A rationale, conceptual framework, and initial curriculum for teaching green building

Jason Ernest Moyer-Schmit

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A RATIONALE, CONCEPTUAL FRAMEWORK, AND INITIAL CURRICULUM FOR TEACHING GREEN BUILDING

A Project
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in
Education:
Environmental Education

by
Jason Ernest Moyer-Schmit
June 2008
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Jason Ernest Moyer-Schmit
June 2008

Approved by:

Dr. Darleen Stoner, First Reader

Dr. Thom Gehring, Second Reader

May 27, 2008 Date
ABSTRACT

This project created a rationale and conceptual framework, as well as seminal curriculum, for teaching green building as a vehicle for environmental education in seventh and eighth grades. The conceptual framework incorporates selected California Science Standards. Green building is the practice of creating sustainable structures, and preserving natural resources and ecological conditions for future generations. Environmental education requires students to be aware of their local surroundings, be knowledgeable of issues, and acquire skills to take action within a community. The foundational concepts in green building and environmental education are shown to be interrelated and tied to a common curricular format. The six lessons utilized constructivist pedagogy, a fundamental practice in teaching environmental issues. Action projects are included as a form of performance assessment.
ACKNOWLEDGMENTS

First and foremost, I must thank Dr. Darleen Stoner for her leadership and insight in environmental education. Through her guidance, I believe I have found my pedagogical niche. I would like to thank Dr. Thom Gehring for sharing his wisdom and experiences to his students. His perspectives on education and society are very endearing. Last, but certainly not least, I must thank my wife, Amy Moyer, for her patience, understanding, and endurance. She spent a lot of nights and days alone as I trekked back and forth to school, went off to do field work, or encapsulated myself in the den.
DEDICATION

To the people of Lake Wobegon, my hometown...

"where the women are strong, the men are good
looking, and all the children are above average."

~ Garrison Keillor
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CHAPTER ONE
INTRODUCTION

While watching the numerous housing developments go up near my home in Twentynine Palms, California, I would see large piles of waste, poor development of building sites, and as reported by some of the new residents, the craftsmanship was of low quality. Judging by the number of television shows dedicated to the topic, the business of remodeling and property flipping had become quite popular. In every incidence, large amounts of material were removed and sent into the local waste stream simply because it did not fit the fads of the time. My frustrations with the aforementioned events were overturned when I learned a proposed observatory and educational facility would utilize green building techniques. During discussions with the managers, it was mentioned how the project could be used to teach the public about sustainable building practices. Being a junior high school science teacher, I realized then the compatibility of teaching the concepts of green building and the science curriculum in the public education classroom, as well as the benefits it would have to students and the local environment.
It is imperative for a community to recognize the needs of the group and promote practices required to perpetuate the whole, including the maintenance of a healthy environment. Armstrong, when reflecting upon the beliefs of the Okanagan culture stated it well when he wrote, “To the Okanagan people, as to all peoples practicing bioregional self-sufficient economies, the realization that the total community must be engaged in order to attain sustainability comes as a result of surviving together for thousands of years” (2005, p. 12). Armstrong, of course, was referring to an indigenous culture holding on to ancient values and beliefs. Their idea of community “encompassed a complex holistic view of interconnectedness” (p. 13). When applied to the decisions and actions of the human population, these practices demand our “responsibility to everything we are connected to” (p. 13).

Building a new home today requires many decisions and a great deal of resources. First, one must consider where the building will be placed and how it will be situated. The home must be designed to meet a full range of functions whether it is meant to satisfy the needs of a single person or a large family. Such considerations are also extended to facilities harboring business and
industrial activities. Decisions regarding the materials to be used for the dwelling’s construction, diverse in the vast home improvement market, are based upon economic factors and personal preferences. The types of relevant resources for the access of required utilities, such as water, gas, and electricity, are also as varied. Finally, consumers are faced with an endless list of choices to satisfy their desire for basic amenities and modern conveniences. Each building for a family, business, and industry is different. They have different needs, reside in diverse settings, and are exposed to various climates. With all of the decisions involved in producing a building, one might suspect an infinite number of structural forms all across the earth.

Very few people get the opportunity to comprehensively design their living space. Homeowners seem to mostly rely on a set number of floor plans and colors. Many of their needs may be met, but possibly not as many had they been greater participants in their home’s design. In the end, one home or building looks much like the one next to it.

Traditional or modern home construction refers to the style of building that has evolved over the past few centuries. Such structures are built in a similar fashion;
they are generally erected with a timber frame over a stone or concrete foundation. The tops of these modern dwellings are covered in some form of shingling, and the interior is shielded from the weather using more lumber, plaster, masonry, or a combination of the three. As time has gone on, new technologies aimed to save the homeowner money have also promoted a type of materialism, which can misguide consumers from the impacts their choices have on the environment. However, as evidenced by the increasing number of environmentally-friendly, or “green,” building materials and products, the realized effects of home construction on local and global ecosystems are increasingly factored into building decisions.

Modern home construction is a creation of our capitalistic perspective. The U.S. economy is often measured by the number of properties being purchased and sold. As such, when the market is flourishing, new housing developments begin to take over a landscape like wheat across an open field. “A modern house is designed to be mass-producible and serviceable with standardized parts so that it can be easily constructed, sold, altered, and resold” (Snell & Callahan, 2005, p. 19). Under these conditions, a great deal of environmental degradation becomes increasingly evident. Recently, there appears to
be an overwhelming swell of information about constructing green buildings.

The goal of this project was to develop a rationale and curricular framework for teaching green building practices to students in grades 7 and 8. Aligned with relevant State Science Standards and California’s approved Environmental Principles and Concepts, several sample lessons were created as a model for possible future curriculum on green building. This new conceptual framework, in Chapter Four, provides a basis for ensuring the applicability of the lessons to develop an understanding of environmental concepts associated with green building.

Curriculum involving green building is intended to promote problem solving, environmental education, and hands-on learning opportunities in core academic subject areas. Problem solving is the essence of a green building curriculum. Students can analyze the changing demographics of local and global populations in their social science classes. They can evaluate their own perspectives, as well as analyze the pros and cons of available technologies relevant to sustainable architecture. Whether a particular building practice is a viable solution to a particular problem does not necessarily need to be answered, but
students should attain an increased knowledge to make more effective decisions in their future.

In the process, students can present their knowledge to the general public, which may result in a change, by favoring more environmentally friendly practices regarding the construction of new homes. This can be accomplished by way of an action project. According to Stoner, action projects are "any activities that get students involved in tackling an environmental issue or problem, or that aim at improving an environmental setting" (2003, p. 2). In addition, action projects "are often most successful when they’re focused on the local community" (p. 2).

Students need to learn now about environmentally friendly home construction. "We need a school-reform model that focuses on the principle of sustainability - figuring out how to live within our means on at both a local and global level" (Sobel, 2005, p. 16). Compromises between the needs of the public and the environment can be made, but a knowledgeable citizenry is required to make the most effective decisions about these issues. Through the implementation of a diverse curriculum centered on constructivism and action can this be accomplished. In doing so, current and future populations can occupy
buildings in a mindful manner with regard to environmental preservation.

A curriculum based on research and solving problems must continually evolve and provide a product made available to the public. Everyone is different. Some individuals may enter a green building curriculum with some knowledge of the topic; some may not even know how a home is assembled. In addition, there may be some students with misconceptions regarding the topic of sustainability. A constructivist model of education will adequately combine the preexisting knowledge among class members into a more understood view of the issue and problems involving green architecture.

This project provides a rationale, conceptual framework, and sample curriculum for teaching green building practices in the classroom. Chapter Two is an overview of the numerous problems associated with traditionally built structures (those most widely used) including impacts on local and global environments and public health. A review of green building techniques is then presented as a solution to the aforementioned problems. A summary of relevant literature in the field of environmental education follows. Variables for environmental literacy, curriculum development,
constructivism, action projects, and a call for educational reform are covered in Chapter Three. A connection between topics in environmental education and green building is established, along with the conceptual framework is presented in Chapter Four. A brief description of possible lessons then ensues.
CHAPTER TWO
GREEN BUILDING AND DESIGN

Introduction

Green building "refers to an attempt to consciously create buildings with an eye to how they interact with our planet's ecosystems" (Snell & Callahan, 2005, p. 17). This definition has a broad meaning relative to the perspectives of those attempting to practice such techniques.

For some, it means focusing on creating a healthy indoor environment inside buildings. For others, it makes sense to focus on improving the mass-produced materials that predominate in modern construction. For still others, it's about eschewing mass-produced components and centralized systems altogether in favor of site-harvested resources, including building materials, electricity, water, and food. (p. 17)

A more simplistic definition could be the use of building techniques, materials, and maintenance to meet the needs of its inhabitants while minimizing the relevant impacts on the environment. In essence, the concepts of green building become a context for a culture focused on sustainability. In accordance with this definition, the
failures of traditionally constructed buildings must be considered.

This chapter will first examine the problems associated with the more popular methods for constructing buildings during recent years. A definition of sustainable development is then outlined. A review of the basic objectives required from any structure follows. Green buildings meet those needs while minimizing impacts made on the environment. The traits of a green building are finally presented. Such practices could alleviate the problems and issues associated with traditional home construction methods.

Problems with Current Construction Methods

"Construction workers turn some 3 billion tons of raw materials - 40 percent of the total flow into the global economy - into buildings each year" (Roodman & Lenssen, 1995, p. 22). Such a demand for natural resources can stress habitats and global ecosystems. As demanded by the laws of thermodynamics, when energy is being used some type of product, including waste, reveals itself. Unfortunately, not all of the results of such work are conducive to a healthy environment. Because of these influences, modern home construction and its contributing
industries inflict a great deal of damage to the environment.

The world's lumber supplies are greatly affected by modern building practices. Construction "accounts for more than a quarter of the world's 3.5-billion-cubic-meter appetite for wood" (Roodman & Lenssen, 1995, p. 22). Fifty percent of the timber harvest in North America alone goes toward the construction, maintenance, and demolition of buildings (State Environmental Resource Center, 2007, Introduction, para. 1). Because of this, the global forest coverage has shrunk by a fifth over the last hundred years (Roodman & Lenssen, 1995, p. 23). Since these stretches of vegetation have been cleared, adjacent regions are more susceptible to the effects of flooding, increased siltation, and the loss of habitat. "These changes have eliminated thousands of plant and animal species and have destroyed the homelands of many indigenous peoples" (p. 23). The destruction of habitat is not the only result of this hunger for lumber. Many nations have "exceeded their domestic capacity to supply wood and have taken to importing large amounts" (p. 24). Wood is considered a low-impact material relative to its impact on the environment. But in addition to the over extensive
harvesting of this resource, the increased distances it is transported requires more energy.

According to the State Environmental Resource Center, 45% of the world’s energy use is somehow related to the fabrication of modern buildings (2007, Introduction, para. 1). Contributors to this total not only include the shipping of non-localized resources, but also the manufacturing and processing of products needed for home construction.

Many substances, whose strength, transparency, and electrical conductance making modern buildings possible require a great deal of processed energy (Roodman & Lenssen, 1995, p. 26). For example, the virgin production of domestically harvested lumber for construction requires 4-5 gigajoules of energy per ton. Steel, on the other hand, uses 25 to 45 gigajoules; plastics use 80 to 220 gigajoules; and aluminum consumes 150 to 220 gigajoules of energy (p. 27).

“Buildings in operation do far more damage than buildings under construction, drawing heavily on energy...flows” (Roodman & Lenssen, 1995, p. 24). In 1992, approximately 34% of the total manufactured energy in the United States was being consumed by inhabited structures (p. 24).
Waste Products Generated

From the culmination of the individual parts to the final product, the housing industry releases numerous waste products: solid waste and air pollutants. Consequently, these byproducts cause degradation of the environment.

Whenever a new building is erected, solid waste is produced, including leftover lumber, concrete, bricks and stone, sheetrock, and other materials removed from any given construction site. In fact, 40% of the solid waste entering landfills comes from the fabrication or renovation of human structures (State Environmental Resource Center, 2007, Information, para. 1). The erection of a "typical, 160-square-meter, 150-ton home in the United States generates some 7-tons of refuse" (Roodman & Lenssen, 1995, p. 24).

The problem of solid waste is compounded by the decreasing number of landfills. The problem is more noticeable in the Northeast; most states in this region have to ship their wastes to other parts of the country (Austin, 1991, p. 53). In addition to the increasing tipping fees and transportation costs, the need to carry debris elsewhere contributes to the air pollution problem (p. 53). Landfill owners are also recognizing the toxicity
of construction waste, causing them to disallow such substances in order to avoid regulatory fines (p. 53). The chemicals in question can leach into the ground polluting both soil and groundwater sources.

Modern buildings also contribute heavily to the problems associated with air pollution. Approximately 50% of the chlorofluorocarbons (CFCs) are generated from traditionally built structures (State Environmental Resource Center, 2007, Fact Pack, para. 1). One of the major contributors to the supply of this ozone-depleting chemical, some scientists say, is polystyrene insulation. This building byproduct may be responsible for up to 40% of the harmful CFCs released into the environment (Austin, 1991, p. 52). Atmospheric ozone is needed for the filtering of harmful ultraviolet radiation from the sun. As this protective layer deteriorates, the incidence of skin cancers and other endemics can increase.

In addition to CFCs, modern buildings are responsible for 30% of the greenhouse gas emissions contributing to both global warming and acid rain (State Environmental Resource Center, 2007, Introduction, para. 1). Not only are these pollutants the result of daily operation modern buildings, but also from the mining, processing, and manufacturing of materials involved in their synthesis.
"Of the copper employed in U.S. buildings (nearly half of the total used in the country), some is recycled material, but 80 percent is extracted and...purified through a process that is one of the largest sources of air pollution in the country" (Roodman & Lenssen, 1995, p. 22). Plastics made from polyvinyl chloride (PVC), used in siding, piping, and windows, also contribute to the problems associated with our atmosphere. These products are very difficult to recycle and their "production and incineration (if that is how it is disposed of) generate carcinogenic dioxins, vinyl chloride monomers, and other pollutants" (p. 22). The processing of metals and production of plastics dole out pollutants to the external environment, but our indoor spaces also possess airborne problems.

Many "modern buildings also create dangerous indoor environments for their inhabitants" (Roodman & Lenssen, 1995, p. 25). According to Roodman and Lenssen, an estimated 30% of new or renovated dwellings suffer from "sick building syndrome" (p. 25). In a quest to maintain an indoor homeostasis, ventilation systems are often installed to control both the temperature and quality of the air. The occupants, however, are subjected to captured, stale air-harboring diseases and molds (p. 25).
To keep climate-controlled air inside, many modern buildings are tightly constructed. As a result, volatile organic compounds (VOCs) seeping "from composite materials, furniture, carpets, and paint...accumulate at concentrations hundreds of times higher than those just outside" (Roodman & Lenssen, 1995, p. 25). Aside from persistent headaches and nausea, long-term "exposure to VOCs may increase the risk of cancer and immune disorders" (p. 25). Thus the modern building can be hazardous to our environment and, in turn, our health.

**Increased Size and Number of Homes**

The average house size has been expanding since World War II (Roodman & Lenssen, 1995, p. 8). This phenomenon continues in industrialized nations even as the average family size has declined. "In the United States, floor space per person more than doubled in new single-family houses between 1949 and 1993" (p. 8-9). Modern homeowners are more grand and materialistic in their ideals regarding their estate. People want media rooms, larger kitchens, a family room, a living room, and numerous bathrooms and bedrooms (p. 9). Though consumers get more of what they want in modern buildings, these structures "are less desirable than they could be" (p. 9). Adding to the impact of increased size is the rise in the number of homes due
to escalating human populations. To meet the needs of our increasingly numerous and expansive domains, a greater demand on natural resources results during the life of new homes.

**Increased Demand on Natural Resources**

Modern structures impact the environment by overusing natural resources during construction and maintenance. “Buildings account for one-sixth of the world’s fresh water withdrawals, one quarter of its wood harvest, and two fifths of its material and energy flows” (Roodman & Lenssen, 1995, p. 5). Renewable resources, such as trees and air, can be regenerated naturally within the Earth’s biosphere. However, these critical components can be consumed more rapidly than they can regenerate; “overexploitation” of these resources would take place (Jacobs, 1991, p. 4). Trees, the major provider for building materials, are susceptible to excessive harvesting. Other resources, both renewable and nonrenewable, can be exhausted through modern construction methods.

Earth’s potable water supplies, renewable through the biosphere’s hydrologic cycle, can be greatly diminished by human structures. Buildings account for 80% of our world’s potable water (State Environmental Resource Center, 2007,
Introduction, para. 1). The United States (U.S.) uses more water on average per person than anywhere else in the world (Fact Pack, para. 2). Nonresidential water usage in the U.S. “accounts for 53% of our total water use, of which 70% is devoted to commercial, institutional, and industrial buildings” (Fact Pack, para. 2). An average U.S. citizen uses three times more water than the typical citizen of Europe and “nearly seven times the per capita average of the rest of the world” (Fact Pack, para. 2).

