as a heat sink.					
	Environmental Footprint						
	Zero Net Energy	The building is an energy producer,					
MATERIALS	**Conservation**						
	Regional Materials	All materials were locally produced based on the distance requirements set by the Living Building Challenge. For example, the still was forged and cut in Honolulu.1	M: Local lava rock is imbedded into the pored concrete wall to provide a local material connection. C: Students learn about the regional material requirements of the LBC and the Energy Lab.	●		●	
	Renewable Materials	Wood is the dominant material used in the building.	renewable FSC wood is the dominant material used throughout the building.	●			
	Re-Use, Recycled Content & Recyclability	Some of the furniture in the building was made from wood cut off the shading devices.					
	Operational Recycling						
	Cradle to Cradle	All wood is FSC[1]					
	Zero Net Waste	During construction, everything was weighed and recycled (LBC requirment).[1]					
INDOOR ENVIRONMENTAL QUALITY	**Natural Ventilation**	Building is shaped like an airfoil to ventilate rooms passively and naturally.[1] There are operable windows in each room along the backside of the building to collect mountains side breezes[3]	M: Operable windows in each room along the backside of the building to collect mountain side breezes.	●			
	Low Material Outgassing	The building has no smell. Visitors enjoy the building and notice that it is odorless.[2]	M: Students love to study in the building because it's a beautiful space and it doesn't have any smell[2]	○			
	Limit Indoor Chemicals						
	Occupant Comfort	CO2 levels are monitored in each room and levels are displayed on the touch screen kiosk. The censors are automatically linked to operable windows which open when levels reach a certain level.2	M: Visitors are able to touch C02 sensors and see the change on the kiosk, and see the fans turn on the windows open.	●			
	Views & Daylight						
WHOLE BUILDING		O: A website for the building has a video tour and over view of the building, has pictures, and provides information on the LBC and LEED .C: Students involved with the design of the building included in the design charrettes and meeting with the architect and engineers.			●	●	

1. UHSG Marine Science. (2010, June 8). Dr. Bill Wiecking leads HPA Energy Lab Tour. Retrieved December 19, 2011, from Vimeo: http://vimeo.com/12389457
2. Wieking, B. (2011, 12 19). Pedagogical Questions about the HPA Energy Lab. (C. Schiller, Interviewer)
3. Hawai'i Preparatory Academy. (2010). The HPA Energy Lab. Retrieved 12 19, 2011, from Hawai'ian Preparatory Academy: http://www.hpa.edu/academics/energy-lab

●	Design Card
•	Image needed to create Design Card
○	Teaching

Integrated Learning Centre (Beamish-Munro Hall)

Intergrated Learning Centre (Beamish-Munro Hall) Queen's University			1998		LEARNING PROCESS			
ENVIRONMENTAL ISSUES			DESCRIPTION OF BUILDING TECHNOLOGY	EDUCATION	MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE	**Ecosystem Site Selection**							
	Walkability							
	Native Landscaping							
	Agriculture							
	Outdoor Classroom							
	Ecosystem Restoration							
WATER	**Conservation**							
	Storm Water							
	Grey Water							
	Black Water							
	Zero Net Water							
ENERGY	**Total Performance**			C: APSC 100: Engineering Practices, statistical analysis from real-cost data and live performance data from the building's HVAC and renewable energy system to do a cost-effective analysis of the buildings systems. C: "Several student projects have compared the power-consumption patterns of Beamish Munro Hall with those of other buildings on campus. Some have designed an ideal `green' alternative building or made recommendations on power saving retrofits to existing buildings."			●●	
	Conservation	**Enclosure**	The total R-Value of the walls is 16.13. reinforced bar (rebar) is exposed in several areas.2 Both the foundation and many aspects of the structural system are exposed. There are several different types of glazing on the buildings west curtain wall with shgc ranging from 0.13 - 0.51 (efficiency was sacrificed for learning opportunities) sensors are also being installed to measure heat and light from the different windows3	M: the center has a cutaway section of the wall that allows visitors to easily see the different insulation materials. O: Some information about the enclosure including window details and wall insulating values are listed on the website C: Courses in thermal transfer use the data from the buildings insulation and windows to analyze heat passage through each assembly.3 R:Students also analyze the envelops effectiveness in different seasons and conditions using historic data.3 R: Multiple window types with different efficiencies are monitored for their heat and light transfer performance.	●	○	●	●●
		HVAC	The building has an Entrapy wheel that exchanges heat and humidity. The building is heated by steam from a campus steam cogeneration plant.2	M: exposed HVAC system complements M: Accessible HVAC control room for tours. O: Description of the Entropy Wheel and air handling unit is available on the buildings website as is real time data for the buildings HVAC system C:"Data from the enthalpy wheel on the transfers of energy and moisture between the two air flows are used in calculations of energy savings and hence of cost-effectiveness. Data are used in both courses and projects." 3 C: Chemical Engineering 319 Take a tour to the mechanical penthouse to see how the mechanical system works Looking at the sensors, computers, actuarators, for real life examples of system processes and management. R: Historic Data from the Entropy Wheel is easily accessible and downloadable on the website.	●●	●	●●	●
		Lighting	There are 458 throughout the building and they are all linked to a networked lighting system. All the lights are on dimmable ballasts Occupancy is monitored through light use in each room.	O: The website lists which rooms are occupied (based on which lights are on) in real-time. O: The website has detailed information about how the networked lighting system and dimmable ballasts save energy. R: Upper-year students projects have analyzed the effectiveness of the motion censored lights and found that they are falsely triggered about 11% of the time3		○○		●
		Process Loads	23 meters collect data through the centers electrical system to monitor lights, the solar array, individual circuits and the computer lab. Each computer in the computer lab is individually monitored and the data is displayed online	O: The website has detailed information about the buildings electrical use and the types of meters used to collect data. R: The electrical monitoring allows the researchers to analyze the different process loads and electrical end uses of the building. R: Each computer in the computer lab is individually monitored to track electrical, and to illustrate their power consumption even when they are not on.		○		●●
	Passive Systems	**Daylighting**	The building uses skylights and light shelves extensively throughout the building. The atrium also has a south facing saw-tooth roof design.	M: The main atrium is entirely daylight O: The building has some basic information about the passive daylighting design systems	●	○		
		Solar Heating						
		Natural Ventilation						
		Cooling						
	Renewable Energy		The solar array consists of 264 panels wired in 22 rows (series). The photovoltaic array is monitored for its power, current, and voltage of each array. That data is live on the website. The ambient solar radiation is also measured and the radiation that reaches each of the 4 arrays.	M: the pv panels are visibly prominent as shading devices along the entire south facing facade. O: Details about they system, including system details, product specifications, and real-time data can be found on the website. O: A fact one sheet of the buildings renewable energy was created to provide thorough information about the system including Project Overview, Construction Challenges, Instrument details, and performance insights. C:The solar array "has served as data source for a course on alternative energy sources, and as a basis for several undergraduate student projects on sustainable technologies and green energy. R: The solar array has been featured in several research papers and a doctoral research project3 R: The PV system was analyzed and the details, challenges, and performance insights were published in one-sheet.	●	●●	●●	●●
	Energy Cascades							
	Environmental Footprint		In 2005, A process called SMART (System of Measurment and Reporting on Technology) was used to track the GHG footprint of the solar array. The assessment concluded that by 2013 the array will have saved 69 tones of ghg from being released	R: In 2005, A process called SMART (System of Measurment and Reporting on Technology) was used to track the GHG footprint of the solar array. The assessment concluded that by 2013 the array will have saved 69 tonnes of ghg from being released				●
	Zero Net Energy							
MATERIALS	**Conservation**							
	Regional Materials							
	Renewable Materials							
	Re-Use, Recycled Content & Recyclability							
	Operational Recycling							
	Cradle to Cradle							
	Zero Net Waste							
INDOOR ENVIRONMENTAL QUALITY	**Natural Ventilation**							
	Low Material Outgassing							
	Limit Indoor Chemicals		A 3 story biowall contain 100 species of plants is located in the buildings lobby. It acts as a biofilter and a 'central aesthetic feature'. The wall naturally removes vocs and co2 as air is as humidity triggered fans suck air through the wall.	M: A beautiful living biowall is easily visible in the building. O: information about how the biowall improves air quality by reducing co2 and VOCs is available online including real-time data, an illustration of the system and a list of common sources of VOCs. C: "Some of the student groups in a first-year problem-based learning course have monitored the performance of the biowall and offered suggestions for design improvements. One discovery has been that VOC data are affected by the placement of the reference sensor. This is an example of students learning not only the specific technology (biowall) but also learning to be mindful of ensuring that their measurements are meaningful."3	●	●	●	
	Occupant Comfort							
	Views & Daylight							
WHOLE BUILDING			C: Multiple course using the Living Building, its systems, and its data in their curriculum. R: the faculty of the Applied Science department have published a paper detailing how the IL Centre is used as a teaching tool for engineering education including how it is integrated into curriculum and research.				●	●