Every increase in square footage of a house requires a proportional rise in energy demands. Currently, more than 50% of U.S. electrical needs are derived from the combustion of fossil fuels, the majority being coal (LPS Industries, 2006, Current Fuel Mix for U.S. Electricity Generation). Coal fired power plants are a major source of pollutants like sulfur dioxide, nitrogen oxides and other particulates (Montana Environmental Information Center, 2006, para. 5). They are the primary source of the carbon dioxide emissions partially responsible for global warming (para. 6). Nationwide, coal burning plants are “responsible for over 40% of the mercury” entering the air (para. 4). A potent neurotoxin, mercury disrupts fetal development, causes neurological disorders, visual and hearing impairment, and cardiac diseases (para. 4).
The mining of coal is also costly with regard to water resources. "As ground water percolates through reclaimed spoils it becomes contaminated with all sorts of previously unavailable chemicals" (Montana Environmental Information Center, 2006, para. 12). Attempts have been made to restore surface waters affected by mining operations, but such efforts have been deemed superficial with little knowledge regarding long-term viability (para. 12). "Over 120 sites across the country have contaminated surface and ground water due to improper disposal of ash from coal-fired plants" (para. 14). In addition, three Superfund sites, areas established by the Federal government for required environmental clean-up, exist as a result of this electrical generation source (para. 14).

Modern buildings "often wear out quickly, wasting resources, money, and human labor" (Roodman & Lenssen, 2005, p. 9). To increase productivity and capitalize on the ever-expanding housing needs of the population, the quality and diversity of new structures has diminished in this age of "assembly line" construction. Consumers often neglect to view the finer details of the product as a whole; "they inadvertently end up giving the industry
leeway to cut corners on energy efficiency, indoor air quality, and durability” (p. 12).

Though signs of builder negligence can be detected after a period of time, natural disasters can quickly expose poor craftsmanship. Hurricane Andrew, which took place in Florida during August of 1992, provided a perfect case for poorly constructed homes. The storm damaged more than 100,000 dwellings at a cost of approximately $30 billion in property damage (Roodman & Lenssen, 1995, p. 12). Further investigations “revealed that widespread and undetected building code violations were responsible for the loss of many homes” (p. 13). And because they were sloppily built, further ecological exploitation and degradation occurred in order to replace those homes initially unfit for their local environment (p. 13). Had more care and proper planning been emphasized in the construction of these neighborhoods, resources might have been more efficiently used. As stated by an architect from the Florida Construction Advisory Council, “...we no longer build structures to last 500 years or more...We design buildings with a lifespan of 30-50 years, then tear them down and put up new ones, creating more debris and a need for materials and supplies” (Austin, 1991, p. 54).
Modern buildings contribute greatly to the problems of pollution, resource depletion, and the general degradation of the environment. But these problems are rooted in two very complex issues. The ever-increasing population is rearing its influence in many aspects of the environment. In addition, economic incentives can drive the actions of the global society with little regard to environmental impacts. To reduce the effects of modern construction in order to promote a healthy existence on Earth, a compromise between the economic interests, the ecological needs of the general human population, and the preservation of our biosphere is necessary. Green building techniques attempt to meet this need by applying a perspective of sustainable development.

Sustainable Development

Aldo Leopold argued, "...a thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise" (Leopold, 1949, p. 224-225). Instead of focusing on individual aspects within the biosphere, the environment is viewed as a network of interrelated ecosystems. Such is the foundation for sustainable development. As defined by the Brundtland Commission in 1987, sustainability is
“development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (President’s Council on Sustainable Development, 1996, p. 1). Such a concept requires a shared vision to provide a healthy biosphere for our children and their offspring; development of this sort creates “the capacity to last or continue” (Jacobs, 1991, p. 72).

Any “policy decision on the environment will involve an ethical choice, since different options will affect different groups of people (and other living things) in different ways” (Jacobs, 1991, p. 77). Sustainability is no different. To gain some form of objectivity, economists often measure the desires and interests of people living today (p. 77). From this information, an optimal level of environmental protection is created in an attempt to reflect the world as it is (p. 77). But this is merely a prediction of future events; later generations may not share the same desires and interests (p. 77). Since this technique cannot be proven by actual facts about the future, this form of evaluation is considered to be normative (p. 77). Instead, the wishes of those who do not yet exist are assumed and “inevitably reflects the values of the chooser,” the existing population (p. 77). As a whole, “sustainability is an ethical concept” (p. 77).
The idea of environmental capacity can be used to direct decisions regarding the preservation of resources for future generations. "Renewable resources are those which, through natural regeneration processes, can continue in supply despite being 'used' by mankind" (Jacobs, 1991, p. 4). Trees are a renewable resource because after being consumed, new trees can grow in their stead. If humans cut down trees faster than they regenerate, eventually the supply of lumber will disappear. "So long as the rate of harvest... does not exceed the regeneration rate..., the resource stock is kept constant" and the environmental capacity of the resource is maintained (p. 87).

Because their quantity is finite (do not regenerate), the management of nonrenewable resources must be analyzed a little differently. If coal is readily being used, the quantity of this fossil fuel cannot remain constant. Environmental capacity becomes useless for future generations as the coal supply is diminished (Jacobs, 1991, p. 90). Instead, sustainability measures for nonrenewable resources are done according relative scarcity, a figure comparing the supply of a particular resource with the level of demand for it (p. 90). If the relative scarcity for a commodity is maintained from one
generation to the next, environmental capacity will be met. But the supply and demand for a nonrenewable resource often changes (p. 91).

The relative scarcity of a nonrenewable can be altered several different ways. Aside from consumption, the supply of these materials can become more economically available as a result of expanding reserves (Jacobs, 1991, p. 91). Relative scarcity can also be altered by increased recycling of resources, slowing the actual rate of their depletion (p. 91). Demand for a nonrenewable stock can also be altered for effective sustainable management. First, resources can be used more efficiently, decreasing the quantity needed for specific tasks (p. 91). Second, "demand for a scarce resource can be reduced...through the substitution of other materials" in greater supply (p. 91). For example, instead of using virgin lumber, recycled plant matter and plastics can be fashioned into beams for use in home construction.

Sustainable management can also operate empirically with the assimilation of wastes. Some products can be readily absorbed by ecological processes (Jacobs, 1991, p. 92). The cleanliness of the environment is naturally regenerated and can be measured much like a renewable resource. However, "stock wastes, such as nuclear
residuals, heavy metals and other toxic materials...can be likened to a nonrenewable resource" (Jacobs, p. 94). Since they cannot be assimilated into their ecological surroundings, they reduce the purity and permanently occupy available space in the environment (p. 94). For any given perception of risk, sustainability offers rules to govern changes in pollution levels and its effects (p. 94). The degradation of the abiotic constituents (the purity of air, water, and soil) and ecological health (for example, in the form of tree loss, toxicity, or presence of diseases) are measurable (p. 94). As a result, a set of optimal pollution levels can be identified, the waste emission rates needed to maintain them, and the policy necessary for meeting these goals can be established for the purpose of sustainable development (p. 94).

Environmental services, unlike the consumption of resources or the assimilation of waste, are continuous processes with no physical product to measure (Jacobs, 1991, p. 94). But in some regard we benefit from the life supporting functions of the biosphere (p. 95). To objectively observe the performance of environmental services, data could be collected concerning numerous indicators such as global temperatures and the incidence of ultra-violet radiation (p. 95). As with wastes, the
environmental capacity is expressed in terms of optimal targets needing to be maintained for future generations (p. 95-96). Sustainability is achieved as a result.

In practice, policy determined for individual indicators must not be viewed independently (Jacobs, 1991, p. 97). "Depletion of resources may reduce waste absorption capacities; pollution can impair the performance of environmental services; impairment of life support services may cause resource depletion" (p. 97). Thus, when establishing targets for sustainability, various environmental effects must be integrated (p. 97). The effects of managing one function of the biosphere can alter outcomes of another. The environmental capacities of these factors "become constraints: if economic activity trespasses beyond them, sustainability is no longer achieved" (p. 101).

"At present, the environmental impact of the global economy is unsustainable" (Jacobs, 1991, p. 105). The overuse of resources and increases in pollution has led to impacts on environmental services. To alleviate this problem, economic activity must be constrained to the limits provided by established environmental capacities (p. 105). In other words, financial growth can be realized without increasing environmental degradation. "In these
circumstances there are two mechanisms available for achieving sustainability" (p. 105). First, the scale of economic activity can be contracted without changing the content of its actions (p. 105). This is contradictory to the desires of economists, since their goal is to increase GNP. Because the content of the economic activity does not change, those in favor of environmental preservation may not approve either. Though occurring at a slower rate, the undesirable effects upon the environment still exist. A second mechanism for economic-environmental efficiency is to change the content of economic activity (p. 105). If less degrading products could be created, the environment would experience fewer stresses while maintaining increases in GNP; a win-win situation. "In theory, if we can do this by a large enough amount, even further growth is not ruled out" (p. 105). To achieve such a result, the flow of resources and the output of economic activity must be analyzed.

To increase efficiency, products stemming from economic activity must be assessed for their "environment-friendliness" (Jacobs, 1991, p. 144). "The difficulties of comparing the environmental impact of different goods are immense" (p. 144). Every aspect of each yielded good and service provided by industry must be
observed, including the byproducts formed from its synthesis. In addition, a crucial issue to be considered is determining "how far back in the production chain the assessment goes" (p. 144). An economic good itself may do little in the way of impacting the environment, but the manufacturing process creating the good may cause pollution, destroy habitat, or emit large quantities of waste. The same could be true of a production chain having little or no impact on the natural world, but the resulting output itself causes major environmental degradation.

As a whole, there are six criteria used when considering a product for economic activity (Jacobs, 1991, p. 144). The first characteristic is the "pollution generated in use or in disposal" (p. 144). This would cover the wastes that cannot be assimilated during production as well as during and after consumption. The amount of energy required for the manufacturing and use is the second aspect to be analyzed (p. 144). Generally speaking, the more energy generated for the creation and usage of a good or service means greater levels of environmental degradation. Another criterion for determining the impact of a product is durability (p. 145). Some items are made to be thrown away while
others are meant to have long life spans (p. 145). The length of time a product is considered depends upon the quality of its assembly. In contrast, the "recyclability or reusability" of an item should be assessed (p. 145). Likewise, the content of recycled materials within a product can alter its environmental impact (p. 145). As the amount of material recycled or reused increases, the volume of waste reentering ecosystems declines. Finally, the biodegradability of a product must be considered (p. 145). At some point, all substances return to the biosphere and their ability to be assimilated can create varying levels of environmental degradation. Plastics and heavy metals are not easily returned; organic matter such as compost or other plant-based materials can be easily reincorporated. These six criteria could be used to develop standards for limiting consumption (p. 144).

Environmental protection comes at a great expense to all. If companies voluntarily act to lessen their environmental impact, they will place themselves at a cost disadvantage with competitors (Jacobs, 1991, p. 41). But if the economic playing field were leveled, with all firms are required to act in the same manner relative to the environmental crisis, then no business would be worse off than others (p. 41). Industries may even find ways to
decrease the costs of preservation. This is the aim of green consumerism. “As consumers increasingly desire environmentally non-damaging products, so profit-making companies will be forced to make them” (p. 41). The very market forces creating the degradation of ecosystems can in fact compel their protection (p. 41). However, there are four hurdles needing to be conquered before environmentally friendly products are demanded by the public (p. 42).

“First, environmentally-sensitive products are usually more expensive than those which are not, since they involve extra costs in production” (Jacobs, 1991, p. 42). It is believed this issue is only an initial setback of goods entering the market whether they are considered “green” or not. As the demand for a product is maintained or increases over time, it is believed, the providing businesses will continue to sell them. In the spirit of competition, these firms will increase their revenue by trying to streamline production and cut costs in order to make the product cheaper. This will prolong demand and profit margins.

Consumers need “to be offered a choice to express their environmental concerns” (Jacobs, 1991, p. 43). It can be said consumers are the ultimate influence on market
forces, but they can only purchase what is offered by producers (p. 43). There is no guarantee that firms, especially those with monopolies, "will invest unbidden in the development of new products and processes in order to satisfy consumers' putative environmental concerns" (p. 43).

Related to the possible lack of choice, "many environmental problems are very remote from the final consumers of products" (Jacobs, 1991, p. 43). Some manufacturing chains are so extensive the environmental degradation they cause is concentrated in a far off place. As such, many environmental problems are experienced by populations in impoverished regions of the world. Uninformed citizens of industrialized societies may be purchasing items while remaining unaware of the damage they inflict in some other part of the world. The biosphere contains a complex network of ecological systems; damage in one area will eventually influence other parts of the world if given enough time.

Relative to the housing industry, green building techniques offer choices allowing the public to become involved in sustainable development. Green building is centered on the "simple notion that the way of life we choose must not lead to circumstances that prevent that
way of life from continuing” (Snell & Callahan, 2005, p. 17). Such practices work with natural processes to create products less damaging to the environment. Recent developments in the field of green building continue to create more choices for consumers to participate in sustainable development. A further analysis of these tactics must begin with a review of the basic functions of a human-built inhabitance.

The Basic Functions of a Building

With all of the options and amenities associated with modern buildings, the average consumer might overlook the true requirements of a sheltered place. A residence provides much more than just “a roof over our heads,” but is “designed to sustain human life” (Snell & Callahan, 2005, p. 15). Our homes are dynamic structures ever changing to meet the needs of their inhabitants. They act like organisms, maintaining a certain level of homeostasis for the productive operation of the events taking place within their shells. A place of inhabitance performs “the same job as some other familiar structures designed to sustain human life: our bodies” (p. 15). A building “sustains human life by mirroring and augmenting the four basic functions of the human body” (p. 16).
First, our bodies have a skeleton creating a calcified network of support and providing a place for our organs to properly function. Like our bones, any shelter includes some form of walls, roof, and foundation where an organism can survive and function. Thus, a building is initially "a self-supporting structure that defines an inside and outside" (Snell & Callahan, 2005, p. 16).

So we may survive, our bodies carry out trillions of chemical reactions. But as the laws of thermodynamics dictate, these processes function most efficiently at an ambient temperature of 98.6 degrees Fahrenheit. Thus, it is imperative for our body to maintain a consistent internal condition. Similarly, a building "maintains an interior temperature that sustains human life in the face of exterior temperatures that wouldn't" (Snell & Callahan, 2005, p. 16). Our ability to be productive hinges upon an internal environment conducive to our proper, daily function. Mechanical internal heating and cooling systems relying on electricity and fuels provide much of our interior climate control. Other technologies such as in-wall insulation assist in maintaining indoor environments.

In our bodies, the "skin keeps out unfiltered water and air, and our immune systems fight off invading
pathogens” (Snell & Callahan, 2005, p. 16). A building also “creates a separation from the outside that protects...its inhabitants from destructive forces” (p. 16). Houses have inner and outer skins in the form of stucco, siding, sheetrock and shingles. They also utilize various types of filters to prevent trespassers, both organic and inorganic, from entering interior living spaces. Organisms require shelter for protection from temporary environmental conditions considered extreme for life. However, they must not be completely partitioned from the outside world.

Human bodies require the intake of nutrients, water, and oxygen in order to maintain operation. In return, they must also expel wastes and toxins created from the conversion of those substances into usable energy. Should the build-up of wastes become excessive, the conditions necessary for life to continue will become compromised. So while human existence must be protected from unhealthy factors, it must continue to have access to external resources. A building acts in the same exact way; a shelter must allow a constant exchange between the inside and outside environment (Snell & Callahan, 2005, p. 16). Water, fuels, and electricity are just a few of the commodities people need to bring into their living space.
And like the human body, residents must also rid their premises of wastes.

At one time in our anthropological evolution, “the body was all the house we needed” (Snell & Callahan, 2005, p. 16). But as our existence became more mobile, “humans encountered climates that pushed our bodies beyond their job descriptions” (p. 16). In the process, we began to clothe ourselves, adjusted to new diets, and demanded a greater diversity of resources. Buildings have evolved the same way. As a consequence of our economically driven culture, our environment has forfeited much to provide homes for our ever growing and increasingly mobile society. Green building practices return our attention to the basic needs of shelter and to alternative construction methods to work with nature rather than expelling it.

The Basic Traits of Green Building Practices

There has been a boon of new technologies promoting the idea of a green lifestyle: alternative building materials, use of solar power, more energy efficient appliances. All of these zero in on the basic provisions of a home while decreasing the impact on the environment. In order to best construct a building promoting environmental sustainability, there are five traits
needing to be considered (Snell & Callahan, 2005, p. 17): site preparation, efficient use of resources during construction and habitation, durability of structures, healthy indoor environment, and providing a sense of place.

Low Construction Impact

First and foremost, green buildings have a low construction impact (Snell & Callahan, 2005, p. 17). According to the laws of thermodynamics, the energy and matter required to create something must inevitably come from somewhere else. "A 'green' building minimizes its impact on the building site and the environment at large through careful, conscious design and by utilizing replenishable materials that create a minimum of ecological destruction through their use" (p. 17). Decisions about how the site itself will be manipulated and the types of materials to be used must be considered.

As such, the erection of any new structure includes a series of destructive acts. "Land has to be at least minimally cleared and reshaped, holes need to be dug, and material resources refashioned to serve the building" (p. 17). The ravagement of natural habitat is inevitable with regard to the expanding need for housing.
Next, alternative materials for building must be considered. Many renewable resources, especially if they are local, allow energy to be used more efficiently. In regard to using local building materials, the "less processing it undergoes, the shorter the distance it is transported, the less energy it uses, and the less pollution it creates" (Roodman & Lenssen, 1995, p. 26).

Unrefined organic building materials could be more easily used and decrease the level waste sent to landfills. For example, over the past couple of decades homes made of straw have garnered renewed interest (Roodman & Lenssen, 1995, p. 29). Straw as a structural medium, replacing wood beams in roots, ceiling, floors, and walls, provides stability and insulative qualities rivaled only by synthetically composed fiberglass sheeting. Should the building be dismantled later, the straw could be composted or simply allowed to decompose back into the local ecological energy cycle rather than being sent into municipal waste streams.

Likewise, the use of naturally occurring inorganics, such as rock, stone, sand or adobe place less stress upon the environment than synthetic materials. Unlike cement or brick, they do not require energy intensive processing and
are often available at or close to the actual building site.

Another way to lessen the impact upon the environment is the reuse of building materials. "Using a scrap of steel or iron rather than virgin products results in an 86 percent reduction in air pollution and a 76 percent reduction in water pollution" (Nebraska Energy Office, 2007, Recycling Facts). Recycling or reusing materials reduces air and water pollution, often conserves energy and water, and maximizes landfill capacities by minimizing what is discarded (Nebraska Energy Office, 2007, Reducing, Re-Using, and Recycling). In addition, such practices help protect our health and environment by removing potentially harmful substances from the waste stream and processing them back into useable products.

Everything from plastics, paper, metals, carpeting, and even some paints can be reincorporated into another building. Demolition crews are able to crush concrete blocks and "mix the resulting powder with additional cement to make new concrete" (Roodman & Lenssen, 1995, p. 31). In turn, the need for unused cement, the manufacture of which can result at a high environmental cost, is decreased. New technologies have increased the availability of recycled resources. Cardboard, newspaper,
and other paper products can be used to produce a sturdy, yet low weight, alternative for lumber or steel for beams, studs, and tiles (p. 31).

"Materials choices are among the most complicated an environmentally concerned" building designer will have to make (Roodman & Lenssen, 1995, p. 31). Considering the variations in function and the nature of environmental interactions associated with accessibility, decisions about what resources will be used are truly vast (p. 31). With the evolution of more green materials and processes, it is hoped building designers will also be able to progress toward more sustainable resources (p. 31-32).

Efficient Use of Resources During Habitation

Buildings are constructed for the habitation of people. Green buildings efficiently use resources through their life, conserving water, fuel, and electricity (Snell & Callahan, 2005, p. 17).

One popular method for reducing the overuse of energy is the purchase of newer, more efficient appliances. "Energy Star is a government-backed program helping businesses and individuals protect the environment through superior energy efficiency" (U.S. Department of Energy, 2007, para. 1). Appliances, ranging from those used in the home to office machines, are scrutinized under a set of
standards focused on the amount of electricity they use and their influence on the environment during operation. If they meet the established specifications for their "functional-type" (for example, refrigerators have different standards than photo copiers), then they are marked with an Energy Star label. Consumers can then choose between items carrying this tag or other less energy-efficient products. Since 2006, enough energy was saved through the purchase of Energy Star appliances to power an additional 10 million homes (para. 2). In addition, greenhouse gas emissions equivalent to the amount released from 12 million cars were prevented from entering our atmosphere (para. 2). The benefits were also economical as an estimated $6 billion dollars were saved as a result of the Energy Star program (para. 2).

The sun is a readily available energy source and alternative to fossil fuel combustion for supplying electricity. "The energy in sunlight striking the earth for 40 minutes is equivalent to global energy consumption for a year" (Zweibel, Mason, & Fthenakis, 2008, p. 64). "Compared to nonrenewable sources such as coal, gas, oil, and nuclear, the advantages [of solar power] are clear: it's totally non-polluting, has no moving parts to break down, and does not require much maintenance" (Go Solar
Company, 2007, para. 13). More importantly, solar generating systems can be installed in a distributed fashion rather than using large scale facilities (para. 13). "Rooftop power can be added as more homes or businesses are added to a community, thereby allowing power generation to keep in step with growing needs without having to overbuild generation capacity as is often the case with conventional large scale power systems" (para. 14).

"Passive solar heating and cooling represents an important strategy for displacing traditional energy sources in buildings" (Solar Energy Society of Canada, 1997, Passive solar energy, para. 1). These techniques, requiring no additional mechanical equipment (as implied by the term "passive"), are implemented through the careful design of the building itself (Passive solar energy, para. 1). "Solar heating designs collect and store thermal energy from direct sunlight" (Passive solar energy, para. 2). A new structure is oriented so as to allow sunlight to enter the interior through windows. Windows facing anywhere within 30 degrees of due south are acceptable (Passive solar heating, para. 1). The resulting greenhouse effect is distributed throughout the building using various techniques including the utilization of
convection currents to provide natural heat. The use of specialized windows, natural structural materials such as clay tiles or walls, and proper insulation techniques can store the heat and redistribute it equally throughout the day and into the night (Passive solar heating, para. 2-5).

"The need for air-conditioning in homes can be greatly reduced or even eliminated by using passive solar cooling" (Solar Energy Society of Canada, Passive cooling, para. 1). This process involves the use of shading or "generating air flows with convection ventilation" (Passive solar energy, para. 2). Adjustable shading devices or exterior vegetation, such as trees, are placed to reduce heat gains from the sun during key parts of the day (Passive cooling, para. 2). Reflective materials used on rooftops or on windows are also available to aid in this process (Passive cooling, para. 3). Properly designing a building to take advantage of naturally occurring cross-ventilation and prevailing winds can also help minimize the need for pumps or fans (Solar Energy Society of Canada, 1997, Passive cooling, para. 3).

"Studies show...that natural light is the best type of light for the human eye, and that proximity to windows improves well-being" (Roodman & Lenssen, 1995, p. 37). Daylighting refers to the use of light from "the
surrounding sky to illuminate building spaces” (Solar Energy Society of Canada, 1997, Daylighting, para. 1). This can be done using skylights, reflective light shelves, and mirrors. A good daylighting system will consider numerous factors, especially the spaces needing to be lit (Daylighting, para. 2) and reduce air-conditioning costs.

Energy conservation is not the only concern of green builders. Water can also be conserved in great quantities through the use of green building techniques.

Most of the water in our homes and workplaces is used for the removal of wastes (Sharpe & Swistock, 2004, p. 3). Toilets are often the greatest user of water (p. 3). Thirty years ago, the average toilet used three to five gallons of water during every flush (p. 4). However, recent innovations have greatly reduced amount of resources needed for operation. Low-flush toilets working with gravity use only 1.6 gallons of water per flush and have become standard in almost all new buildings (p. 4). “Air-assisted toilets, which require compressed air for waste removal,” are even more effective by using only 0.5 gallons during each use (p. 5). Air-assisted toilets require a “small ¼-horsepower compressor, with an air line to each toilet” (p. 5). But they are not as involved as
another waste removal system requiring no water: composting toilets. "Composting toilets are expensive and difficult to retrofit. They require a commitment to management and must be tended to ensure proper operation" (p. 6).

Aside from toilets, there are other plumbing and appliance alternatives available for conserving water on a daily basis within buildings today. Low-flow showerheads and sink faucets can save over 3,000 gallons of water per person annually (Sharpe & Swistock, 2004, p. 5). Newer models of dishwashers and washing machines can further reduce the annual water consumption by another 3,395 gal/person (p. 5). By implementing these strategies, the operation of water heaters will be reduced. So in addition to saving water, modifications made in a home’s plumbing and appliances could save 600 kilowatt-hours per person yearly (p. 5). Thus, a family of four could save up to $400 a year by conserving water in these ways (p. 7).

Green building designers also consider the ways to utilize outdoor water more efficiently. "Since most water outside is used to water plants, landscaping with drought-tolerant (called xeriscaping) and native plants can greatly reduce consumption" (Sharpe & Swistock, 2004, p. 8). In addition to appropriately using mulch and more
efficient and timely drip irrigation systems, another 25-75 percent in water savings can be realized. Rainwater harvesting is another possible water conservation tactic. This is accomplished by placing storage containers under downspouts to collect runoff from roofs and eaves (p. 8). Buildings could also be made to channel rain into water storage tanks instead of sloughing it off, reducing the consumption of potable water (Roodman & Lenssen, 1995, p. 37).

Durability of Structure

"Quality is one of the keys to ecological design" (Roodman & Lenssen, 1995, p. 15). Green buildings are made to withstand the test of natural events and consumer desires.

Using natural, localized materials adapted to withstand a site specific climate can increase the lifespan of a building. For instance, many ancient cultures relied on earthen materials such as stone, soil, and plants indigenous to their region of habitation (Roodman & Lenssen, 1995, p. 28-29). The products of their labor can often still be found today, centuries later. "The long history of earthen materials makes them seem primitive, but they are fully appropriate for today's small and medium-sized buildings" (p. 28).
Regarding the durability of any structure, Snell and Callahan concisely stated:

Natural resources in the form of building materials, tools, and fuels, as well as human energy and ingenuity, come together to create a building. The longer that building lasts, the longer the time before the environment is asked to give up those resources again to replace the building. (2005, p. 17)

The longer period of time a structure can be useful, the longer it will take before its constituent materials enter the waste stream and into our landfills. In addition, as long as a structure, or any aspect of it, does not need to be replaced, there will be less of an impact upon the environment.

Nontoxic, Healthy Indoor Environment

A green building needs “to provide a healthy indoor environment while doing nothing to harm the outdoor environment” (Snell & Callahan, 2005, p. 17). This can be addressed through the consideration of products used, treatment to components, and building ventilation.

Many materials used in buildings can, throughout their operation, release hazardous chemicals into internal and external environments (Roodman & Lenssen, 1995,
p. 26). "The increasing use of toxic chemicals in building materials has resulted in a relatively new condition known as Sick Building Syndrome" (Allen et al., 2001, p. H5). Inhabitants and their surrounding environment can become ill while being exposed to volatile organic compounds such as formaldehyde and urea, used to pressurize and treat lumber. Symptoms arising from such conditions can include fatigue, lethargy, headaches, dizziness, nausea, and forgetfulness (p. H5).

There are many pollutants capable of infiltrating any living space. People living or working in buildings with poor ventilation systems are more susceptible to outbreaks of airborne pathogens caused by viruses, bacteria, and other microorganisms (Allen et al., 2001, p. H5). In situations such as these, improper circulation allows dangerous species of molds and other fungi to develop in damp walls, ceilings, carpets, or furniture (p. H5). The combustion of fossil fuels in furnaces, stoves, or other appliances releases toxic gases such as carbon monoxide, nitrogen oxide, and sulfur dioxide (p. H5). Aside from being lethal in high concentrations, they also act as greenhouse gases aiding in global climate change. Volatile organic compounds found in paints, glues, and solvents can lead to damage in major organs as well as some forms of
cancer (p. H5). Found in many of the traditional building materials such as treated lumber, particle board, foam insulation, carpet, adhesives, and fabrics, formaldehyde can cause complications in the upper respiratory tract (p. H5). A properly planned green building can alleviate some of the risks involved with these substances. A well planned ventilation system can circulate fresh air throughout a home while maintaining energy efficiency (Allen et al., 2001, p. H1-H3). Filtration systems need to be adjusted and tuned to adapt to changing seasonal conditions (p. H3).

With regard to building materials, there are many alternatives using nontoxic chemicals on the market. Wood treated with borax "is safe to handle and dispose of, and is effective against rot, fungi and wood destroying insects" (Allen et al., 2001, p. M4). To reduce exposure to harmful chemicals, such as formaldehyde, some types of plywood are processed using polyvinyl alcohol, "one of the safest bonding agents available" (p. M6). Cabinets and finishing supplies are also beginning to use nontoxic methods. Alternative covering techniques, available in the way of veneer plaster, milk paint, and lime washes do not produce volatile organic compounds and are very enduring (p. M13).
"Most people are aware of outdoor air pollution and its effects on our health, but many are not aware that indoor air may be 2 to 5 times more heavily contaminated" (Allen et al., 2001, P. M13). Since people tend to spend up to 90 percent of their lives indoors (Roodman & Lenssen, 1995, p. 5), the long-term medical effects could become quite costly. By using nontoxic, green alternatives, better living conditions can exist.

Providing a Sense of Place

"How buildings look reflects how they are made" (Roodman & Lenssen, 1995, p. 20). The lack of both ingenuity and desire to better incorporate living spaces with local ecology can result in a lack of pride and commitment amongst inhabitants. Many of the characteristics possessed by traditionally constructed buildings are formulated by engineers and governments far from where the dwelling will operate (p. 20). With regard to residential areas, “developers have gone from constructing homes one at a time to entire neighborhoods in which any variation is superficial” (p. 21). As living spaces continue to lack diversity, a sense of regional and personal identity may be lost.

“One of the biggest sources of our environmental woes is the constant and polluting movement of humans about the
planet" (Snell & Callahan, 2005, p. 17). In order to establish and maintain a sustainable lifestyle, people need to be less mobile (p. 17). As a society, we need to associate ourselves socially, physically, and spiritually with a place (p. 17). Time is necessary to develop friendships, develop healthy soil to grow food, or nurture trees to support a home’s cooling strategy (p. 17). “These things simply won’t happen if [people] aren’t sufficiently seduced by [their] home to stay there for the many years it will take to turn it into a real place that nurtures both its inhabitants and the environment” (p. 17). As a result, residents may be more concerned with their living and working environments and take better care and maintenance of these places. In summary, a green building “needs to be beautiful, a place this is hard to leave...and unthinkable to neglect” (p. 17).

Incorporating any of these traits - low construction impact, resource efficiency, durability, toxicity, and beauty - into a building is complex and demands a combination of idealism, realism and compromise (Snell & Callahan, 2005, p. 17). A great deal of research and planning prior to construction must take place to most appropriately reduce environmental impacts caused by the erection and operation of any building. The number of
alternatives and considerations are vast with new innovations being discovered regularly. In order to promote the longevity of any dwelling or work place, individual differences, preferences, and needs of the inhabitants must be factored in. "An ideally 'green' building, then, must be a very specific thing, matching...idiosyncratic personal needs with the fabric of [its] exact local environment" (p. 17). These characteristics can be reflected in a more objectivistic set of standards, further defining the concept of green building.

Leadership in Energy and Environmental Design

Many organizations, both publicly and privately funded, only describe specific techniques for constructing low-impact housing. But none of them offer an objective definition for green building. There do exist, however, numerous rating systems measuring the impacts associated with structural projects.

The Leadership in Energy and Environmental Design (LEED) Rating System has the most widely used standards for designing green buildings (Fowler & Rauch, 2006, p. 30). This system rates projects using a number of "credits" in order to be certified in one of four levels
Over 400 buildings in the U.S. have received LEED certifications, approximately 3400 more are seeking assessment (Fowler & Rauch, 2006, p. 30).

For new construction, the LEED rating system "consists of seven prerequisites and 69 potential credits in six categories" (Gourley, 2005, p. 14): Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environment Quality, and Innovation and Design. The Sustainable Sites prerequisite refers to the management of a project’s setting, including erosion control, open space, and accessibility to utilities and public transportation (p. 15). Using standards outlined for Water Efficiency, "LEED promotes water-use reduction through resourceful landscaping, wastewater technologies, and high-efficiency plumbing design" (p. 15). Energy and Atmosphere is concerned with the efficient use of energy and the amount of pollutants inevitably released by a building, especially as a result of heating and cooling mechanisms (p. 15). The Materials and Resources prerequisite assesses the usage of recycled or reused materials (p. 16). This category also acknowledges the utilization of local and regional substances as well as the management of construction wastes (p. 16). The rating system’s standards for Indoor Environment Quality analyzes
the types of pollutants being released to living space of the building during its operation (p. 16). Finally, buildings exhibiting features going above and beyond the requirements necessary for LEED certification, credits are awarded for Innovation and Design (p. 17).

The concept behind this rating system is to communicate a comprehensive comparison between buildings with regard to their sustainable design (Fowler & Rauch, 2006, p. 30). As complete as this may sound, the LEED Ratings System can experience annual minor adjustments with major updates every three to five years (p. 30). As a result of these ever-evolving standards and the relativity of the aforementioned traits, a concrete definition for green building remains elusive.

Conclusion

At some point in human history, our dwellings became barriers to the natural world. Homes have been designed to keep nature out. No longer are they associated with specific seasonal conditions or locale. As a result, destructive impacts have inflicted the environment, compromising the health of our planet and existence. The "building industry is beginning to recognize the shortcomings of its products, and to discover that there

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are readily available, cost-effective remedies” (Roodman & Lenssen, 1995, p. 48). But the problems associated with traditional construction methods are quite overwhelming, especially regarding the impacts on the environment.

A comprehensive strategy including the promotion of education for professionals and the public about the problems of modern structures and the benefits of green buildings is required (Roodman & Lenssen, 1995, p. 48). On a more practical level, people need to be instructed about these techniques and technologies to stimulate consumer interest (p. 50). To promote these ideals, educational curriculum aimed at seventh and eighth grade students was created. By introducing these concepts at an early age, a more knowledgeable citizenry could be developed, promoting environmental health and future sustainability.
CHAPTER THREE
REVIEW OF ENVIRONMENTAL EDUCATION LITERATURE

Introduction

"An environmental educator...uses information and educational processes to help people analyze the merits of the many and varied points of view usually present on a given environmental issue" (Hug, 2005, p. 47). Likewise, the construction of a building includes many decisions based on a diverse range of needs and beliefs. Green building techniques primarily promote an ethic supporting sustainable development. As such, the topic of green building is a great context for environmental education (EE).