1. Lay, David, interview by Craig Schiller. *Interview about the Beamish-Munro Hall and how its being used as a teaching tool* (12 1, 2011).

2. Queens University, Faculty of Applied Science. *Live Building Inergrated Learning Centre.* 2010. http://livebuilding.queensu.ca/ (accessed 5 1, 2011).

3. Renee, Stephen, David S. Lay, and James D. Mccowan. "Using the Technology of University Buildings in Engineering Education." *International Journal of Engineering Education* 24, no. 3 (2008): 521-528. http://livebuilding.appsci.queensu.ca/ilc/kiosk/livebuilding/greenTemps.php

●	Design Card
●	Image needed to create Design Card
○	Teaching strategy but insufficient for Design Card

Integrated Teaching and Learning Laboratory

Integrated Teaching and Learning Laboratory **University of Colorado at Boulder** 1997					LEARNING PROCESS			
ENVIRONMENTAL ISSUES			DESCRIPTION OF BUILDING TECHNOLOGY	EDUCATION	MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE	**Ecosystem Site Selection**							
	Walkability		The building is located in the center of the University of Colorado's Boulder campus, an extremely Walkable location for students.					
	Native Landscaping							
	Agriculture							
	Outdoor Classroom							
	Ecosystem Restoration							
WATER	**Conservation**							
	Storm Water							
	Grey Water			M: The buildings plumbing pipes are exposed throughout the building	●			
	Black Water			M: The piping for the restrooms is visible through and exposed wall.	●			
	Zero Net Water							
ENERGY	**Total Performance**							
	Conservation	**Enclosure**		M: Rebar around concrete structural elements are exposed M: Multiple materials and structural elements are used to display the diversity of engineering possibilities M:There is an exposed slice of wall covered in plexi glass. O: a sign explains how the rebar in the concrete incrassates its structural strength O: There is a sigh describing the walls construction next to an exposed section.	●●●	●●		
		HVAC		M: The Mechanical room is easily accessible as well as color coded to create a connection between the components of the HVAC system and their function. M: Ventilation shafts are exposed through out the buildings. M: the air handling unit is completely accessible, you can walk in it. M: VAV boxes are visible and labeled in the ceiling plenum O: visitors of the mechanical room, can go on a color-coded scavenger hunt to find the different mechanical systems. O: There are signs informing visitors of the purpose of the large and exposed ventilation ducts. O: There are signs in the accessible air exhaust unit.	●●●●	○●		
		Lighting						
		Process Loads	Each classroom is connected to a different circuit breaker which is monitored independently.	M: The data cables for the entire buildings are easily visible and accessible. M: A dumby and identical circuit in the mechanical room shows visitors and students what the inside of a master circuit breaker looks like. M: A dumby circuited breaker in the the hall way shows visitors and students what the inside of an actual circuit breaker look like O: Interpretive signage explains the role the networking wires have in the building C: Each classroom has a seperate and accessible circuit breaker so electrical engineering students can monitor, analyze, and compare the electrical use for each C:Dummy circuit panels allow students to get a feel for resetting a circuit breaker	●●●	●	●●	
	Passive Systems	**Daylighting**						
		Solar Heating						
		Natural Ventilation						
		Cooling						
	Renewable Energy							
	Energy Cascades							
	Environmental Footprint							
	Zero Net Energy							
MATERIALS	**Conservation**			O:A diversity of structural materials are used throughout the building to display the different possibilities of material use.	○			
	Regional Materials							
	Renewable Materials							
	Re-Use, Recycled Content & Recyclability							
	Operational Recycling							
	Cradle to Cradle							
	Zero Net Waste							
INDOOR ENVIRONMENTAL QUALITY	**Natural Ventilation**							
	Low Material Outgassing							
	Limit Indoor Chemicals							
	Occupant Comfort		The building uses a variety of sound dampening strategies to reduce ambient noise and echoes in the open space. These include acoustic tiles, on the walls and under desks, as well as angled white boards.	M: Acoustic dampeners are visibly prominent throughout the interior of the building. O: Signage in the building describes how various acoustic dampening elements and designs are used throughout the buildings to minimize noise disturbances.	○	●		
	Views & Daylight							
WHOLE BUILDING			The building regularly gives tours to community members and schools. There are signs throughout the building that allow visitors to have a self guided tour. Also most of the buildings systems are exposed to allow visitors see how the building functions, these include,			●		

1. Carlson, Lawrence E., interview by Craig Schiller. What was the vision for the ITLL and how is it used as a teaching tool? (2012 18-May).