This chapter will summarize literature on environmental education topics relevant to green building curriculum. First, the definition and goals of EE are presented. Then an overview of The Tbilisi Declaration, a document concerning the development of EE curriculum, is provided. In turn, an outline of the variables influencing ecological literacy is given. Pedagogical methods, including action projects and constructivism, are then emphasized. Finally, a call for educational reform toward place-based education is made.
Stapp’s Definition and Goals of Environmental Education

Designed to reach students of all ages, EE is “aimed at producing a citizenry that is knowledgeable concerning the biophysical environment and its associated problems, aware of how to help solve these problems, and motivated to work toward their solution” (Stapp et al., 2005, p. 34). According to Stapp et al., four goals relevant to EE are steadfast. First, there must be a clear understanding of our inseparable role in a system consisting of humans, culture, and the biophysical environment (p. 34). In addition, we have “the ability to alter the interrelationships of this system,” including how we produce or obtain goods and services (p. 34). Through various activities, especially economic, we have the ability to either “strengthen, weaken, or maintain the interrelationships between the system’s major components” (p. 34). The second goal of EE is to establish a “broad understanding of the biophysical environment, both natural and [synthetic], and its role in contemporary society” (p. 34). Thus, society needs to gain knowledge of the biosphere and the processes operating within and how our actions affect the biophysical environment. Thirdly, EE promotes an “understanding of the biophysical
environmental problems confronting [society], how these problems can be solved, and the responsibility of citizens and government to work toward their solution” (p. 35). Not only must people be aware of the ecological problems surrounding them, but also to take an active part in resolving these conflicts. Finally, EE should cultivate attitudes “of concern for the quality of the biophysical environment which will motivate citizens to participate in biophysical environmental problem-solving” (p. 35).

The planning of a building incorporates all of Stapp’s goals. When considering green design, one must also think about the ecological and cultural environment, effects upon the surrounding ecosystem, and how to best alleviate related conflicts between developers, municipalities, and the biophysical aspects of the building site. Green building can be a forum for environmental education.

The Tbilisi Declaration

In the Fall of 1977, the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the United Nations Environment Programme (UNEP) conducted the world’s first Intergovernmental Conference on Environmental Education. Taking place in Tbilisi, Georgia
(Soviet Union), participating countries recognized the impact human activities had on the global environment, placing the Earth’s inhabitants in danger. Based on this conclusion, The Tbilisi Declaration, outlining the roles, objectives, and characteristics of environmental education, was composed. It is considered a significant document in environmental education. As such, curriculum focused on green building and design should be aligned with the goals and objectives found within this document.

The Tbilisi Declaration set forth three fundamental goals for environmental education. Firstly, environmental education should “foster a clear awareness of, and concern about, economic, political and ecological interdependence in urban and rural areas” (Intergovernmental Conference on Environmental Education, 2005, p. 15). Secondly, every person should be provided with “opportunities to acquire the knowledge, values, attitudes, commitment and skills needed to protect and improve the environment” (p. 15). In the end, educational practices should “create new patterns of behavior of individuals, groups and society as a whole towards the environment” (p. 15). The document also outlines numerous principles for environmental education within the confines of the aforementioned goals.
Overall, The Tbilisi Declaration provided an outline of objectives to help individuals and social groups, through education, develop the tools necessary to solve environmental problems. First, environmental education must allow participants to "acquire an awareness and sensitivity to the total environment and its allied problems" (Intergovernmental Conference on Environmental Education, 2005, p. 16). It must also provide a means for obtaining relative knowledge; social groups and individuals need to "gain a variety of experience in, and acquire a basic understanding of, the environment and its associated problems" (p. 16). This educational vehicle must allow people to derive a "set of values and feelings of concern for the environment and the motivation for actively participating in environmental improvement and protection" (p. 16). Environmental education must promote the procurement by students of "the skills necessary for identifying and solving environmental problems" (p. 16). Lastly, such a program should "provide social groups and individuals with an opportunity to be actively involved at all levels in working toward resolution of environmental problems" (p. 16). Environmental education curricula focused on these five objectives would eventually lead to an environmentally literate populous.
Variables of Environmental Literacy

As the field of environmental education has evolved, the principles established by the Tbilisi Declaration still stand as a strong foundation for the development of environmentally literate citizens (Simmons, 2004, p. 1). The level of environmental literacy one achieves is based on a set of variables, as developed by the North American Association for Environmental Education (Volk & McBeth, 2005, p. 74). Affect, the first variable, "refers to factors within individuals which allow them to reflect on environmental problems/issues at the intrapersonal level" (p. 74), including environmental sensitivity and conceptual awareness of values relevant to a particular issue. An environmentally literate citizen has a wide range of knowledge comprising of ecological concepts (ecological literacy) and of the particular issue itself, both environmentally and socio-politically (p. 74).

Another relevant variable is locus of control, or the assumption of personal accountability (p. 74). Finally, environmentally literate individuals have developed the cognitive ability to display responsible behaviors (p. 74). These people possess action skills; they are capable of selecting appropriate action strategies and can create, evaluate, and implement an action plan (p. 74).
Environmental Sensitivity

Environmental sensitivity is an important precursor to the development of an environmentally literate and responsible citizenry (Sward & Marcinkowski, 2005, p. 306). While no established definition of environmental sensitivity has been completely accepted, Peterson (as cited in Sward & Marcinkowski, p. 303) interpreted it as "a set of affective characteristics that result in an individual viewing the environment from an empathetic perspective." In other words, individuals develop a "connectedness" with their natural surroundings.

Environmental sensitivity is developed through life experiences, especially those taking place in the outdoors in non-formal educational settings. Peterson conducted a survey of 22 environmental educators, between the ages of 22 and 50, to determine the major variables contributing to individual environmental sensitivity (2005, p. 297). Data from the study revealed several factors subscribing to the participants' views of environmental issues (p. 298). Individuals begin acquiring environmental sensitivity, on average, at about 12 years of age; all participants had an enlightening encounter with nature prior to turning 18 years (p. 298). The participants in the study also acknowledged two major contributors to
their level of environmental sensitivity: major outdoor experiences and interactions with important role models (p. 298).

Of the variables indicating strong environmental sensitivity, participation in a major outdoor experience was the most potent (Peterson, 2005, p. 298). As a child, such activities could include exploring or playing outdoors, hunting and fishing, and time spent with youth organizations or group camping trips (p. 298). In relation to this, “a personal loss of a natural area where the participant often visited or played had a profound effect” on those participating in the study (p. 299). As a result of this, focusing environmental education curriculum on “local issues or problems may exert a more influence” on the development of environmental sensitivity (p. 299).

Having had as a child a role model demonstrating environmentally responsible behaviors or providing outdoor experiences is another powerful indicator for environmental sensitivity (Peterson, 2005, p. 298). Many of the role models described by the subjects in Peterson’s study were non-familial, especially teachers (p. 298). Teachers tended to stimulate “interest in environmental systems” and provided “educational and professional guidance” (p. 299). Familial ties to outdoor experiences
also contributed heavily to one’s environmental sensitivity (p. 298). These associations may coincide with a specific place, primarily during adolescence.

Studies similar to that of Peterson’s were conducted, and they “all obtained very similar and, therefore, corroborating results” (Sward & Marcinkowski, 2005, p. 304). Environmental sensitivity is the foundation for teaching environmentally responsible behaviors.

Environmental sensitivity “is the first major variable in what is hypothesized to be a linear sequence from entry to ownership to empowerment” (Chawla, 1998, p. 370). But in addition to environmental sensitivity, students of environmental education curriculum should also develop a sense of conceptual awareness of relevant issues.

Conceptual Awareness

A level of conceptual awareness “seeks to guide the development of...how individual and collective actions may influence the relationship between quality of life and the quality of the environment” (Hungerford & Volk, 2005b, p. 120). In doing so, students examine how cultural and individual behaviors influence the environment from an ecological perspective (p. 120).

“The goal of education is not mastery of subject matter but mastery of one’s person” (Orr, 2004, p. 13).
Students of environmental issues must be aware of the values they possess, as well as those of others, regarding their ecological surroundings. The views regarding these conflicts can be categorized into numerous value descriptors (Hungerford, Litherland, Peyton, Ramsey, & Volk, 1996, p. 34). Those who are considered aesthetic show the “appreciation of form, composition, and color through the human senses” (p. 34). They observe and hold dear the diverse beauty found in their natural surroundings. People who are strongly economic view the world in terms of materials, services, and the profits associated with them (p. 34). Ecological views pertain to natural biological systems and principles; scientific values are associated with the process of empirical research and the knowledge gained from it (p. 34). People who most support education see the world in terms of using and communicating knowledge toward others (p. 34). Other value descriptors include, but are not limited to, egocentric, ethnocentric, legal, political, recreational, and religious (p. 34). Regardless of specific descriptors, a student’s values cannot be applied to environmental issues unless participants are ecologically literate.
Ecological Literacy

Ecological literacy, termed the Ecological Foundation Level by Hungerford and Volk, seeks to provide learners with sufficient ecological knowledge to permit the making of ecologically sound decisions with respect to environmental issues" (2005b, p. 120). When teaching students about human influences upon nature, basic ecological concepts should be included. Instruction should show relevancy with regard to subjects such as population growth, energy flows in nature, and interactions between humans and the environment (p. 120). To fix a car, a mechanic must understand the inner workings of the numerous systems making it run. The same applies to our environment; to clearly comprehend the overall scheme of our surroundings and solve the problems within, we need to be well-versed in the cycles and scientific laws governing nature. “An ecologically literate person would have at least a basic comprehension of ecology, human ecology, and the concepts of sustainability, as well as the wherewithal to solve problems” (Orr, 2005a, p. xi).

We, as humans, need to be aware of our place within the global ecosystem. Our actions and pursuits have profound effects upon the Earth and all that resides upon it. According to Orr, this awareness carries with it an
imperative; "we ought to pay full and close attention to the ecological conditions and prerequisites that sustain all life" (2005a, p. ix). As such, environmental education must include the various technical aspects of all fields of nature study, or a systems approach to the world around us. When successful, the learner becomes a whole citizen not only educated in a set of subject areas, but also capable of relating these various fields into a working knowledge of the natural world and the preservation of it.

**Knowledge of Issues**

Value systems can often be clarified when assessing issues and their various solutions. Educational curriculum providing these opportunities allow "for the development of the knowledge and skills necessary to permit learners to investigate environmental issues and evaluate alternative solutions for solving these issues" (Hungerford & Volk, 2005b, p. 120).

Many issues considered by environmentally literate citizens can be classified into one of two categories, environmental issues and socio-political issues. A person with knowledge of environmental issues has "an understanding of environmental problems and issues caused as the result of human interaction with the environment" (Volk & McBeth, 2005, p. 74). Knowledge of socio-political
issues similarly encompasses the comprehension of the impacts made by human cultural activities (p. 74). The latter category also requires "an understanding of the relationship between beliefs, political systems, and environmental values of various cultures" (p. 74).

By researching the numerous aspects regarding such conflicts, students discover the diverse range of associated perspectives. All plausible solutions to an environmental issue will have ecological, economic, and even cultural implications (Hungerford & Volk, 2005b, p. 120). In any case, the various consequences as a result of some action must be considered. Thus, the more informed people are about an environmental issue, the better equipped they will be to make the most effective solution.

**Locus of Control**

Values and beliefs associated with a particular issue influence a person's behavior. Likewise, the amount of reinforcement taking place as a result of those behaviors can affect the actions of an individual (Neil, 2005, para. 4). If a link between an action and its relative consequence is observable, then choices regarding such behavior will be more predictable (para. 4). However, the connection between behaviors and relevant reinforcers may not be obvious; reactions to such scenarios become more
random (para. 4). In other words, “people hold expectancies and these expectancies influence [behavior]” (para. 3). The belief in the amount of effectiveness actions may carry is a mental representation based on past outcomes and the situation being confronted (para. 3). These expectancies influence an individual’s judgment of the likelihood of obtaining a desired outcome (para. 3). “These beliefs about whether a behavior will meet with a rewarding outcome” become a person’s locus of control.

As a measurement for locus of control (LOC), a linear continuum from external LOC to internal LOC was developed by Rotter (Neil, 2005, para. 4). A person having a strong external LOC “believes that his/her [behavior] is guided by fate, luck, or other external circumstances” (Neil, 2006, para. 4). Individuals falling on this end of the spectrum believe they are not responsible for the problems or issues in their lives; they do not see any links between their behavior and reinforcers. Those on the other end of the continuum have an internal LOC. These individuals “believe that his/her [behavior] is guided by his/her personal decisions and efforts” (para. 4). People tending toward the latter end of the spectrum feel they control the events in their lives; reinforcers, whether
they are positive or negative, occur as a direct result of the choices made by an individual.

Specific characteristics relative to either end of the LOC continuum are not generally seen as being better than the other. However, “psychological research has found that people with a more internal locus of control seem to be better off” (Neil, 2006, para. 6). People who have a strong sense of personal control while maintaining a realistic sense of their circle of influence are achievement oriented and tend to obtain greater levels of status within organizations (para. 5-6). By having an internal LOC, learners can greatly influence the amount of environmental change carried out. If a high percentage of a local population maintains an external LOC, they will take on a sense of apathy with regard to environmental problems. People need to realize their behaviors will have an effect on their surroundings and world they in. If people can see the relevancy of their actions to such issues, then they may be more willing to make change in order to achieve the desired environmental reinforcers.

By promoting an internal locus of control, effective change can be realized and practiced by groups and individuals. Likewise, an environmentally literate society acknowledges the values and beliefs of the population when
considering a local issue. Thus, it is very important to analyze a problem or issue from all viewpoints when considering possible solutions. Once the best solution has been decided upon, a plan for action can be conceived.

**Action Skills**

By learning action skills, participants obtain the abilities necessary “to take positive environmental action for the purpose of achieving and/or maintaining a dynamic equilibrium between quality of life and the quality of the environment” (Hungerford & Volk, 2005b, p. 121). It is not enough for citizens to simply become educated about a problem; they must also learn how to physically resolve it. As a result, people become a functional element within their own community. According to the Rural Challenge Research and Evaluation Program, “a grounded, rooted learner understands his/her actions matter, that they affect the community beyond the school” (as cited in Sobel, 2005, p. 12).

Action projects can become vehicles for empowerment as well as develop an active and informed citizenry. Peterson stated, “Individuals sensitive to the environment possess a basic appreciation and concern for the natural environment, yet this appreciation and concern may not be
intense enough to motivate them to alter their behavior on behalf of environmental quality“ (2005, p. 298).

Action projects are “activities that get students involved in tackling an environmental issue or problem, or that aim at improving an environmental setting” (Stoner, 2003, p. 2). Teachers guide their students to select, research, and create solutions to better their community. In the process, learners gain an appreciation for their local environment, receive hands-on training in problem solving, and apply concepts from all subject areas. As a result, students take ownership of their learning and get the opportunity to become empowered citizens.

Whether they are simple or complex, action projects provide hands-on, cross-curricular learning opportunities. For example, sixth grade students in Needles, California chose to adopt an endangered desert tortoise (Stoner, 2003, p. 27). By doing so, these children covered language arts standards by developing posters about the local reptile. They also became “Tortoise Talkers” and presented relevant information to the public. Math skills were enhanced by accounting donations and other fundraising events. To understand the tortoise’s physiological and ecological needs, science topics must be examined. The students also interacted with State and Federal agencies
to purchase habitat and propose land-use changes, which satisfied social studies content.

The process of successfully starting an action project such as the one described above requires careful planning. Prior to beginning a project, student input must be continually encouraged and valued. Participants must first pool information and become informed about problems or issues needing to be resolved within the community (Stoner, 2003, p. 12). The entire process of an action project encourages students to become a part of the solution rather than promote the problem. Those who participate in such experiences learn not only to actively make change within their community, but may gain a greater sense of the inner workings of their environment as well. In essence, students and adults alike can gain appreciation for their locality by becoming a part of it.

Any curriculum seeking to empower students to display environmental behavior requires some level of environmental sensitivity. But, as Peterson suggested, just because one has a high level of environmental sensitivity does not necessarily result in responsible environmental behavior; empowering students how to act must be emphasized. "Individuals possessing an environmental ethic take purposeful actions...make decisions by weighing the
rights of individuals and society along with the ecological integrity of the natural community” (Peterson, 2005, p. 296).

Creating a citizenry skilled in taking action for change, the major variable for empowerment, is the cornerstone of training in environmental education (Culen, 2005, p. 41). Constructivism, a pedagogical practice lending itself to an issues and action based focus on environmental education, to achieving this empowerment.

Constructivism

Constructivism involves three views of human learning and instruction. “It refers to a philosophical view about the nature of reality and perception, is a theory about how people learn, and - more and more often - represents a series of teaching strategies” (Colburn, 2000, p. 9). From a philosophical sense, “constructivists argue we make our own world view and knowledge” (p. 9). Individuals develop their own knowledge based on unique experiences and perceptions. As a result, “individual students bring with them personal beliefs and knowledge about how the world works” (p. 9). A constructivist-learning model utilizes the prior knowledge attained by students, regardless of
accuracy, to teach students more effective views of the natural world.

"Teaching is about helping students understand how and why scientifically accepted explanations explain and predict what will happen" (Colburn, 2000, p. 10). A constructivist model initiates such instruction through an "Invitation Phase." During the first phase, students acknowledge preconceptions regarding the focused topic. It is important to observe the diversity in ideas; "students are far from being 'empty vessels' waiting to be filled with new knowledge" (Colburn, 2000, p. 10). Students may have preconceived notions about the world around them. Some of the ideas they harbor may be correct; other times they are not. The purpose of constructivist instruction is to give students an opportunity to analyze their own ideas and develop a perception more "generally agreed upon by the majority of the scientific community" (p. 10).

The "Exploration Phase" is the second step in a constructive learning model. This can be done through experimentation and problem solving tasks. It is through such activities students become "clear in their understanding of their own ideas," an essential step in teaching new concepts (Colburn, 2000, p. 9). Experiments should be open-ended, maintain engagement and challenge
students, rather than following a predesigned procedure (p. 11). By performing open-ended activities, students begin to "see flaws in their thinking and be more ready for alternative explanations" (p. 11).

After collecting data, students will begin to propose new explanations or solutions to the questions regarding a specific topic. During this phase, students review their work and collaborate with their peers to assess proposed explanations related to the observed phenomena. Students can become involved in debate over accepted and preconceived ideas. According to Zeidler, "change (theory or conceptual) does not necessarily happen in incremental linear steps; rather mutual factors... continually restructure...personal knowledge" (1997, p. 485). In the end, students develop a greater level of literacy of a topic and may adopt a more effective model about the natural world.

Finally, assessment in a constructivist model should be authentic, where students perform a "noncontrived task...or are involved in other real-life problem solving situations" (Colburn, 2000, p. 11). Through hands-on, shared activities, effectively assesses what, how, and why students are executing a specific task (p. 11). Action projects, lab experiments, and similar types of student
opportunities can be a crucial component in the education of young minds and can act as a tool of communication for the community at large.

A constructivist approach can be of a great help in solving the problems associated with modern buildings. Efforts are needed to "educate the general public and stimulate consumer interest" in green building practices (Roodman & Lenssen, 1995, p. 50). A greater demand for these technologies would "accelerate their dissemination and commercialization" and alleviating stresses placed upon the environment by the building industry (p. 50). In other words, an educational curriculum focused on green building could, as is the goal of environmental education, promote citizenship behaviors amongst its students.

Educational Reform

The integration of environmental education as a tool for pedagogical reform "could create a powerful way to promote both responsible environmental citizenship and effectively restructured education" (Sussman, 2000, p. 32). To accomplish these goals, numerous practices need to be more prevalent within classrooms. First, standards must be in place to in order to define what students need to know (p. 33). The State of California has developed
content standards for a wide range of subject areas. Where traditional pedagogical methods have relied on memorization and repetitious practice, many "curriculum reform efforts promote a greater focus on skills such as logical analysis and problem solving" (p. 33). Students must be required to investigate and realize important concepts rather than being drilled on a series of facts as told by a book or teacher. Rather than covering a large array of content in a superficial way, classrooms should promote a deeper analysis of fewer subjects (p. 33). Often, students attend class and leave with a feeling of irrelevance. They do not clearly comprehend why the information they just gained could be of any use (p. 33-34). Curriculum reform efforts must emphasize "real world topics" and learning situations stressing the practicality of the subject matter (p. 34). "Environmental topics are particularly appropriate for curricula that emphasize the world beyond the classroom, depth of treatment and higher order thinking skills" (p. 34). In order to improve education, schools need to increase the opportunities for multidisciplinary/team teaching (p. 34). Also, classroom teachers should be encouraged to practice constructivist pedagogy promoting active, cooperative, and hands-on learning (p. 35). Investigations using diverse
forms of technology should also take place (p. 35). As demonstrated by the lessons in this project, environmental topics are "particularly appropriate for multi-disciplinary and hand-on instruction" (p. 35). In addition, constructivist, student-centered learning can take place through a series of action projects, a key component in environmental education (p. 35). Due to the first-hand nature of this type of instruction, the use of portfolios, research presentations, and community involvement become excellent forms of performance assessment as a way to check for learning (p. 36). Based on these descriptions, an educational reform supportive of students learning about issues concerning the environment is place-based education.

Place-Based Education

An educated citizenry acknowledges the needs and problems of their immediate surroundings; action projects foster the education of place. "Place-based education is the process of using the local community and environment as a starting point to teach concepts...across the curriculum" (Sobel, 2005, p. 7). Just as portrayed in the real world, mathematics, science, language, history, art, and all other subjects traditionally kept separate are
integrated to create real world learning experiences (p. 7). Such pedagogy emphasizes a hands-on and collaborative approach to education (p. 7). As a result, students develop a stronger connection to their community, enhanced appreciation for the natural world, and a heightened commitment to serving as active, contributing members of society (p. 7). "Community vitality and environmental quality are improved through engagement of local citizens, community organizations, and environmental resources in the life of the school" (p. 7).

Place-based education is environmental education on a practical level. Rather than focusing on issues and global environmental catastrophe, place-based education "takes us back to basics, but in a broader and more inclusive fashion" (Sobel, 2005, p. 8-9). It teaches "about both natural and built environments" and considers all aspects of a location or situation (p. 9). "The history, folk culture, social problems, economics, and aesthetics" their interrelationships are all examined within the community and environment (p. 9). When presented this way environmental education can be radically conceived and be viewed as being fundamental to the public in all ranges of communities regardless of nationality or social class.
Place-based education then becomes a crucial part of educating for sustainability (p. 9).

For the sake of those who stand by the qualities of standardized education, place-based education does in fact increase overall student performance. Schools using place-based techniques as the core of their curriculum showed improvement on most, if not all, on state testing and general student performance (Sobel, 2005, p. 28). The results included: improved scores in core academic subjects (reading, math, science, and social studies), an increased ability to make connections and transfer knowledge from one context to the next, and students learned to “do science” rather than just learn about it (p. 28). Many of the schools examined were “in urban neighborhoods with diverse racial profiles and high percentages of students receiving free or reduced lunches” (p. 28). In spite of this, classroom discipline problems had declined and students embraced the opportunity to learn at a higher level (p. 28).

There are four other reasons why place-based learning should be integrated into our schools (Orr, 2005, p. 90). “First, it requires the combination of intellect with experience” (p. 90). Instead of just allowing lecture to be the center of cognitive growth, as found in a regular
classroom setting, the study of place allows for "direct observation, investigation, experimentation, and skill in the application of knowledge" (p. 90). It does away with overspecializing by focusing upon the interrelationships between subject areas (p. 91). "Places are laboratories of diversity and complexity, mixing social functions and natural processes" (p. 91). Problems in the environment and community cannot be solved by relying on a single context (p. 91). Place-based education reemphasizes the art of living well (p. 92). There is a distinction between residency and inhabitation. "A resident is a temporary occupant, putting down few roots and investing little, knowing little, and perhaps caring little for the immediate locale beyond it ability to gratify" (p. 92). On the other hand, an inhabitant develops a relationship with his/her community (p. 92). "Historically, inhabitants are less likely to vandalize theirs or others' places...make good neighbors and honest citizens" (p. 92). They become the "bedrock" of a stable community (p. 92). Finally, education regarding local places instills "an applied ethical sense toward habitat" (p. 93).

A curriculum for green building would provide a perfect forum for place-based education. Whether it is considering the local climate, selecting naturally adapted
materials, or maintaining the condition of a house, how a building interacts with its ecological and societal place is fundamental. While studying green building and design, students investigate their surroundings and make valuable decisions about how structures should be assembled in their community. By taking this hands-on approach, they would be more able to communicate the possible need for change or practice it themselves as they grow older. But before such a curriculum can be developed, a conceptual framework must first be established.
CHAPTER FOUR
CONCEPTUAL FRAMEWORK AND RATIONALE FOR
A GREEN BUILDING CURRICULUM

Introduction
Realizing the need to change the building industry, governments have enlisted the use of codes and incentives to influence compliance (Roodman & Lenssen, 1995, p. 49). But these strategies do little in the way of informing the public or encouraging builders "to innovate beyond the norm" (p. 49). Rather than merely using the law, strategies associated with environmental education could be very effective in promoting change toward green building and design.

Educating for Sustainability
Environmental education and its associated vehicles provide the foundation for the development of an educated citizenry committed to sustainability. It allows students to develop skills needed for systems thinking. Systems thinking is "thinking that synthesizes and evaluates linkages among disciplines is needed if we are to understand the global implications of environmental and economic decisions" (President's Council on Sustainable Development, 1996, p. 5). In turn, students can learn how
to analyze problems from various perspectives, including those which are multicultural (p. 6). The message of sustainability must be relevant in its message around the world and "encompass an appreciation of diverse cultures" (p. 6). By realizing various viewpoints, individuals can learn the importance of partnerships when trying to resolve environmental problems. Educating for sustainability will mean reaching out beyond the classroom to "involve business and others with specialized expertise throughout the community" to collaborate on resolving conflicts (p. 6). By participating in this process, students will gain a greater sense of empowerment. They may realize the importance of and the effective ways to express their views, thus becoming responsible citizens in society (p. 6).

Teaching about green building meets the needs required for sustainable education. Students are presented with an issue and its associated problems to consider in a holistic manner. Various points of view, both economic and environmental are addressed providing an opportunity to make personal choices based on objective and ethical values. Students can take part in an action project. As a result, they experience real-world applications of interrelating subjects and become empowered citizens.
within the community. The development of an educated public willing to make responsible change in their immediate surroundings can go a long way toward conserving our biosphere; sustainable development can be greatly benefited by local action and citizenship behaviors.

Educating for Citizenship Behavior

"Citizenship behavior can be developed through environmental education" (Hungerford & Volk, 2005a, p. 323). But to do so properly, several critical components must be addressed within a given context. A conceptual framework and curriculum focused on green building can meet these factors.

The first critical component is the instruction of ecological literacy (Volk, 2005, p. 141). To resolve issues, such as those associated with green building in an informed and responsible manner, a learner must be knowledgeable of ecological consequences related to proposed solutions (p. 141). When planning to build an environmentally friendly house, the various types of materials available must be researched and chosen. Preference is given to local products able to work with or withstand the natural process surrounding a chosen site.
Knowledge about the local ecosystem is required to do this effectively.

The second component of a proper environmental education curriculum involves the provision of opportunities for learners to increase their environmental sensitivity (Volk, 2005, p. 142). This concept expresses a view of respect for ecological stability and the promotion of harmonic interactions between humans and the natural environment (p. 142). Environmental sensitivity can be promoted by getting students outside to study and observe their biophysical surroundings first-hand (p. 142). In order for students to adequately observe the four functions of a building (which are similar to the human body in its interactions with the environment), they must observe the natural systems taking place outside of the classroom. In addition, environmental sensitivity can be addressed by analyzing the consequences upon the environment as a result of constructing or demolishing buildings. On a more practical level, students could erect a small structure on campus using green building techniques.

The subject of green building has several issues needing to be studied. For example, a critical factor in determining the selection of environmentally friendly
products is affordability. Impoverished societies or individuals may be forced to select cheaper, less durable materials or techniques with which to build. In turn, students studying why certain structures are constructed in a given manner must consider both environmental and economic perspectives. This situation exemplifies the third critical component in environmental education curriculum, in-depth knowledge of issues (Volk, 2005, p. 143). A demand is not only placed on the variety of existing issues, but also their relative consequences and environmental implications (p. 143). “Differing beliefs and values are what drive issues” (p. 143). In an attempt to resolve these conflicts, students must consider all points of views. To sum up, issue analysis requires students to “analyze and understand the complex nature of issues” (p. 144).

“Research indicates that responsible citizen behavior is enhanced when students become actively involved in the investigation of environmental issues” (Volk, 2005, p. 144). The identification of an issue and its component parts is not enough. Curriculum for environmental education must give students an opportunity to develop skills in problem-solving, information-accessing, and processing (p. 144). Learners must make observations and
make decisions based on their collected data. Relative to green design, investigations regarding the effectiveness of specific building materials or techniques could be done. For example, analysis of various roofing styles and their ability to maintain interior temperatures could be performed. Students could test ceramic tiles, asphalt shingling, steel sheeting, and plants (as used in a living roof system). Once the relevant data has been collected, the implications for using each method can be properly discussed. Student decisions about the types of materials best suited for their locality can result. The skills acquired during issue analysis can lead to active citizenship.

The fifth component critical for curriculum in environmental education is the acquisition of citizenship skills (Volk, 2005, p. 144). “Knowing what these skills are and how to practice them is an important contributor to responsible environmental behavior” (p. 144). There are several classified forms of citizenship skills, but persuasion and consumer action are the most relevant to the topic of green building. Persuasion is the “act of trying to convince a person or group of persons that a certain action is correct” (p. 144). By studying specific a specific green building technique, such as people using
solar powered photovoltaic panels in their homes, students can research and possibly demonstrate the effectiveness of its usage. A class of learners might even be able to promote political action to make solar panels more available. When promoting the idea of green building, many decisions are economic in nature. Thus, students can research and possibly test various building alternatives. After a careful investigation of different types insulative materials, for example, pupils in a class can share their findings with the community relative to effectiveness and environmental impact. With this information, the public may be more inclined to purchase one type of insulation over another. This is known as consumer action, the act of using economic power to support certain ideas (p. 144). In any of these cases, students are put in position where they can influence the actions of others, another critical component in environmental education.

"Locus of control may be influenced when a student learns and applies citizenship action skills" (Volk, 2005, p. 145). The examples described above all involve students actively engaged in making changes within their community. When provided with such opportunities, where an application of action skills can be successfully applied,
an increase in an internal locus of control can result. According to existing research, an important factor determining the ability to practice citizenship behaviors is the person's level of effectiveness to make change (p. 144). Thus, a conceptual framework with supportive curriculum designed to allow students to investigate and promote various building practices can promote responsible environmental behavior. Green building, as described, can be a vehicle for meeting this component and goal.

Conclusion

An aim of education is the shaping of desired behaviors, including those pertaining to responsible citizenship, within a society (Hungerford & Volk, 2005, p. 313). Research has indicated an effective development of these qualities through environmental education (p. 323). In light of this, a curriculum focused on green building can play a role as a modality for such instruction. Green building requires students to be knowledgeable of ecological processes and their interactions with human society. Green building is littered with issues needing to be investigated and communicated to the general public. Such a program would provide the opportunity for students to become active
members within the community and gain a greater sense of effectiveness, an internal locus of control. "A grounded, rooted learner understands that his/her actions matter, that they affect the community beyond the school" (Sobel, 2005, p. 12). A conceptual framework and related curriculum focused on green building and design can provide students to become so.
CHAPTER FIVE
DESIGN OF CONCEPTUAL FRAMEWORK AND GREEN BUILDING CURRICULUM

Conceptual Framework for Green Building Curriculum

Before developing the lessons and conceiving a green building curriculum, an outline of overlying concepts was deemed necessary and had to be developed. In attempting to do so, the lack of a cohesive set of definitions relative to learning about green building and design became evident. While the Leadership in Energy and Environmental Design (LEED) Ratings System (see Chapter 2) gives a very basic framework for assessing the environmental impact of a given building, the document did not lend itself to pedagogy. After a great deal of researching publications, books, and websites, it was determined the definitions and descriptions of green building concepts as presented by Snell and Callahan (2005) were the most appropriate. The Snell and Callahan descriptions could be closely tied to LEED, but are written to accommodate changes in the ever-changing subject of green building. The Conceptual Framework for Green Building Curriculum (see Appendix A) was developed in the master’s project to create a foundation for lessons on green building in a context for
environmental education. Most of the conceptual framework is author-created; however, concepts drawn from other sources are identified with a reference to the source.

Section A of the conceptual framework focuses on teaching sustainability, a major objective for both of the fields of environmental education and green building. Ecological literacy and knowledge of alternative building methods are emphasized. Mentioned in this part of the framework are concepts related to ecological cycles and the need to erect dwellings with the ability to work with biophysical systems. Characteristics of green building such as durability, efficient use of resources, and low construction impact as they relate to sustainable development are also included.

Section B of the framework centers on the structure and function of a building and its interactions with the environment. A human built structure can be compared to the human body as they both provide a self-supporting structure, desirable internal conditions, and protection from harmful external environmental factors while maintaining a constant exchange between it and the surrounding ecosystem. Given all of this, a building must provide specific needs to occupants. As a result, any work
or living space should be constructed to adapt to the changing needs of its inhabitants.

Section C, Economic Choices and Civic Responsibility, supports how students would be able to investigate issues in green building, unifying the objectives of environmental education and green building. Students make decisions and observe the consequences resulting from their actions. By promoting citizenship behaviors, students may influence changes within the building industry, especially from a consumer perspective.

In order to be implemented within a public school setting, a curriculum for green building must include accepted state standards for learning, listed in Section D. Science is the most logical choice for focus. Learning objectives associated with density, properties of matter, principles relevant to energy, and physical definitions can be found in the California State Science, most notably at the junior high and high school level. As such, the lessons written for this project were designed primarily for seventh and eighth grade science classes and emphasize state standards pertaining to data collection and analysis skills, critical components for any environmental education program.
Overview of Sample Curriculum

As presented in the conceptual framework, the subject of green building could act as an integrating context for environmental education. The lessons can aid in the development of citizenship behaviors amongst students; in doing so, ecological concepts, knowledge of issues, and assessment of personal values can be included. Students can practice problem-solving and decision-making by investigating and analyzing data relative to specific environmental issues. In addition, opportunities for developing and carrying out action projects can be addressed.

As a precursor for developing relevant environmental curriculum across the state, California passed the Education and the Environment Initiative. This legislation provided the basis for requiring environmental education practices to be used in public schools as well as standards for instruction. "Based on contributions of over 100 scientists and technical experts," the Environmental Principles and Concepts will "serve as the foundation for developing the Model Curriculum" for grades K-12 (California Environmental Protection Agency, 2004, p. 1). To remain consistent with upcoming legislation, relevant standards from California's Environmental Principles and
Concepts were also applied to the activities provided in this project.

The subject of green building is riddled with numerous issues and problems. Thus, pedagogy centered on a constructivist model is utilized. The lessons provided in this project attempt to have students review their existing beliefs regarding selected topics in home construction. Next, the students gain information through investigative, often hands-on, cross-curricular activities. Students conduct different forms of research related to green building and design. Since current information on green buildings is found readily on the internet, access to computers is important. Students gather this information and share their findings with the rest of the class. Assessment generally comes in the form of making educated decisions about how specific aspects of a building should be handled.