●	Design Card
●	Image needed to create Design Card
○	Teaching strategy but insufficient for Design Card

Intelligent Workplace

Intelligent Workplace **Carnegie Mellon University**			1997		LEARNING PROCESS			
ENVIRONMENTAL ISSUES			DESCRIPTION OF BUILDING TECHNOLOGY	EDUCATION	MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE	**Ecosystem Site Selection**		Built on top of an existing building	M: the IW was uniquely built on top of an exiting structure with drastically different architecture to make the addition easily visible	●			
	Walkability		Bike racks within building					
	Native Landscaping							
	Agriculture							
	Outdoor Classroom							
	Ecosystem Restoration							
WATER	**Conservation**							
	Storm Water							
	Grey Water							
	Black Water							
	Zero Net Water							
ENERGY	**Total Performance**		Intelligent control system minimizes energy use. The data for the system is stored in large servers within the building					
	Conservation	**Enclosure**	internalized structure allows for wrapping of insulation to eliminate thermal bridging. Highly insulating panels (R44 on roof)1	M: The visible interior structure and the amount of glazing is drastically different from the 'standard' building M: Sections of the windows and insulation are on display so occupants can see and feel a highly efficient double glazed window. O: I sign in the IW explains how the structure was prefabricated and rapidly constructed R: Multiple types of glazing is present in the office to analyze the visual and thermal performance of the different windows.	●●	●		●
		HVAC	Split thermal and ventilation systems. Modular and individually operated water based cooling. Radiant façade with water mullions. Desiccant heat recovery unit and displacement ventilation.1 HVAC is divided between the north and south sections of the building (water in the north, air in the south) for comparison research.	M: The water mullions are easily identifiable on the interior of the façade and they can be easily felt. M: Ventilation shafts are visibly prominent throughout the interior of the space and bring fresh air to each office O: The HVAC system is thoroughly covered on buildings tours and in the building brochure O: The HVAC system is described on a sign in the building R: The components of the ventilation and heating and cooling systems have been a focus for PhD research for the CBPD. One paper found that the entropy wheel reduced heating loads by 77% and 83% heat recover effectiveness	●●	●○		●
		Lighting	T5 Lamps and individually dimmable ballasts, with high efficient reflectors, with reloadable task lights. Daylight spectrum lights and occupancy sensors. Intelligent lighting controls.1	O: A sign in the IW describes the highly efficient lighting systems used in the office. R: PhD research has focused on lighting and lighting controls into the IW		●		●
		Process Loads		M: Exposed data cables under the raised floor	●			
	Passive Systems	**Daylighting**	Building massing and orientation to maximize daylight. Clearstory, north facing windows and a predominantly glass facade. Light redirecting interior blinds, cloth diffusers over head, and dynamic shading devices re-direct light and prevent glare.1	M: During most days the building is 100% daylight providing a drastically different ambiance than most office buildings. M: Internal shading devices are a visibly prominent part of the interior that reduce glare while providing occupant comfort and control. M:External shading devices are visibly prominent along the exterior. C: Course 48-721 Building Control and Diagnostics, several graduate students studied the daylighting control system. R: The daylighting technologies and control systems have been the subject of several PhDs.	●●●		●	●
		Solar Heating						
		Natural Ventilation	Natural ventilation with stack assist/ roof top ventilators[1]					
		Cooling	Natural Cooling with stack assist/ roof top ventilators[1]					
	Renewable Energy		PV on shading devices, small but the roof is designed to have a much larger array installed.[1]	M: The PV panels on the side of the building act as shading devices and move to track the sun. They are also a visibly prominent part of the exterior. M: An inoperable PV panel is located in the office so visitors can see up close and feel the technology. R: The renewable energy technologies, including the photovoltaic array and the solar thermal system have been subjects of numerous research and PhD theses.	●●			●
	Energy Cascades		Water mullions use water heated with waste heat, Heat Recovery[1] Waste heat from biodiesel power into water mullions.[2]	R: Research has been conducted on waste heat being used to heat the water mullions.				●
	Environmental Footprint							
	Zero Net Energy							
MATERIALS	**Conservation**		Structure designed to reduce material use through system integration and reconfiguration. For example, air diffuses are movable.[1] Elimination of caulk due to integrated design[3]	O: A sign talks about the structure and how its was designed to conserve materials.		●		
	Regional Materials		Local fabrication, PPG glass[3]	O: Mention that the materials were fabricated locally on tour.		○		
	Renewable Materials							
	Recycled Content & Recyclability		Prefabrication of materials allows for in-factory recycling. Use of recycled materials. Façade is modular, reconfigurable and designed for assembly/disassembly and re-use (bolted not welded)1 100% recycled steel and Aluminum.3	M: The nuts and bolts of the façade (for easy disassembly) are visible throughout the center.	●	○		
	Operational Recycling							
	Cradle to Cradle							
	Zero Net Waste							
INDOOR ENVIRONMENTAL QUALITY	**Natural Ventilation**		All windows are operable. Natural ventilating with the roof top ventilaters[1]	M: All windows are operable in each office space	●			
	Low Material Outgassing		Material out gassed off-site because they were prefabricated in a factory.[1]					
	Limit Indoor Chemicals		Air Quality sensors continually test air quality in space.[2]	M: An abundance of plants within the space purify air while creating a very comfortable space R: Sensors regularly take air samples to measure air quality, including mold.	●●	○		●
	Occupant Comfort		Individual control of air, light, temperature, and ergonomics. Operable windows in each space.[1]	M: An abundance of plants within the space purify air while creating a very comfortable space M: Individual air-conditioners in each office space C: A course Productively, Health and the Quality of Buildings use the design of the IW as a way to improve occupants' comfort			●	
	Views & Daylight		Enclosure maximized individual access to daylight and view of the natural environment. Also dynamic shading devices and cloth overhangs prevent glare 1	M: Each office has floor to ceiling views. M: There is a vegetated outdoor meeting space with excellent views for occupants to enjoy	●●			
Whole Building			O: tours of the building are given by professors and graduate students. O The office is used to host university classes as well as meetings. O: there is a scale model of the office that displays the details of the building. O: A brochure of the IW contains detailed system and product descriptions R: The building stores all the data from its numerous sensors in a data servers on site			●●●●		●

1. Center for Building Performance and Diagnostics. The Robert L. Preger Intelligent Workplace: A living Laboratory at Carnegie Mellon University. Brochure, Pittsburgh: Carnegie Mellon University.

2. Center for Building Performance and Diagnostics. IW Short Tour. Carnegie Mellon University, 7 5, 2011.
3 Loftness, Vivian, interview by Craig Schiller. Questions about the IW and how it teaches. (July 8th, 2011).