The lessons were mostly designed for use in the science classroom. But cross-curricular suggestions are also provided. It is believed, through further development of other lessons in the future, numerous thematic units could be implemented within a team of teachers. The first lesson in this project, titled "Being a Homebody," should be the first one presented during the school year. The
rest of the curriculum could be performed in any order. The lessons can then be used as a yearlong unit, or as anchor activities for individual chapters within the science curriculum.

Being a Homebody

Before investigating the various alternatives available for producing a green building, students must first learn about the basic functions of any dwelling. In the first lesson, "Being a Home Body" (see Appendix B), Snell and Callahan’s metaphor assimilating the functions of the human body with those of a house is utilized (2005, p. 15-16). Students are asked to think about themselves and determine the needs of their physical form. Students classify these requirements into the four categories of function: provide structure and separation from harmful factors, connect and interact with the environment, and regulate internal conditions. The class is then asked to envision their bodies as homes for existence, much in the same way a house provides a place to live. Through the use of a graphic organizer, students brainstorm how their house functions as a body. As an assessment, students take their charts home and list how their residence accomplishes the four functions.
Through inquiry and sharing, the objective of "Being a Home Body" is to build the students' awareness of the basic requirements of a building. Students must consider some very basic ecological concepts when investigating how their home interacts with its external surroundings. Though no opportunity for action or solving of issues is involved, "Being a Homebody" provides a foundation for other lessons.

**Keeping it Local**

Many of the relevant green building issues involve the selection of materials. "Keeping It Local" (see Appendix C) is a lesson analyzing the advantages and disadvantages of using local materials. The main part of this activity involves a race whereby students must collect specifically colored building blocks and toothpicks to create a small structure. Depending upon the specifications provided by the instructor, students must travel different distances to acquire their materials. Once students have assembled their model buildings, they have an opportunity to observe how their creations withstand designated climatic conditions. Those structures composed mostly of the "local materials" should prove to be the most durable. However, local materials may be nonrenewable; there would only be so many "blue colored"
blocks available. The class discusses problems, such as energy usage and pollution associated with obtaining building materials.

Along with realizing environmental impacts, such as habitat destruction and the problems associated with the burning of fossil fuels, "Keeping It Local" can also be used to teach students about economic conflicts with environmental conservation. Though some products are more affordable, they may have greater costs on the health of the environment. The durability of buildings is also addressed when a fan is used to blow the non-local materials down. Many cross-curricular opportunities exist with this lesson, especially in mathematics when students are asked to calculate equations involving work and energy.

**Insulation Investigation**

Selecting environmentally-friendly materials is a fundamental aspect of green building. This is very evident when considering insulation. Placing insulating materials in the exterior walls of a house conserves energy by preventing the transfer of energy between the interior of the living space with the outdoors. However, certain types of materials used in this capacity can lead to negative impacts on the environment. "The Insulation Investigation"
(see Appendix D) focuses on green alternatives to this problem.

Fiberglass sheets are commonly used in modern buildings because of their low cost and easy installation. But this substance can become airborne creating damaging conditions leading to respiratory problems. In addition, it is not easily reabsorbed by the local ecosystem. "The Insulation Investigation" looks at alternatives to fiberglass, including straw, cob (a mixture of clay and straw), and sand. Students directly observe the effectiveness of these and possibly other materials as building insulators through the use of special chambers made from plastic soda bottles. They also search the internet for benefits and problems associated with the use of these methods. After sharing the information, students make conclusions about the best techniques for insulating a house. The activity involves a strong constructivist approach by employing internet research, hands-on experiences, and group dialogue prior to making an educated decision.

It must be noted similar activities such as this already exist. However, they make use of calorimeters considered too small to properly test the effectiveness of materials such as straw and cob. By using the larger
container, the assimilation between the activity and actual building conditions is increased. In addition, the method used in this project appears to better meet middle school standards for science. Many students entering seventh grade science classes have very little experience using scientific equipment. “The Insulation Investigation” is visual and includes the use of triple beam balances.

**Alternative Roofing Experiment**

In the same spirit of “The Insulation Investigation,” the “Alternative Roofing Experiment” (see Appendix E) focuses on using low impact building materials. Specifically, the production and removal of asphalt shingles can have numerous impacts on the environment. Gasses and wastes created by their manufacture can be toxic. The roofs of buildings must be periodically replaced. As a result, these shingles are sent into the waste stream. Since roofing materials are not readily biodegradable, they require large quantities of landfill space in addition to slowly leaching chemicals into ground water supplies. A more natural method of roofing is needed.

A living roof system utilizes the heat capacity of water and the protective qualities of soil and plants to provide coverage on a building. After some modification,
the top of a structure is covered with soil whereby native plant species are installed. The plants and soil store water, which absorbs heat energy from the sun. As a result, the areas closest to the ceiling within the living space are cooler than if asphalt shingles were used. In addition, a living roof system is developed to be more permanent than its synthetic counterpart. Should the roof need replacement, the majority of the materials can be recycled, composted, or simply allowed to be reabsorbed into the ecosystem.

Plastic soda bottles are used to compare the effectiveness in maintaining consistent temperatures beneath a shingle and living roof model. Though standard thermometers could be used, the use of computer-linked probeware is much more effective. Students research the benefits and problems with each method prior to making decisions regarding what they conclude is the best method for roofing a building. The use of modern technology in this lesson has been shown to be very motivational for participating students.

You’ve Got the Power!

In “You’ve Got the Power!” (see Appendix F), alternative forms of energy generation are discussed with special attention being made toward photovoltaic power.
This lesson requires students to research one of several sources for useable electrical power. First, students are exposed to various demonstrations showing how energy is converted into usable electricity. Next, they are organized into groups of three to four students. Each group will be responsible for researching the pros and cons of an alternative energy source; topics for this project include tidal energy, hydroelectric dams, fossil fuels, biomass, photovoltaic cells, geothermal power, and energy obtained from windmills. The groups present their findings with the help of a visual aid. The students, as a class, then assess the various forms of energy and make choices about which alternative would best provide electricity while minimizing environmental impacts.

When researching the topic of solar power, new information regarding the connection of individual photovoltaic panels and their possible contribution to the electric grid was discovered by this author. As one of the selling points for photovoltaic power, solar panels can be installed on the roofs of a building. In doing so, the personal power source is linked to the electric company’s meter. When the building is drawing power from the utility, the meter runs forward charging the consumer for electrical usage. However, during the day, the
photovoltaic panels input electricity into the system. When this happens, the electric meter runs backward crediting the resident for the contribution to the grid. As a result, it is possible for a homeowner to negate their own electrical intake and be charged nothing each month by the electric company. In addition, the need for power generated by fossil fuels, an unrenewable and a high impact resource, is lessened. Through personal interviews, solar panel vendors verbally described this system to the author, but had no means for demonstrating it. As a result, a model involving a simple circuit involving a two-way switch and motor was developed for this lesson.

Go With the Flow

A great deal of electricity in traditional buildings is used for heating and cooling the internal living spaces. To make this system more efficient and conserve energy, vents should be placed to take advantage of the natural tendencies of airflows. Since less dense, warmer air rises and cooler, denser air sinks, a circular current develops known as convection.

In the lesson titled “Go with the Flow” (see Appendix G), students learn and observe the effects of changing temperatures and densities on fluids. First, they are provided an opportunity to measure the densities of
various substances. After recording and analyzing the 
data, the class observes the relationship between density 
and the ability to float by placing the items in a tank of 
water. Students are then required to graph and observe how 
density can change when temperature increases and 
decreases. This is done by capturing air in a Boyle’s Law 
Apparatus, a large plastic syringe sealed to prevent the 
exchange of air within the vessel. When the contained air 
is placed in a cooler of ice, the volume of the gas 
lowers. The apparatus is then placed in boiling water. The 
volume of the air expands and pushes the plunger outward 
from the syringe. Afterward, a tank of water is placed 
above a small hot plate using a set of bricks. The hot 
plate is positioned under one end of the tank and a bag of 
ice is placed on the surface of the water on the opposite 
end. As the coincidental heating and cooling of the water 
takes place, a convection current is observed by placing a 
few drops of food coloring into the tank.

Recommendations

As mentioned, these lessons had been developed and 
informally assessed in this author’s classroom over the 
past three years. Some were also field tested with the 
general population at Environmental EXPO in 2007 at
California State University, San Bernardino. Overall, it is assumed these activities could be effective in educating middle school students about insights in the building industry and associated environmental issues. These lessons are simply a small sampling of what could be included in a curriculum focused on green building.

The lessons included in this project could be easily complimented by other, preexisting activities. For example, a lesson focusing on energy conservation can be found in Roa’s *Environmental Science Activities Kit* (1993, p. 181). Students are required to assess their electrical usage and determine the associated financial cost. They then consider ways of reducing the amount of energy used in the home. This lesson could be easily coupled with “You’ve Got the Power!” as presented in this project. Students could couple their decisions concerning individual power usage with finding alternative energy sources in order to gain more depth and systemic view of solving environmental issues associated with electrical generation.

Depending upon the resources available to the school and community, groups of students could apply their knowledge of green building to design and construct a structure. For example, students in Ojai, California
helped manage project focused on permaculture, the "use of ecology as the basis for designing integrated systems of food production, housing, appropriate technology, and community development" (Praetorius, 2006, p. 6). To promote this concept, participants in the program designed and constructed a greenhouse made of straw bales to assist in garden maintenance (p. 7). Similar buildings could be constructed on other campuses, or even within communities. Models of green buildings could even be constructed for public viewing, increasing awareness in the process.

Conclusion

The lessons provided in this project are a vehicle not only to teach green building, but also as a means of incorporating state educational standards into holistic and authentic action projects. Curricula, especially those in science, have a tendency to be text oriented with various opportunities for small hands-on applications. However, many students do not make the connection between such activities and real world experiences. The pedagogical methods outlined in this project allow for more student involvement within the community and provide a bridge between the classroom and the higher level, authentic application of educational standards. In
addition, problem solving skills, practicality, and an increased sense of credibility could be experienced by students participating in such a learning environment. As a result, citizenship behaviors are taught. This is environmental education, and the issues and practices associated with green building can be taught effectively.
APPENDIX A

CONCEPTUAL FRAMEWORK FOR GREEN BUILDING CURRICULUM
Conceptual Framework for Green Building Curriculum

A. Green Building and Sustainability

1. Sustainable development meets the needs of the present without compromising those of future generations (President's Council for Sustainable Development, 1996, p. 1).
2. Green building "refers to an attempt to consciously create buildings with an eye to how they interact with our planet's ecosystem" (Snell & Callahan, 2005, p. 17). Methods for building green are diverse and are dependent upon the resources of the local environment
   a. The concept of green building centers on the concept of sustainability; the way of life we choose must not lead to circumstances preventing that way of life from continuing.
   b. Constructing buildings with more care and for greater longevity can reduce the amount of materials entering the waste stream.
      i. Natural building materials can be more readily assimilated into the environment than those synthetically treated or manufactured.
      ii. By reducing, recycling, or reusing building materials, the amount of waste entering landfills can be decreased.
   c. A green building uses alternative materials and methods to preserve unrenewable resources, or those slow to recover such as lumber, reduce environmental impacts, and promote healthy living conditions.
   d. A building can be constructed to use energy efficiently and reduce the need for electricity and fossil fuels.
      i. Natural processes, such as the water cycle, convection currents, and greenhouse effect can maintain internal building conditions while minimizing the use of less passive energy sources.
      ii. The use of local materials can increase the durability of a building and reduce the amount of energy needed for its construction.

B. Structure and Function of Green Buildings

1. All buildings including green buildings assimilate the functions of the human body by providing basic needs for survival.
   a. A building is a self-supporting structure that defines an inside and outside environment. The structure of a house includes walls, roof, and foundation.
   b. A building maintains an interior temperature that sustains human life in the face of exterior temperatures that wouldn't.
   c. A building creates a separation and protection from the exterior environment while allowing the constant exchange with outside elements needed for the survival of its inhabitants.
   d. The basic needs provided by a green building can be met with little impact to its local environment.
2. Changes made to one aspect of a building results in alterations of other parts of the structure in order to accommodate the initial change.
a. A building should be constructed to the specific needs of the intended occupants and within the limitations of environmental conditions.
   i. A building should provide a healthy internal environment for its residents.

C. Economic Choices and Civic Responsibility

1. Information about green building practices can be shared to promote environmental welfare.
2. Individual decisions regarding healthy environmental practices are based on educated, personal judgments ultimately demonstrating more effective uses for natural resources and preservation of ecological processes.
3. Decisions regarding the implementation of alternative building methods must include consideration for financial, environmental resources, and maintenance costs.
4. Energy is obtained at a cost, both economically and environmentally. Decisions regarding energy needs must consider the impacts of its consumption.
5. Individuals can reduce negative impacts upon the environment by practicing and promoting responsible behaviors.

D. Scientific Concepts and Processes

1. The physical characteristics of a substance determine its ability to conduct or insulate energy.
   c. Water has a great capacity to capture and store heat. As liquid water absorbs energy, it has a greater chance of changing into a gas (California Department of Education, 2003, p. 135).
   d. As energy is absorbed, the motion of the molecules within a substance increases and its density decreases (California Department of Education, 2003, p. 135).
2. Energy is conserved; it is not spontaneously created or destroyed (California Department of Education, 2003, p. 162).
   a. Usable forms of energy must be transformed from another source (California Department of Education, 2003, p. 162).
   b. Energy is required to transform energy from one form to another (California Department of Education, 2003, p. 162).
   c. Work and energy are directly related. As the amount of work increases, the amount of energy needed to do the work increases (California Department of Education, 2003, p. 163).
3. Information regarding green building practices can be researched through research and scientific methods.
   a. Models and graphs can be constructed using quantitative data to demonstrate natural processes (California Department of Education, 2003, p. 150).
   b. A variety of print and electronic sources can be used to collect information and evidence regarding a specific topic (California Department of Education, 2003, p. 124).
   c. In order to comprehend a particular topic, appropriate tools must be used to accurately collect pertinent data (California Department of Education, 2003, p. 124).

4. Information describing the scientific findings of a specific experiment can be communicated both written and orally (California Department of Education, 2003, p. 124).
APPENDIX B

LESSON: BEING A HOME BODY
Being a Home Body

A. Grade span: 7-8

B. Objectives: Students will be able to...
1. assimilate the functions of a building with those of the human body.
2. define the four functions of a building and the body as structure, temperature, connection, and separation.
3. describe how a building and the body carry out the four functions.
4. define homeostasis.
5. research information associated with a specific topic.
6. compose a graphic organizer comparing the properties of two different subjects.

C. Summary of Lesson
While the other activities in this curriculum are flexible in the way of when they can be implemented in the classroom, "Being a Home Body" is meant to be the first one performed sometime near the start of the school year. This lesson is primarily focused on seventh grade science standards. However, it could assist with reviewing previously covered content at the beginning of the eighth grade year.

This lesson introduces students to the basic objectives to any dwelling. Modern buildings give consumers more of what they want, but use resources very inefficiently (Roodman & Lenssen, 1995, p. 9). Since World War II, floor space per person has more than doubled in new homes while the average family size has declined (p. 8). Nowadays, homeowners want media rooms, home offices, exercise rooms, huge kitchens, and three bathrooms (p. 9). Residents have lost sight of what is actually needed from their home. As a result, they use water and energy less efficiently, waste natural and financial resources, and possess unhealthy indoor environments (p. 9).

In this lesson, students are reminded of the fundamental basis for their home and how it is similar to a living being. First, students review the concept of homeostasis, the body's ability to maintain internal conditions. The human body, just like a house, protects life by providing structure, managing a comfortable temperature range, ensuring separation from harmful elements, and maintaining helpful exchanges with the surrounding environment. After defining these factors, students then develop a series of graphic organizers comparing the basic functions of a house and the human body. The activity provides students with an opportunity to apply the concept of homeostasis and become familiar with their own home.

D. Materials
Overhead projector, Your Body is Your Home overhead, Home Body worksheet, poster paper

E. Procedure

Part I: What does a house provide?
Time: approximately 60 min.

1. Begin the activity by asking students to define the term homeostasis. Homeostatis is the body's ability to maintain internal conditions. If our body could not maintain a standard set of internal conditions, then we would not be able to survive. One could
say, then, the human body “houses” life. Ask students to take out a sheet of paper and make a list of the functions our bodies perform to maintain our existence.

2. Put students into groups of three to four. In each group, students will share their individual lists with each other. Provide a large sheet of paper to each group. Require each group to divide the paper into four sections. Define the four categories of functions in the human body:
   - **Structure** defines the arrangement, shape, and size of the human body.
   - **Temperature** is maintained within a comfortable range for various reactions to take place in the human body.
   - The human body has tissues and organs providing **separation** from outside elements that could cause us harm.
   - However, some **connection** or exchange is maintained with the outside and community. These connections are necessary for the intake of nutrients, removal of wastes, assist in maintaining internal temperatures, and to continue experiencing occurrences in one’s physical surroundings.

   The groups will record these definitions onto each of the four sections on their poster paper. Now ask the students to take the items mentioned on their lists and record them into the four categories. They will also need to identify the organs performing these activities. This should be done with markers for presentation to the rest of the class. Items from the lists can be placed into more than one category.

3. When students have finished making their posters, have the class recognize any patterns that may appear. In general, the following ideas should be evident:
   - The human body maintains structure through the use of a skeleton.
   - The human body maintains internal temperatures through a series of reactions called metabolism. It also sweats and circulates blood and air to regulate these conditions. The organs of the cardiovascular system are most responsible for this.
   - Separation of the bodies internal environment with external conditions is performed by the skin and immune system.
   - Connections between the human body and the external environment are provided by the nose, mouth, pores, and excretory organs. The nervous system also senses outside conditions so the body can adapt.

Part II: Comparing the Body with a House  
Time: approximately 60 minutes, separated over two class sessions

1. As mentioned earlier, inform the class their bodies are like a house. Using an overhead projector, display Figure 1. Go through the chart and describe various categories in association with the student posters made previously.

2. Hand out the “Home Body Worksheet” (Figure 2). The directions require each student to take the worksheet home and fill it out in accordance to their observations of their own home. They will need to list the various methods or materials used in their house to provide structure, maintain temperature, provide separation, and staying connected with the outdoors. Students should be encouraged to work on this assignment with their parents. They will then provide a corresponding list of body organs performing
similar functions. An example is provided on the worksheet; bones and cartilage does for the human body what wooden framing and nails do for a house. If needed other examples may be given, such as...

- A heat pump for a central heating system could be assimilated to the lungs or the heart. The heat pump regulates temperature by pushing warm air throughout the house through ductwork and vents. The lungs do the same thing for the body, as does the heart only with blood and vessels.
- Some students may have evaporative cooling systems in their home. This would be similar to sweat glands, which also cool the body through evaporation.
- Windows allow light inside and permit visual access to the outdoors. The eyes also permit light inside the body and use it to witness events taking place outside of the body.

Allow the class an adequate amount of time outside of class to complete this activity. Since each house may maintain internal conditions differently, student answers will vary.

3. When students have finished completing their charts, ask them to share their findings. Display a copy of Figure 2 on an overhead projector and complete it as the class shares their answers. Verbally reinforce the similarities between the human body and a house. Ask the class again for the definition of homeostasis and how it is maintained in both the human body and a house.

Part III: Assessment
Time: approximately 30 min.

1. Ask students to take out a sheet of paper and answer the following questions (display the questions for the class to see):
   a. What is homeostasis?
   b. What are the four categories of functions used to maintain homeostasis?
   c. How is the human body similar to a house? Provide at least two examples.

2. Provide students time to complete the questions in class. Collect and correct when all have finished.

F. Answers to Discussion Questions

Part III: Assessment Answers
   a. Homeostasis refers to the body’s ability to maintain stable internal conditions.
   b. To maintain homeostasis, the human body must provide structure, maintain consistent temperatures, keep separation from the external environment, while providing various connections with the outside.
   c. A house provides structure, consistent temperatures, separation and connection very similarly to how the human body. By doing so, they help preserve life. There are various examples in how the two do this; answers to this part of the question may vary.
G. Interdisciplinary Applications:

Language Arts: Using their data recorded on the Home Body worksheet, students could write a comparison/contrast essay relative to the functions of the human body and their home.

Social Science: Students could research the different types of housing used by other societies around the world or through history. They could also then relate these methods to the four categories of function provided by a house.

Science: Students could research further on the topic of human organ systems. Separated in groups, they could discover how the organ systems themselves work. Afterward, they could compare their findings with the mechanisms provided by the specific components in a house.

H. Relevant 7th & 8th Grade Content Standards for California

7th Grade Science
5a. Students know plants and animals have levels of organization for structure and function, including cells, tissues, organs, organ systems, and the whole organism.
5b. Students know organ systems function because of the contributions of the individual organs, tissues, and cells. The failure of any part can affect the entire system.
5c. Students know how bones and muscles work together to provide a structural framework for movement.
7b. Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project.
7e. Communicate the steps and results from an investigation in written reports and oral presentations.

8th Grade Science
9e. Construct appropriate graphs from data and develop quantitative statements about the relationships between variables.

I. Relevant California Environmental Principles

Principle III: Natural systems proceed through cycles that humans depend upon, benefit from and can alter.
Concept a: Students need to know that natural systems proceed through cycles and processes that are required for their functioning.

Principle V: Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.
Concept a: Students need to know the spectrum of what is considered in making a decision about resources and natural systems and how those factors influence decisions.
The human body has functions similar to those of a house.

<table>
<thead>
<tr>
<th>The Human Body</th>
<th>A House</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure</strong></td>
<td></td>
</tr>
<tr>
<td>Skeleton</td>
<td>Foundation, walls, roof</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td></td>
</tr>
<tr>
<td>Food, metabolism, sweat, circulating air</td>
<td>Passive solar, evaporation, circulating air, mechanical heating and cooling</td>
</tr>
<tr>
<td><strong>Separation</strong></td>
<td></td>
</tr>
<tr>
<td>Skin</td>
<td>Exterior and interior coverings</td>
</tr>
<tr>
<td><strong>Connection</strong></td>
<td></td>
</tr>
<tr>
<td>Mouth, nose, pores, excretory organs, nervous system (eyes, tongue, nerves)</td>
<td>Doors, windows, vents, plumbing, electrical wires</td>
</tr>
</tbody>
</table>
**Home Body**

Directions: Using this worksheet, inspect your own house. For each of the categories below, list how your home provides these services. Your answers should be specific in listing the types of materials used to make these accommodations. List your answers under the heading “A House.” Under the heading “The Human Body,” list the organs in your body performing similar functions under each category. Use your textbook for assistance. An example is provided below.

<table>
<thead>
<tr>
<th>The Human Body</th>
<th>A House</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure</strong></td>
<td></td>
</tr>
<tr>
<td>bones, cartilage</td>
<td>wood, nails</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Separation</strong></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Connection</strong></td>
<td></td>
</tr>
</tbody>
</table>

An example is provided below.
J. Resources


APPENDIX C

LESSON: KEEP IT LOCAL
Keep it Local

A. **Grade span: 7 & 8**

B. **Objectives: Students will be able to...**
   1. draw a line graph showing the relationship between work and distance.
   2. calculate the slope of a line.
   3. describe the relationship between distance traveled and energy usage.
   4. discuss the pros and cons of using local materials for constructing new buildings.
   5. identify local, natural materials that can be used for the construction of new buildings.

C. **Lesson Summary**

As the human population and, in turn, the market for housing expand, the home construction industry has become very complex. Machines do much of the work with regard to the processing of natural resources and shipping them to project sites. This mechanization has made it easier to access materials from all around the world at little financial cost. But “distance has insulated [developers] from the environmental consequences of their choices, facilitating destructive decisions” (Roodman & Lenssen, 1995, p. 11).

“The roots of the problems caused by building lie in the industrial revolution” (Roodman & Lenssen, 1995, p. 10). With the increased use of machinery, demand for energy rose greatly. This led to a sharp rise in the burning of fossil fuels, which resulted in higher levels of greenhouse gas emissions. In addition, machines allow for mining, harvesting, and transportation of materials to take place much more quickly. As a result, environments are being altered at a massively destructive rate (p. 11). Industrialization of the home construction market has also led to the development of new materials by “turning naturally occurring substances into pollution-intensive, mass-produced materials such as steel, cement, and plastics” (p. 11). The production of all the components going into a modern house encompasses a global effort.

The separation between a new house and the industries creating its parts has led to a lack of diversity and durability in structures. Consumers rarely build their own facilities, relying mostly on the open market (Roodman & Lenssen, 1995, p. 12). Because designers too have become increasingly absent from the actual building site, there is less consideration for the actual climate the project must endure. As a result, new dwellings “wear out sooner than they should and waste large amounts of resources” (p. 12). “Keep it Local” gives students an opportunity to apply physical concepts to the housing industry and observe the benefits of using local materials for the construction of a building.

The lesson provides a series of activities where students can relate the principles of work and energy to the transportation of distant materials. In Part I, students define the term work and its relationship to energy. Students graph the relationship between force and distance and observe increases in work as distance increases, a directly proportional relationship. A review of linear equations is also included. Part II involves an informal contest where students construct a small model using specific materials strategically located in the room. One student will obtain building blocks from a nearby location, while other volunteers must venture to other places in the room to obtain their medium. The latter participants will transport their materials back to the starting location and construct their model. Afterward, climatic conditions are introduced to show the effectiveness of the various materials to withstand local conditions. The class should observe differences in energy and the durability of the structures created. In Part
III, students assess naturally occurring resources found in their real-world locale. They will use their observations from the previous two parts to determine the viability of local materials for use in home construction. Groups will illustrate such a house and present the pros and cons of their design.

D. Materials
Graph paper, overhead projector, ruler, transparency (lined for graphing), at least 40 building blocks (such as LEGO or MEGABlocks) in each of two colors, toothpicks, rubber bands, electric fan

E. Procedure

Part I: Graphing Work v. Distance
Time: approximately 60 min.

1. As an introduction to the lesson, ask the students to define force, work, and energy. For the purposes of this lesson, a force is any push or pull. Work is done when a force is applied over a given distance. Energy is the ability to do work. In essence, energy and work are one and the same; energy is needed to do work. Work is defined as the amount of force applied over a given distance. Force is any push or pull.

2. Hand out a piece of graph paper and a straight edge to each student. Using an overhead projector and a graph paper transparency, show the class how to construct their graph showing work against distance. Work, measured in joules, will be numbered from 0 to 500 in increments of 20 on the y-axis. Number the x-axis from 0 to 100 in increments of 5. The latter will represent distance measured in meters. Label the graph accordingly and title it “Relationship Between Work and Distance.” Use the example in Figure 1 for assistance.

3. After students have set up their graphs, instruct them to write the equation for work on their paper:

\[ W = Fd \]

\[ W = \text{work in joules (J)} \]

\[ \text{Where: } F = \text{force in Newtons (N)} \]

\[ d = \text{distance in meters (m)} \]

If students are familiar with manipulating their units of measure in an equation, a brief discussion about where these designations come from could be done. For this exercise, force will be a constant at 5 newtons. Thus, students will obtain their data using the following equation:

\[ W = (5N)d \]

Students will then establish an “input/output” chart on their graph paper. Using the latter equation, they will calculate the amount of work done at 0 m, 20 m, 40 m, 60 m, 80 m and 100 m.

4. Once they have done this, they may plot their points onto their graph and connect them with a line. The line for this data should be linear and rises as distance increases.
Figure 1: Graphing Work versus Distance

Using the information above, the coordinates for a graph can be calculated as follows:

\[ W = (5N)d \]

<table>
<thead>
<tr>
<th>d (m)</th>
<th>W (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>40</td>
<td>200</td>
</tr>
<tr>
<td>60</td>
<td>300</td>
</tr>
<tr>
<td>80</td>
<td>400</td>
</tr>
<tr>
<td>100</td>
<td>500</td>
</tr>
</tbody>
</table>

The relationship between work and distance is directly proportional. Thus, energy and distance is directly proportional. As the distance an object is carried increases, the amount of energy needed to move it also increases.

The further away people go to get their building materials, the more energy is used. An increase in the use of fossil fuels results.

5. Display the following questions on an overhead projector. When students have finished plotting their graphs, they will copy and answer the following questions.

a. What is the slope of the line you plotted? Explain how you got this answer.

b. What is the y-intercept of the line you constructed for this activity?
c. Is the relationship between work and distance directly proportional or inversely proportional? Explain how you determined this.

d. Work is the same as energy. According to the line graph, what happens to the amount of energy as the distance increases?

e. How much energy is required to move a brick weighing 10 N a distance of 5000 m? Show your work and circle your answer.

6. When students have finished answering the questions, discuss the answers with the class. Point out how the equation for work is like a linear equation:

\[ y = kx + b \]

Where: 
- \( y \) = coordinate
- \( k \) = slope
- \( x \) = coordinate
- \( b \) = y-intercept

Some students may already have observed this and explained this in their answer for question “a.” For those students who need to review, demonstrate this on the overhead projector on the graph showing how to obtain the rise and the run. Then divide the rise by the run to calculate slope. Point out how the calculated slope equals the constant force provided at the beginning of the activity.

7. Discuss the answers for the remaining questions. Students will need to observe how the amount of energy used is increased as the distance a force is applied increases.

Part II: The Benefits of Using Local Goods
Time: approximately 30 min.

1. Ask the class for six volunteers to take part in a brief race. Two of the volunteers, Group A, will construct a small structure shaped like a box using toothpicks. The second pair of students, Group B, will construct a box using a set of blocks of one color randomly stacked on the nearest table. The final pair of students, Group C, will create a box using blocks of another color randomly stacked on a different table located on the opposite side of the classroom.

2. Assemble 10 bundles (at least) of 20 toothpicks. Place the bundles in one corner of the classroom. Sort the building blocks into two different colors. Randomly stack the blocks, with their corresponding color, into two piles. Each pile should be placed on opposite ends of the classroom; one pile will be located on a table where the three groups will build their boxes.

3. Have the three pairs of students assemble around a table, the “Housing Development.” When the instructor says “GO!” the three groups will obtain their materials and begin constructing their boxes on the same table they started at. Group A will get the bundles of toothpicks, pull them apart and stack them into a box. Group B will use the blocks stacked on the starting table to build their structure. Group C will do the same, but they will have to get their blocks from the other side of the classroom. The groups need to build only a simple, uncovered box (four walls are all that is necessary). The first group to use all of
their materials to build their box is considered the winner. The other groups should continue to finish their boxes.

4. Once all three boxes have been put together, the class should discuss what they observed and answer the following questions:
   a. Which group finished their box first? Second and Third? Why did this happen?
   b. Which of the materials were most abundant? If the groups had to pay for their materials, who would pay the most? Who would pay the least?

5. The teacher will take out a fan. Once plugged in, the teacher can turn the fan on high and aim it towards the two buildings. The fan should be placed so the blades are about 50 cm from each structure. The toothpick structure should blow over.

6. As a class, discuss possible answers to the following questions.
   a. Which material was more adapted to withstand the conditions of the land where the structures were built? How does the activity relate to homes built in the community?
   b. Which person had to use the most energy to build their structure? Was all the energy they used worth it in the end?
   c. What materials are used to construct homes in your community? Are those materials local or shipped in from another place?
   d. For those materials needing to be transported to the construction site, what types of energy are being used? How does the use of these resources affect the environment?
   e. If more local resources were used, what materials would be predominantly used to build houses in your community? Would houses look different or the same? Explain.

Part III: Assessment
Time: approximately 60 min.

1. Instruct students to think about and record, on a separate sheet of paper, what resources are abundant in their local environment. Then have them imagine and record what a house made from those materials would look like.

2. Organize students into groups of 3 or 4. Provide each group with a large sheet of drawing paper and markers (or the like).

3. Ask the students to take their individual ideas and combine them with those from their other group members into a single design. Each group will record their design onto the large piece of paper. The groups will present their work to the class. In their presentations, they will include a list of the major materials used in their house, an overview of their design, and the advantages and disadvantages of using these resources. When the class is finished, have each group present their work to the class. When all of the presentations are finished, ask the class if they would be willing to live in the houses designed by the groups. Discuss student answers to these questions.
F. Answers to Discussion Questions

Part I: Graphing Work v. Distance
a. The slope of the line is 5. This can found by realizing the equation for work is in the same form as a linear equation. The force, 5 N in this case, represents \( k \), which is the slope. The slope could also be found by finding the rise and run between any two points on the graphed line. Using the plotted points, a student would most likely find the rise to equal 100 and the run to be 20. When dividing the rise by the run, the slope would equal 5.
b. The y-intercept of the graphed line is 0.
c. The relationship between work and distance is directly proportional. This can be concluded by observing the graphed line to be linear.
d. Because energy equals work, and the work done increases as distance increases, the amount of energy used increases as the distance this work was done increases.
e. Since energy equals work, we can use the equation for work to determine the amount of energy used. Thus,

\[
W = Fd
\]

\[
W = (10 \text{ N})(5000 \text{ m})
\]

\[
W = 50000 \text{ Nm} = 50000 \text{ J}
\]

The amount of energy used is equivalent to 50000 J

Part II: The Benefits of Using Local Goods
4a. Group B should have finished their wall first, simply because they didn’t have to leave the table to construct their boxes. Depending upon how easily students can separate the toothpicks from their bundles, Groups A or C will come in second.

4b. The toothpicks were more abundant. By virtue of their quantity, the toothpicks might be cheaper in cost. However, discussion regarding added fuel costs as well as impacts on the environment may ensue. Overall, the blocks used by Group B may be considered equal or less costly than the toothpicks.

6a. The structure made from building blocks was more effective than the one made from toothpicks. Materials from local resources could be better suited to build homes with because they are already adapted to the existing environmental conditions.

6b. The buildings made by Groups A and C required more energy because the materials needed to be delivered from another place. The builders had to travel a farther distance to obtain their materials. As distance traveled increases, the more energy is used.

6c. Answers will vary. More than likely, most of the houses are made primarily of wood products. Depending upon the location of your school, wood products may or may not be from local sources.

6d. Currently, the transportation of goods from place to another requires the burning of fossil fuels. As a result, the purchasing of materials from non-local sources contributes to air pollution.

6e. Answers will vary. A possible answer for students living in a desert ecosystem would be a house constructed mostly of dirt. Depending what methods of construction are used, the house made of dirt may or may not look like other “traditionally” built homes.
Part III: Assessment
Results of the presentations will vary from group to group. Advantages to using local resources for home construction should include a reduction in the use of fossil fuels and the use of materials better suited to the elements within the environment. A disadvantage to using local resources is the continued degradation of habitat and possible higher costs of materials, depending upon the resources being utilized.

G. Interdisciplinary Applications:

Language Arts: Students could research the advantages and disadvantages of various home building techniques. Their findings could be organized into a comparison/contrast essay. A persuasive essay could also be composed to inform others, including citizens within the community, about the advantages of building with local resources.