●	Design Card
●	Image needed to create Design Ca
○	Teaching strategy but insufficient for Design Card

Living Learning Center

Living Learning Center Washington University in St. Louis 2009					LEARNING PROCESS			
ENVIRONMENTAL ISSUES			DESCRIPTION OF BUILDING TECHNOLOGY	EDUCATION	MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE		**Ecosystem Site Selection**	Building replaced a parking lot	O: Sign inside that explains the site was previously developed O: Information on the site ranging from biology, geology and fungi can be found on the website. C: Universities come to the site to study its ecosystems (woods, prairie, ponds, and savannas)		● ●	●	
		Walkability						
		Native Landscaping		O: Website has a list of all specs (with photos) found on the site C: universities come to the site to study flora and fauna		●	●	
		Agriculture	The Tyson Summer Seminar Series is held every Thursday thought the summer and food is provided from the adjacent garden.	O: Science lectures are hosted at the center		●		
		Outdoor Classroom	The deck is used as an outdoor classroom and is connected to the interior classroom via a set of large garage doors.	M: The outside deck is often used as a classroom	●			
		Ecosystem Restoration	Part of the Living Building Challenge is a "habitat exchange' the size of the building was purchased by the Nature Conservancy and will remain untouched for the life of the building. Bat houses were building under the eaves and are monitored by bat cams1	O: Bat cams film the bat housed under the eaves.		●		
WATER		**Conservation**				●		
		Storm Water		M: Beautiful rain chain collects water from roof into a cistern for irrigation. O: Sign highlights that the rain garden	●	●		
		Grey Water		O: sign highlights that sink water is from rain water that has been purified		●		
		Black Water	Compost is used in adjacent gardens[2]					
		Zero Net Water	As part of the Living Building Challenge, the center has to be net zero water annuallly[2]	O: Sign that describes the LLC is designed for net zero water		●		
ENERGY		**Total Performance**	Real Time data display of energy production and consumption.[4]	O: Energy output on a real time display monitor in the lobby		●		
	Conservation	**Enclosure**	R-30 roofing and wall systems[4]					
		HVAC	high efficiency HVAC systems[4]	M: Sign explains how the building is heating and cooled as efficiently as possible with efficient equipment, separate zones and ceiling fans.		●		
		Lighting						
		Process Loads						
	Passive Systems	**Daylighting**	Most spaces use daylighting. The building has a E-W orientation for maximum daylighting.					
		Solar Heating	The building has a E-W orientation for maximum solar gain.					
		Natural Ventilation	Seasonal with open garage doors and windows.[4]					
		Cooling						
		Renewable Energy	The center has two sets of PV panels (with a total of 23.1 kw)	M: Two of the panels are prominently displayed in the front of the building and track the sun horizontally and vertically. O: The solar panels are a detailed stop on the tour of the building.	●	●		
		Energy Cascades						
		Environmental Footprint						
		Zero Net Energy	The facility is NET ZERO annually[1]					
MATERIALS		**Conservation**	Building doors were salvaged from and light fixtures came from an old school[1]					
		Regional Materials	Eastern Red Cedar and Red Maple were used in the flooring and siding and taken from within two miles of the building (on the centers site)[1] Structural wood is FSC and came from within 200 miles.	O: Interior sign explains that the siding and the decking come from renewable sources harvested on site.		●		
		Renewable Materials	Eastern Red Cedar and Red Maple were used in the flooring and siding and taken from within two miles of the building (on the centers site)[1]	M: The extensive use of renewable materials on the outside is very visible. They are not as visible on the interior. O: Interior sign explains that the siding and the decking come from renewable sources harvested on site.	●			
		Recycled Content & Recyclability	All furniture in the center is from recycled material, is repurposed or rapidly recyclable.[5]	O: A sign explains that all furniture comes from recycled material and is easily recyclable.		●		
		Operational Recycling						
		Cradle to Cradle						
		Zero Net Waste	100% of construction waste was diverted from a landfill[4]					
INDOOR ENVIRONMENTAL QUALITY		**Natural Ventilation**						
		Low Material Outgassing	As part of the Living Building Challenge, "Red Listed" chemicals are banded banned such as PVC, lead, mercury and voc in all finishes4	O: A sign briefly describes that the Living Building Challenge bans certain materials that are hazardous to humans or the environment.		●		
		Limit Indoor Chemicals	As part of the Living Building Challenge, "Red Listed" chemicals are banded banned such as PVC, lead, mercury and voc in all finishes4					
		Occupant Comfort	Demand control ventilation tied to CO2 sensors.[4]					
		Views & Daylight						

1. Hellmuth, Daniel F., Kevin G. Smith, Deborah Singer Howard, and Matt Ford. "Nature's Way." High Performing Buildings, Fall 2010: 70-78.
2. Washington University in St. Louis. WUSTL's Living Learning Center shares the world's first full "Living Building" certification. 2010 йил 12-October. http://news.wustl.edu/news/Pages/21315.aspx (accessed 2011 йил 15-June).
3. Hellmuth, Daniel F, and Neil Myers. "The Living Learning Center: "One of the Greenest Buildings in the World"." Chicago: School & College Building Expo, 3 14, 2011.
4. Bicknese, Ralph C., and Daniel F. Hellmuth. "LLC Goes Beyond Green." Commercial Building Products. October 2010. https://ilbi.org/about/About-Docs/news-documents/pdfs/llc-goes-beyond-green (accessed July 14, 2011).

●	Design Card
●	Image needed to create Design Card
○	Teaching strategy but insufficient for Design Card

McLean Environmental Living and Learning Center

McLean Environmental Living and Learning Center Northland College 1998					LEARNING PROCESS			
ENVIRONMENTAL ISSUES			DESCRIPTION OF BUILDING TECHNOLOGY	EDUCATION	MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE	**Ecosystem Site Selection**							
	Walkability							
	Native Landscaping							
	Agriculture		There is a community garden adjacent to the MELLC and there is a greenhouse in the dormitory that is cared for by the students	O: A community garden is located on site C: Students maintain the greenhouse in the dormitory. C: Students learn organic gardening principles and manage the community garden adjacent to the building.		●	●●	
	Outdoor Classroom							
	Ecosystem Restoration							
WATER	**Conservation**		two composting toilets, low flow water fixtures[1]	O: The two composting toilets are used for demonstration puprposes2. C: Students maintain the composting toilets and use the fertilzer1		●	●	
	Stormwater							
	Grey Water							
	Black Water		Use of composting toilets as fertilizer					
	Zero Net Water							
ENERGY	**Total Performance**		40% more efficient than code, based on detailed analysis of the first year from 70 monitoring devies3 Roughly 50% when renewable energy is included2	O: Energy Usage data to be shared on the website2 C: Students continue to monitor and compare energy use year to year3. R: CDH Energy Corporation conducted an extensive energy use monitoring project for 1 year.2		○	●	●
	Conservation	**Enclosure**	Attic: cellulose R-value of 45, Wall: fiberglass and foam R-value of 25[4]	C: Students worked with the architects and the Northland College Master Planning Committee to select low-e windows[1]			○	
		HVAC	NO air conditioning, high-efficiency gas boiler for space heating, heat recovery unit in ventilation system.[4]					
		Lighting	T-8 lamps in hallways, CFL in common areas and student rooms, motion sensor lighting controls in common areas[4]	M: Students can see when the lights automatically turn on and off in the hallways due to the motion sensors	○			
		Process Loads	Each apartment as an electric meter to monitor each rooms energy use[2] Highly efficient appliances[4]	M: Residents can see their real-time electrical use O:Students are encouraged to regularly record their electricity consumption	●	○		
	Passive Systems	**Daylighting**						
		Solar Heating	Passive solar design in the south wing[4]					
		Natural Ventilation	Operable windows[4]					
		Cooling						
	Renewable Energy		20 kw wind turbine, three pv arrays (one stationary, one horizontally tracking, and one vertical and horizontal tracking) total of 3.2 kwh, 14 solar water panels2 Renewable energy only provides ~6% of the buildings needs1	M: Both solar and wind energy systems are visibly prominent part of the buildings as well as the college's campus C: The two most prominent pv arrays track the suns movement both horizontally and vertically, dynamically changing throughout the day. C: Students installed Photovoltaic panels on the college's Library	●●		●	
	Energy Cascades							
	Environmental Footprint							
	Zero Net Energy							
MATERIALS	**Conservation**							
	Regional Materials		Cedar shakes on exterior walls and other wood milled from close by[2]	C: students worked with architects and the Northland College Master Planning Committee to select regional materials[2]				
	Renewable Materials		Linoleum floors and bio-compost countertops[1]	C: Students worked with architects and the Northland College Master Planning Committee to select countertops made form bio-compost materials and linoleum floors[1]				
	Recycled Content & Recyclability		Recycled carpet and furniture made from recycled milk jugs and steel[1] Recycled toilet partitions[4]	C: Students worked with architects and the Northland College Master Planning Committee to select recycled carpet, furniture (composed of recycled milk jugs and steel)[1]			●	
	Operational Recycling		Tons of cardboard were recycled on site[3]					
	Cradle to Cradle		FSC hardwoods[2]					
	Zero Net Waste							
INDOOR ENVIRONMENTAL QUALITY	**Natural Ventilation**							
	Low Material Outgassing		Low-VOC carpet (in some areas) and paint[4]	R: The Energy Center of Wisconsin analyzed VOC and CO2 concentrations into eh HVAC exhaust air. Results were the buildings was "generally well-ventilated"4				●
	Limit Indoor Chemicals						●	
	Occupant Comfort							
	Views & Daylight							
WHOLE BUILDING			O: Tours of the C: Students wrote a "Memorandum of Understanding" with over 40 sustainability design priorities focusing on Site, Water, Energy, Materials, and Indoor Environmental Quality.			●	●	

1. Northland College. McLean Environmental Living and Learning Center. http://www.northland.edu/sustainability-campus-initiatives-MELLC.htm (accessed 6 11, 2011).

2. Second Nature. EFS Profiles: Wendy and Malcolm McLean Environmental Living and Learning Center. 2 20, 2002. www.secondnature.org/efs/sdprofiles/northland.htm (accessed 2 24, 2011).
3. Second Nature. EFS Profiles: Wendy and Malcolm McLean Environmental Living and Learning Center. 2 20, 2002. www.secondnature.org/efs/sdprofiles/northland.htm (accessed 2 24, 2011).
4. Bensch, Ingo. Northland College's Environmental Living and Learning Center. Program Evaluation, Madison: Energy Center of Wisconsin, 2000.
5. American College & Univesrity Presidents' Climate Commitment. *Climate Leadership for America: Education and INnovation for Prosperity.* Annual Report, ACUPCC, 2009.

●	Design Card
●	Image needed to create Design Card
○	Teaching strategy but insufficient for Design Card

Phillip Merrill Environmental Center

Philip Merrill Environmental Center Chesapeake Bay Foundation 2001					LEARNING PROCESS			
ENVIRONMENTAL ISSUES			DESCRIPTION OF BUILDING TECHNOLOGY	REASONS FOR INCLUSION	MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE	**Ecosystem Site Selection**		Building built on footprint of existing buildings2 Construction did not touch previously undisturbed parts of the site. Maintained exciting native landscaping and mature trees.3					
	Walkability		Bick racks, showers and changing room, free battery sharing for electric cars, located on sight. 2 Electric, natural gas, and hybrid vehicles are available for use3					
	Native Landscaping		Important to organization[2]	M: There is a beautiful natural wetland that surrounds the building and is protected by a land trust. O: Signs along a path in the wetland highlight native species and describe how the ecosystem works. C: the signs on the wetland path were created by art students from a local university.	●	●	●	
	Agriculture							
	Outdoor Classroom							
	Ecosystem Restoration		Habitats on sight such as, wetlands, meadows, and an underwater oyster reef were restored by planting native trees and underwater grasses. CBF has planted hundreds of trees, shrubs and grasses. Worked with local community to form a local land trust to protect the entire property.1	M: the land around the building is a naturally restored wetland . O: Short description of ecosystem restoration on website called "Healthy Habitats" with a small image. O: Worked with local community to from a land trust to protect the entire property. TOURS?	●	○ 🔴		
WATER	**Conservation**		90+% less water use than comparable office building. Composting toilets use no water at all.1 Water efficient appliances and native landscaping.2	O: Short description of water conservations strategies on website under "Rainwater" and "Composting Toilets". Description of annual savings from water conservations strategies and composting toilet payback on the building's designated webpage. Tours?		🔴		
	Storm Water		Parking spaces moved underground to reduce amount of impervious paving.2 Water from the roof drains through filters into collection cisterns. Outside parking uses permeable pavers.3 A bioretention treatment system is also used (manmade wetlands) to filter water before it flows into a creek.1	M: Rainwater collection cisterns are a prominent element of the building. M:white porous pavement provides a visual contrast to traditional black parking lot pavement. O: Short description of storm water strategies under "Rainwater" and "Bioretention", each with a small image on the buildings designated webpage. TOURS?	🔴 ●	○		
	Grey Water		Rainwater is treated with a sand filter.3 It is re-used for sinks, laundry, mop sinks, fire, desiccant unit make-up, and irrigation.1	O: There are signs over every sink that say "Rain Water Do Not Drink"		🔴		
	Black Water		Composting toilets don't use water, but the compost is used as topsoil for landscaping	O: There are signs over every composting toilet that explain that the toilet uses no water or chemicals and that the waste is being composted		🔴		
	Zero Net Water							
ENERGY	**Total Performance**		The building is 56% better than the national average for similar office buildings, equalizing to an annual savings of nearly $100,0001	O:Annual energy savings compared to average building are listed on the building's designated webpage R: Continuous monitoring by the U.S NREL		🔴		🔴
	Conservation	**Enclosure**	High R-Value SIP panels with foam core insulation that is 4 to 8 inches think[1] R23.5 walls, R30 roof, R20 floor. 0.32 U-value windows with 0.49 sghc[3]	O: Material used in the enclosure are on display in the building to be seen and felt. M:Short description of SIP panels under "Insulated Panels" on the building's designated webpage with a small image.	🔴	○		
		HVAC	Geothermal system used for heating and cooling.2 48 Wells go 300 ft deep and provide one-third of the centers energy needs1 Desiccant dehumidifier and heat recovery wheel3	M:Short description of geothermal wells under "Geothermal Wells" on the building's designated webpage with a small image.		○		
		Lighting	Light Sensors to automatically dim lights when daylighting is adequate.[3]					
		Process Loads						
	Passive Systems	**Daylighting**	Southern window wall lights the entire building, open office layout helps make this possible.1 Also, clerestory windows and appropriate shading devices to reduce glare2	M: Prominent shading trellis along south façade. M: Open interior is beautifully daylight O: Short description of water conservations strategies on website under "Rainwater" and "Composting Toilets".	○ 🔴	○		
		Solar Heating	Orientation takes advantage of solar heating.[2] Heating and cooling systems do not run for 33% of the year.[1]	O: Short description of building orientation and solar heating under "Less Electricity"		○		
		Natural Ventilation	Orientation takes advantage of prevailing winds.2 Sensors determine when the outdoor conditions are appropriate and the HVAC system shuts down and dormer windows automatically open. Also a sign notifies employees that it is ok to open windows. Heating and cooling systems do not run for 33% of the year.1	O: Sensors cue interior signs that notify employees when it is ok to open windows. M:Short description of the sensors linked to the window signals under "Natural Ventilation" on the building's designated webpage with a small image. R: MIT research on the viability of natural ventilation in mid-Atlantic region of the US R: R: Berkeley used the center as a case study in their mixed-mode database to analyze the effectiveness of the natural ventilation and efficient heating and cooling strategies	🔴	○		🔴 🔴
		Cooling						
	Renewable Energy		PV system and solar water heating system.1 Solar hot water system provides all the hot water for the center. PV provides about 30% of the of the buildings electrical needs	M:Short description explains the building has both a PV and solar water system under "Solar Power" on the building's designated webpage with a small image.		○		
	Energy Cascades							
	Environmental Footprint							
	Zero Net Energy							
MATERIALS	**Conservation**		SIP panels use a faction of the wood needed in conventional framed structures.[1]	M: Material used in the enclosure are on display in the building to be seen and felt BUT no connection to sustainability other than very brief labels. O:Short description how SIP panels use less materials is under "Insulated Panels" on the building's designated webpage with a small image.	○	○		
	Regional Materials		50% from within a 300-mile radius.[2]					
	Renewable Materials		Cork flooring and wall panels regenerate in 7-9 years, bamboo in stairs and lobby flooring can be harvested every 3-5 years, posts, beams, and trusses are made from Parallam (strand lumber from fast grown wood)1	M: There is an abundance of renewable materials used on the interior of the building that are visually prevalent. O:Short description what renewable materials were used is under "recycled and renewable materials" on the building's designated webpage with a small image.	🔴	○		
	Recycled Content & Recyclability		Galvanilume is made from recycled steel panels and used for siding and roofing; ceiling tiles are 78% recycled mineral wood and cellulose fiber; rebars are 95% recycled steel; particle board is 100% recycled wood fiber1	M: Material used in the enclosure are on display in the building to be seen and felt BUT no connection to sustainability other than very brief labels. O:Short description what renewable materials were used is under "recycled and renewable materials" on the building's designated webpage with a small image.	○	○		
	Operational Recycling							
	Cradle to Cradle		Wood in the building is all FSC.[1] All existing structures on sight were re-used for materials[2]					
	Zero Net Waste							
INDOOR ENVIRONMENTAL QUALITY	**Natural Ventilation**		Carbon dioxide monitor and automatically controlled operable windows.2 Sensors detect when the conditions are favorable outside and turn on indicator lights so employees know they can open the window.3	M: Sensors cue interior signs that notify employees when it is ok to open windows. O:Short description of the sensors linked to the window signals under "Natural Ventilation" on the building's designated webpage with a small image. R: MIT research on the viability of natural ventilation in mid-Atlantic region of the US R: Berkeley used the center as a case study in their mixed-mode database to analyze the effectives of the natural ventilation and efficient heating and cooling strategies	🔴	○		🔴 🔴
	Low Material Outgassing		Materials with low or no VOC were chosen, such as flooring, paints and adhesives[1]	M:Short description of material off gassing under "material off gassing" on the building's designated webpage with a small image. TOURS?		○		
	Limit Indoor Chemicals							
	Occupant Comfort		Extensive shading devices to control glare[3]. In-depth post-occupancy evaluation of human factors[2]	M: visually Prominent shading devices on south façade prevents glare into the office. O: Extensive post-occupancy survey conducted by MIT. R: MIT studied the of the effects of IEQ on worker productivity, comparing the building against national averags.3	○	●		●
	Views & Daylight		Extensive windows, views of Chesapeake Bay[2]	M:Extensive views and windows facing the Chesapeake bay	🔴			
WHOLE BUILDING			O: The center regularly gives tours to industry professionals and school groups. O: The center brings non-environmental people into the center to experience a green buildings through by hosting events (corporate retreats, conferences, weddings). The center even has its own designated wing to host the events. R: The center has been used as a high-performance case study by several leading institutions such as NREL and University of California at Berkeley.			🔴 🔴		🔴

Chesapeake Bay Foundation. The Philip Merrill Center: CBF's Headquarters. 2012. http://www.cbf.org/Page.aspx?pid=389 (accessed 3 13, 2011).

U.S. Department of Energy. *The Chesapeake Bay Foundation's Philip Merrill Environmental Center.* 8 15, 2002. http://eere.buildinggreen.com/overview.cfm?projectid=69 (accessed 5 17, 2011).
B. Griffith, M. Deru, P. Torcellini, P. Ellis. Analysis of the Energy Performance of the Chesapeake Bay Foundation's Philip Merrill Environmental Center. Technical Report, Golden: National Renewable Energy Laboratory, 2005.

🔴	Design Card
●	Image needed to create Design Card
○	Teaching strategy but insufficient for Design Card

Sidwell Friends Middle School

SIDWELL FRIENDS MIDDLE SCHOOL SIDWELL FRIENDS SCHOOL 2006					LEARNING PROCESS			
ENVIRONMENTAL ISSUES			DESCRIPTION OF BUILDING TECHNOLOGY	EDUCATION	MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE		Ecosystem Site Selection	Addition to existing building. Built over a previous parking lot[1]	O: Mentioned briefly on building's website		○	●●	
		Walkability	Underground parking lot covered with a green roof. $35 incentive to staff who drive 80% less[2]	M: It is obvious that some of the parking is underground but not obvious as to the benefits	○			
		Native Landscaping	Areas converted to 'micro-restoration' space that showcase native ecosystems. Over 80 regional species planted.2 Many native species planted on the green roof, biology bond, and constructed wetlands.1	M: Students can experience the seasonal changes of over 80 different regional species through sight and smell. O: The building's designated website lists some of the species and their location	●	●		
		Agriculture						
		Outdoor Classroom	Biology pond acts as an outdoor classroom where students can examine species	C: The biology pond, the green roof, and the constructed wetlands were designed specifically to be used as an outdoor classroom	○	○		
		Ecosystem Replacement	Natural pathways were created to allow fauna to travel between the site's adjacent watersheds. Constructed wetlands and green roof with native species acts as habitat for birds and insects1 Greenroof "component of science curriculum"2 The buildings grounds are certified wildlife habitat by the National Wildlife Federation.4	M: Native floura and fauna can be seen throughout the grounds. O: Description of each constructed habitat can be found on the building's designated website. O: All wildlife sighting on the grounds are documented on the buildings website. C: The 8th grade environmental science class studies all the buildings green systems and strategies.	●	●●		
WATER		Conservation	93% less water is used treating sewage on site and through water efficient landscaping using native plants1 Also sensor operated bathroom faucets are used2	O: The building details how much water it is saving through conservation measures in real-time through the buildings designated website		●	●	
		Stormwater	Green roof diverts water to a biology pond and rain garden. Storm water flows through a bioswale to rain garden. Hard surface runs through a filter to a constructed wetland. Greenroof "component of science curriculum"2. students study plants, animals, and microorganisms in the biology pond1	M: An aeration course visually connects the storm water collected on the roof to the biology pond. O: Designated website, has a virtual tour that describes and connects each part of the storm water management system. R: Students researched the what happens to the storm water at Sidwell and created a PowerPoint that is on the website	●	●		●
		Grey Water						
		Black Water	Additional filtration of wetland water and UV filter clean water to city municipal quality, but due to health coeds, water is only used in toilets and urinals1 Water is also used in cooling tower.2	M: Re-used black water is dyed blue to identify it comes from a re-used source. O: Real time wastewater flow data displayed on website. O: Each part of the black water system is explained and identified in the buildings virtual tour. O: Sign wrapped around the trickling filter describes the waste water system C: The 8th grade environmental science class studies all the buildings green systems and strategies.	●	●●●		
		Zero Net Water						
ENERGY		Total Performance	60% less energy than comparable building meeting the minimum ASHRAE 90.1-1999 requirments.[1] 45% less than a building of same size and oreientation.[3]	O: Total building performance is briefly mentioned in the buildings over view on the website		○	●	
	Conservation	Enclosure	Roof, walls, and windows are 200% better than ASHRAE standards2. Prefabricated R-30 walls.3 Exterior Light shelves and Low-e Windows and Vertical Solar Fins, green roof, and reflective roof1	M: The building has a lot of different pieces to the façade but not particularly to increased performance. O: The Designated website has a virtual tour that describes the different parts of the enclosure that are high performance	○	●		
		HVAC	Cooling tower and Heat Recovery Wheel are used to increase efficiency[1]	O: The Designated website has a virtual tour that describes both the cooling tower and the heat recovery wheel and how they increase performance		●		
		Lighting	Occupancy Sensors. Dimming ballasts to ensure light is only used when daylight is insufficient. Highly efficient bulbs.[2]	O: The Designated website has a virtual tour that describes the occupancy and photo sensors that reducing interior lighting use		●		
		Process Loads						
	Passive Systems	Daylighting	Interior light shelves. Horizontal and Vertical shading devices on SO, E & W sides of building[1]	M: The buildings numerous horizontal and vertical shading devices are a prominent part of the façade. O: The virtual tour on the website describes how each type of shading devices works.	●	●		
		Solar Heating						
		Natural Ventilation	Solar chimneys are a dedicated outdoor-air vent. System[2] That are linked to science classrooms and window sensors, have windchimes![1]	M: The solar chimneys are a prominent part of the roof top and wind chimes in the ventilation shafts create music when the solar chimneys create a convection cycle. O: The virtual tour on the website describes how the solar chimneys work.	●	●		
		Cooling						
		Renewable Energy	PV array generates 5% of building[1]	M: Solar panels are a prominent part of the roof but not visible unless you have roof access. O: An explanation of the PV system can be found not the buildings virtual tour. O: Real-time data of electricity produced is shows on the buildings website. C: The 8th grade environmental science class studies all the buildings green systems and strategies.	○	●●		
		Energy Cascades	Centrally located power plant for entire school campus[2]					
		Environmental Footprint						
		Zero Net Energy						
MATERIALS		Conservation	Many reclaimed materials such as: cladding from 100 yr old western cedar wine barrels, flooring and decking from Baltimore Harbor pilings, and stone.[2]	M: The façade of the buildings is made up of refurbished materials and looks drastically different than a typical building. O: The virtual tour highlights what parts of the building are made of refurbished materials.	●	●	●	
		Regional Materials	78% of the materials in the building were manufactured within 500 miles. A list of all material manufactures and installers are listed on the website.1	O: The buildings website lists all the materials that came from regional manufactures, which promotes local business and material use		●		
		Renewable Materials		C: Students study each aspect of the buildings systems in their environmental science class, but images are needed				
		Recycled Content, Recyclability & Reuse	11% of the buildings materials are from recycled sources[1]	O: The virtual tour of the classroom highlights materials that come from recycled sources.		●		
		Operational Recycling	60% of construction waste was diverted from landfills and recycled[1]	buildings website R: Students researched where the trash from Sidwell goes and created a PowerPoint that is on the website		○		●
		Cradle to Cradle	FSC wood was used.[1] LCA studies conducted[2]	O: One of the highlighted items in the virtual tour briefly mentions that some of the wood comes from certified sources		○		
		Zero Net Waste						
INDOOR ENVIRONMENTAL QUALITY		Natural Ventilation	Solar chimneys on roof create a convection current that draws in air from open windows.[2] Air is drawn threw vertical shafts in the buildings which have air chimes built in them. When windows are opened in some classrooms the HVAC shuts off. Operable windows in every room.[1]	M: Solar chimneys are a prominent part of the roof. O: The virtual tour descries the air handler system and the solar chimneys and how they optimize fresh air.	●	●		
		Low Material Outgassing	Low VOC carpets, paints, glues and adhesives[1,2]	O: Virtual tour descries some of the materials that are low-VOC		●		
		Limit Indoor Chemicals	Walk-matt at each entrance, all cleaning products are Green Seal Certified[1]	M: Walk-off mats at each entrance O:Website specific to green housekeeping practices.	○	●		
		Occupant Comfort	CO2 monitoring in each room that is connected to the HVAC that automatically adjusts its fresh air delivery.[1]	M: small CO2 monitors in each room. O: Virtual tour highlights how the CO2 monitors ensure proper ventilation	○	●		●
		Views & Daylight	Optimal use of daylight in classrooms is used. School is participating in a study of green buildings to confirm optimal daylighting = health, happiness, and improved learning. Skylights are also used in some rooms.1	O: Virtual tour highlights that maximizing natural daylight and bringing nature closer in views was a design priority		●		●

1. Sidwell Friends School. *MS Green Building.* http://www.sidwell.edu/middle school/ms-green-building/index.aspx (accessed 2011).
2. U.S. Department of Energy. Sidwell Friends Middle School. 10/7/2011. http://eere.buildinggreen.com/overview.cfm?projectid=775 (accessed 2011).
3. Kierantimberlake. Middle School, Addition and Renovation. 2011. http://www.kierantimberlake.com/featured_projects/sidwell_school_1.html# (accessed 5 31, 2011).
4. Selby, Sally, interview by Craig Schiller. Questions about Sidwell Friend's Green Middle School (6 13, 2011).

●	Design Card
●	Image needed to create Design Card
○	Teaching strategy but insufficient for

The Phipps Conservatory Welcome Center

The Phipps Conservatory Welcome Center **The Phipps Conservatory**			**2006 (1893 original structure)**		**LEARNING PROCESS**			
ENVIRONMENTAL ISSUES			DESCRIPTION OF BUILDING TECHNOLOGY	EDUCATION	MULTISENSORY	OUTREACH	CURRICULAR	RESEARCH
SITE	**Ecosystem Site Selection**							
	Walkability							
	Native Landscaping		Drought resistant lawn reduces water consumption by 81%					
	Agriculture		The new Center for sustainable Landscapes will produce its own food.	O: The Phipps hosts a weekly farmers market on its grounds O: The Phipps is also a CSA pickup site		●●		
	Outdoor Classroom							
	Ecosystem Restoration							
WATER	**Conservation**		Highly efficient water fixtures such as waterless urinals	O: small signs near the waterless urinals explain how they work O: Website has small amount of information about the water efficient fixtures.		●○		
	Stormwater		Front lawn is planted over porous geoblock					
	Grey Water							
	Black Water							
	Zero Net Water							
ENERGY	**Total Performance**		The Welcome Center saves nearly 40% in energy costs compared to comparable buildings. A integrated computer control system and a solid oxide fuel cell converts natural gas into electricity with remarkable efficiency. The computer system is tied to weather data and opens and closes vents according to external and internal conditions.	M: The energy cell is displayed in a highly visible location. O: There is an interactive kiosk next to the fuel cell that provides detailed information about the buildings green energy design and the fuel cells function.	●	●		
	Conservation	**Enclosure**	12,000 sf of double paned roof glass, half of which opens through a computer controlled system. Thermal mass is located on the NW and NE walls. Green roof over the support facilities help insulate the building.					
		HVAC	A integrated computer control system and a solid oxide fuel cell converts natural gas into electricity with remarkable efficiency. The fuel cell provide 5kW of energy and the waste heat is used for the tempered water system. Radiant root zone heat for plants and radiant heat for visitors.1					
		Lighting						
		Process Loads						
	Passive Systems	**Daylighting**	The atrium has a fritted glass dome that reflects light throughout the day.	M: the glass dome provides a beautifully daylight space.	●			
		Solar Heating	thermal mass is located on the NW and NE walls to collect heat during the day and release it at night.	O: Website has a small amount of information about the buildings efficient lighting design		○		
		Natural Ventilation	Earth tubes are coupled with a roof ventilation system in the Tropical Forest Conservatory					
		Cooling	Earth Tubes (six 24 inch diameter 300 foot long tubes) bring fresh earth cooled air at a constant 55 degree temp. Earth tubes also partially heat the incoming air in winter. 12,000 sf of double paned roof glass, half of which opens through a computer controlled system to eliminate the greenhouse effect.1					
	Renewable Energy		100% of the electricity is offset by renewable sources.	O: website has a small amount of information about renewable energy purchasing.		○		
	Energy Cascades		Waste steam is piped under the sidewalks to de-ice them during the winter.					
	Environmental Footprint							
	Zero Net Energy							
MATERIALS	**Conservation**							
	Regional Materials		Locally milled limestone	O: The website has information about the buildings recycled and regional material use.		●		
	Renewable Materials		Bamboo flooring					
	Re-Use, Recycled Content & Recyclability		Recycled steel and glass. 100% recycled paper towels	O: Small signs explain how the paper towel is 100% recycled		●		
	Operational Recycling		Onsite recycling and composting program. Paper, plastic, glass, cans and cardboard are recycled. All post-consumer food waste is composted. All plates, and utensils, are vegetable based and compostable.	O: Excellent signage over the waste bins to show patrons which products are recyclable and compostable. The sign has actual pictures of the products used.		●		
	Cradle to Cradle							
	Zero Net Waste							
INDOOR ENVIRONMENTAL QUALITY	**Natural Ventilation**							
	Low Material Outgassing		Low or no VOC paints, adhesives, and carpets.					
	Limit Indoor Chemicals		Green Seal Cleaning products	O: Website has small amount of information on low or no VOC materials.		○		
	Occupant Comfort			M: The large amounts of glass create an inviting and comfortably daylight space that is very popular with visitors.		●		
	Views & Daylight							
WHOLE BUILDING			O: The Phipps Conservatory has and education and outreach program in which they give tours and hold workshops that connect the Phipps with curriculum standards. O: The website has a lot of information on why the Welcome Center's sustainable design features and the green building practices of the Phipps Conservatory. O: The website has an excellent video that highlights the green building features. O: The Phipps hosts corporate events and retreats to bring community members into the building. C: The Phipps offers field trips and green tours to school groups and makes a connection to state curriculum and education standards.			●●●	●	

I

1. Ogrodnik, Kelly, interview by Craig Schiller. *How is the Phipps used to teach sustainability?* (8 17, 2011).

●	Design Card
●	Image needed to create Design Card
○	Teaching strategy but insufficient for Design Card