Social Science: Students could research the different types of housing materials used by colonists and pioneers as they migrated across the United States. Log homes were predominantly found on the east coast and mountain regions. Across the plains, sod houses were constructed. In the arid parts of the nation, adobe was utilized. A map of what types of materials were used for shelter during our country’s development could be constructed. This activity could be expanded to various regions of the world. Students could analyze the advantages and disadvantages of each technique, how these methods were best suited for their given locality, and whether or not these methods are still being used.

Science: Using a spring scale, students can drag objects of various mass over different distances. After recording the force needed to move the object, they can calculate the work done to move the objects. After comparing the various results, students will be able to observe how changes in mass and distance can influence the amount of work performed. They will also be able to further establish the need for energy to do work (more massive objects needed more force to move, thus requiring more energy). In the average home, energy use is not measured in joules; it is measured in kilowatt hours (kWh). Students could be asked how to convert energy data into power, which is measured in kWh.

Mathematics: Practice problems related to work, energy, and power could be assigned.
H. Relevant 7th & 8th Grade Content Standards for California

7th Grade Science

7b. Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project.

7e. Communicate the steps and results from an investigation in written reports and oral presentations.

8th Grade Science

2d. Students know how to identify separately the two or more forces that are acting on a single static object, including gravity, elastic forces due to tension or compression in matter, and friction.

9d. Students will recognize the slope of the linear graph as the constant in the relationship \( y = kx \) and apply this principle in interpreting graphs constructed from data.

9e. Students will construct appropriate graphs from data and develop quantitative statements about the relationships between variables.

9f. Apply simple mathematical relationships to determine a missing quantity in a mathematical expression, given the two remaining terms.

9g. Distinguish between linear and nonlinear relationships.

7th Grade Mathematics

1.1 Compare weights, capacities, geometric measures, times, and temperatures within and between measurement systems (e.g., miles per hour and feet per second, cubic inches to cubic centimeters).

1.2 Construct and read drawings and models made to scale.

2.4 Relate the changes in measurement with a change of scale to the units used (e.g., square inches, cubic feet) and to conversions between units (1 square foot = 144 square inches or \([1 \text{ ft}^2] = [144 \text{ in}^2]\), 1 cubic inch is approximately 16.38 cubic centimeters or \([1 \text{ in}^3] = [16.38 \text{ cm}^3]\)).

8th Grade Algebra I

24.3 Students use counterexamples to show that an assertion is false and recognize that a single counterexample is sufficient to refute an assertion.

I. Relevant California Environmental Principles

Principle III: Natural systems proceed through cycles that humans depend upon, benefit from and can alter.

   Concept a: Students need to know that natural systems proceed through cycles and processes that are required for their functioning.
Concept b: Students need to know that human practices depend upon and benefit from the cycles and processes that operate within natural systems.

Principle IV: The exchange of matter between natural systems and human societies affects the long-term functioning of both.
Concept b: Students need to know that the byproducts of human activity are not readily prevented from entering natural systems and may be beneficial, neutral, or detrimental in their effect.
Concept c: Students need to know that the capacity of natural systems to adjust to human-caused alterations depends on the nature of the systems as well as the scope, scale, and duration of the activity and the nature of its byproducts.

Principle V: Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making process.
Concept a: Students need to know the spectrum of what is considered in making decisions about resources and natural systems and how those factors influence decisions.

J. Resources
APPENDIX D

LESSON: INSULATION INVESTIGATION
Insulation Investigation

A. Grade span: 7-8

B. Objectives: Students will be able to...
   1. observe the physical properties of various building materials.
   2. discuss the pros and cons of various building materials.
   3. contrast an insulator from a conductor.
   4. describe the motion of particles through insulators and conductors.

C. Lesson Summary

"Heating and cooling...account for 50 to 70% of the energy used in the average American home" (Department of Energy, 2002, Introduction para. 2). The quality of the type of insulation used is rated in terms of thermal resistance, or R-value (How Does Insulation Work for You? para. 2). As the R-value of an insulating material increases, so does its effectiveness.

Depending upon the type of insulating material used, the energy savings gained from the utilization of such materials could be outweighed by the environmental costs. Fiberglass insulation is hazardous to the lungs, eyes, and skin. It is not readily decomposed in landfills and can be transported by high winds into unprotected environments. There are alternative, natural substances to fiberglass insulation, like cellulose or recycled paper, which pose much less of a threat to local ecosystems. But the focus of this lesson is on alternative structural materials.

Rather than using a skeletal structure utilizing a wooden or steel frame, some buildings use a monolithic design composed of natural materials (Snell & Callahan, 2005, p. 48). Straw bales, cob (a mixture of mud and straw), and sand/soil can be used for walls. Since there are no spaces in a monolithic wall, a separate insulating substance is not viable. Instead, the monolithic design requires the structural medium to also provide separation between interior and exterior temperatures.

Though there are many advantages and disadvantages to both skeletal and monolithic designs, the purpose of this lesson is to measure the insulating effectiveness of the various materials mentioned: fiberglass (as found in a skeletal structure), straw bales, cob, and sand. In Part I, students form a kinesthetic model to transport marbles from one side of the classroom to the other. While doing so, students will observe how insulators having a high R-value differ in effectiveness to those possessing a low thermal resistance. In Part II, students use the information gained from the previous activity to measure the insulating properties of fiberglass, straw, cob, and sand. Students will place some ice into a calorimeter made from a 2 liter plastic bottle and one of the aforementioned substances. After allowing a specified amount of time to pass, students calculate how much of the ice had melted. The calorimeter displaying the least amount of melted water will have the highest R-value. In Part III, students assemble a graphic organizer brainstorm the possible pros and cons of each of the tested materials. In Part IV, they assess their predictions by researching these and possibly other types of structural or insulating substances and present their findings. In addition to understanding the properties of insulators, the overall goal of this lesson is to give students an opportunity to be aware of the diverse range of building materials being utilized.

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D. Materials
Four plastic 2 L bottles, clay, straw, fiberglass insulation, ice, plastic wrap, tape, scissors, triple beam balance, sand, plastic bags, 4 pieces of 1” diameter PVC pipe each cut in 12” lengths, strainer, beaker, paper cups, Insulation Investigation worksheet

E. Procedure

Part I: Describing Insulation
Time: approximately 20 min.

1. Ask students if they know what is meant by home insulation; field responses accordingly.

2. Obtain 50 marbles and ask the class to leave their seats and form and come together as a group; students should be about 1 to 2 feet apart. Once students have arranged themselves, instruct them to maintain their position.

3. Stand on one side of the group and place the marbles in a large container. Place a second container on the opposite side of the students. The two receptacles should be about 5 meters away, but within reach of the students standing on the outer edge of the group. If needed, adjust student positions to meet the latter requirement. Instruct the class to transport the marbles from one can to the other. However, in addition to staying in place, no student can possess more than one marble at any given time. When they are allowed to begin, individuals closest to the first container should begin pulling out the marbles and handing them to adjacent students. The marbles should be passed from one person to the next as they make their way to the second bucket. Time how long it takes for the class to transport the marbles from the first container to the second.

4. Keeping the containers in the same place, ask the students to spread out while staying between the “imaginary planes” of the two receptacles. In other words, students will have to spread out laterally from their peers. Allow three students to be placed immediately around each of the containers. The class will transport the marbles just as they did previously. However, they will probably take longer to do this second time around. Also, it is possible the students will drop marbles to the floor, rendering them trapped in the human maze.

5. Once finished, have the class sit back down in their seats. Display the times for each trial to the class. The second trial where students were spread out should have taken longer. Students should cite the increased difficulty of transporting the marbles from one container to the next in the latter scenario; since students were further apart, they needed to be more careful about getting the marbles to the next person without dropping them.

6. Refer to previous lessons dealing with density. Some substances have a greater density. Since the molecules making up a solid are closely packed together, they tend to transfer energy (like the marbles) more quickly than water or air (least dense). Define conductor and insulator:

Conductor: a substance that is able to readily transfer energy from one place to another. Examples include copper wire and other metals, some types of rocks

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Insulator: a substance that does not readily transfer energy from one place to another. Examples include plastics, rubber, wood, and straw.

7. Ask the class to determine which of the two scenarios represented a conductor and an insulator.

Part II: Insulation Investigation

Time: approximately 120 min.

1. Prior to this part of the lesson construct a set of insulation chambers, one set per group. To construct each set, acquire four plastic, 2 L soda bottles, emptied and rinsed clean. Carefully cut and remove the curved top from the bottle. Stuff the bottom of one bottle with fiberglass insulation (wear eye protection and gloves). Then hold a 1 ft piece of 1 inch diameter PVC pipe vertically on top of the fiberglass in the bottom of the bottle. Stuff more fiberglass insulation around the pipe so the level of the insulation is level with the top (where it was cut) of the bottle. Cover the top of the fiberglass with plastic wrap, but leave the hole of the pipe accessible. Tape the edges of the plastic wrap to help keep the insulation in place. Stuff fiberglass insulation into the top (previously removed) of the bottle. Trap the insulation in the bottle top by taping another piece of plastic wrap over the wide end. Repeat this process, but replacing the fiberglass insulation with straw for one bottle, sand in a second, and cob in the last bottle. To mimic the use of sand bags as a building material, it is best to pour the sand into plastic baggies then stack the bags around the PVC pipe. Cob is a mixture of clay and straw. Add enough water to get the appropriate consistency (firm, but soft enough to manipulate easily). Using your hands, mix enough pieces of straw to provide a consistent distribution of straw throughout the clay.

2. Present the following scenario to the class: A thermos or cooler can keep substances both warm and cold for a long period of time. Are these devices conductors or insulators? Students should be able to recognize both coolers and thermoses as being insulators since energy is not easily transferred from one place to another.

3. Refer students to the design of a house; are there times when we need the inside of a house to stay warm? Or to stay cool? Students should respond by noting weather changes where internal building temperatures need to be maintained at a comfortable level. As a result, houses are constructed to include fiberglass insulation to help keep stable internal temperatures and avoid the waste of energy in heating and cooling costs. Display the fiberglass sample constructed for the experiment (see step 1). Do not remove the insulation from the container; fiberglass insulation should not be handled by students without gloves. Ask students why fiberglass makes a good insulator. Responses should include the apparent lack of density of the material.

4. Organize students into groups of 2-3 and handout the Insulation Investigation worksheet (see Figure 1). Groups will follow the procedure to make measurements about the various building materials, straw, cob, sand, and fiberglass. A blank line has been included should other materials be included and other insulated bottles created for comparison.

Note: The various samples in the Insulation Investigation could also be split up amongst groups for measurement. They could then share data for analysis should time be limited.
Insulation Investigation

Objective: Students will investigate the insulating abilities of various materials.

Materials: paper cup, ice, four insulation chambers (one for each sample to be tested), strainer (or filter), beaker

Procedure:
1. Obtain a plastic bottle containing one of the materials listed on the chart below and an empty paper cup. Using a triple beam balance, find the mass of the paper cup and record your measurement in the appropriate space on the chart.
2. Fill the paper cup with ice, which can be obtained from your instructor. Use the balance to measure the mass of the cup with ice.
3. Pour the ice into the chamber of the insulated plastic bottle. Cover the chamber with the appropriate insulated lid. Allow the ice to sit in the bottle for 10 minutes.
4. While the ice is in the bottle, subtract the “Mass of empty paper cup” from the “Mass of cup and ice.”

\[
\text{Initial mass of cup and ice} - \text{Mass of empty paper cup} = \text{Initial mass of ice}
\]

Record your answer in the appropriate space under “Initial mass of ice.”
5. Place a strainer over a beaker. Once the ice has been in the insulated chamber for 15 minutes, uncap the bottle and pour the ice into the strainer. Quickly place the unmelted ice back into the paper cup. Measure the mass of the paper cup with the remaining ice; record this data into the appropriate space in the chart. Subtract the “Final mass of cup and ice” from the “Initial mass of cup and ice” to find the “Final mass of ice.”

\[
\text{Initial mass of cup and ice} - \text{Final mass of cup and ice} = \text{Final mass of ice}
\]
6. Calculate the “Percent of ice unmelted” by using the following equation:

\[
\frac{\text{Final mass of ice}}{\text{Initial mass of ice}} \times 100\% = \text{Percent of ice unmelted}
\]
7. Repeat steps 1-6 for the other samples listed on the chart. Once finished, make a bar graph of your data on the back side of this sheet and answer the analysis questions.

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Mass of empty paper cup (g)</th>
<th>Initial mass of cup and ice (g)</th>
<th>Initial mass of ice (g)</th>
<th>Final mass of cup and ice (g)</th>
<th>Final mass of Ice (g)</th>
<th>Percent of ice unmelted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straw</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cob (clay &amp; straw)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiberglass</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>
Create a bar graph of your data

Insulating Ability of Various Building Materials

<table>
<thead>
<tr>
<th></th>
<th>Straw</th>
<th>Sand</th>
<th>Cob</th>
<th>Fiberglass</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Ice Unmelted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis Questions

1. Which of the materials had the greatest percentage of unmelted ice? What does this mean about its ability as an insulator?

2. Of the four materials, which was the poorest insulator? Why do you think this was so?

3. Which of the results surprised you the most? Why?
Part III: Comparing Building Materials
Time: approximately 90 min.

1. Ask students about the relationship between insulation and the interior conditions of their home. Students should recognize the need for putting some type of material within walls exposed to exterior conditions in order to maintain internal temperatures. Inform the class that the four materials studied in the lab are used in the construction of houses.

2. After the initial discussion, assign each group of students one of the materials sampled in the Insulation Investigation. Instruct students to research their topic and create a list of benefits and problems in using these materials in home construction. Students should have access to computers and the internet when carrying out this research.

3. Once students have assembled their lists, they are to make a poster displaying the information they found. A “T-chart” is recommended, but other graphic organizers could be used. Groups will present their findings to the class and display their posters within the room.

Part IV: Assessment

Provide some time for students to look over the various posters. Then assign a short essay answering the following questions:

If you were to build a house, which of the following materials would you use to construct the walls: fiberglass, straw, cob, or sand? Explain why you chose this material.

Answers to the assessment question will vary, but should reflect the information provided in the lesson.

F. Answers to Discussion Questions

Part II: Insulation Investigation
The lab results should show fiberglass as being the most effective insulator. Straw should be quite comparable to the fiberglass. The sand and cob should have the least amounts of unmelted ice. The results for the natural materials, straw, cob, and sand, will vary. Cob will vary the most depending upon its straw content.

Analysis Questions
1. Fiberglass should have the most ice remaining. Thus, fiberglass is the best at insulating interior environments. Depending how well the straw had been packed into the bottle, it may show better results than the fiberglass.
2. The cob or sand will have least amount of ice remaining. The clay in the cob and the sand both have fewer air spaces to deter the transfer of heat from the outside of the bottle.
3. Student answers will vary.
Part IV: Assessment

Student research and their displayed information will varied. However, some things they should find and note:

- Fiberglass insulation is cheap and easy to install. It saves energy by being and excellent insulator. However, this material is hard to get rid of as construction or demolition waste. Fiberglass pollutes the air and can be blown from landfills to litter landscapes.

- Straw bale construction doubles as an insulator and structural medium. Straw is renewable and can be easily reabsorbed by local ecosystems, thus reducing the need for landfill space. Straw can be found almost anywhere as a local material. A house using straw bales must be constructed skillfully to reduce molding and other structural problems; there are few contractors skilled in straw bale construction. Not all jurisdictions permit housing built from straw bales.

- Cob is also a natural substance doubling as an internal temperature regulator and structural medium. Cob is more of a re-emitter of heat than an insulator. Cob can use local clays for construction, but building sites possess such substances. Making cob and cob bricks is very labor intensive and time consuming. Not all jurisdictions will permit this form of home construction.

- Sand or soil bags can be made and used at any building site. Though not a great insulator, it still can regulate interior temperature by absorbing and re-emitting heat. If the house is demolished, the sand can return straight to the site they were taken from. Sand bags can be used as a solid structural medium. Many jurisdictions may not permit this type of construction yet.

- Other insulating materials that could be tested in this activity include cotton, cellulose, and foam.

G. Interdisciplinary Applications:

Language Arts: Students could compose a comparison/contrast essay discussing the characteristics of two or more of the materials discussed. A persuasive essay could be written as a means for changing local building codes to permit alternative construction techniques.

Social Science: Students could research the different types of housing used by colonists and pioneers as they migrated across the United States. Log homes were predominantly found on the east coast and mountain regions. Across the plains, sod houses were constructed. In the arid parts of the nation, adobe was utilized. Students could create bottles testing these materials and include them in the Insulation Investigation. In doing so, they would need to cite where and when these practices were predominantly used during history.

Science: Earthen materials regulate temperature through the absorption and reemitting of energy throughout a 24-hour period. Students could work together in designing an experiment testing this characteristic in such substances. A lab of this nature could not include cob and sand, but also adobe, concrete, and rammed earth. The color and reflectivity of exterior surfaces can also help control indoor temperatures. Likewise, students could test these effects using labs available from Flinn Scientific, or create an experiment on their own.

Mathematics: Students could research unit prices for the materials tested in the Insulation Investigation. They could then calculate and compare possible cost estimates specific to the use of these building methods. Students could also compare energy savings between a properly and improperly insulated house.
H. Relevant 7th & 8th Grade Content Standards for California

7th Grade Science

7b. Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project.

7e. Communicate the steps and results from an investigation in written reports and oral presentations.

8th Grade Science

3d. Students know the states of matter (solid, liquid, gas) depend on molecular motion.

3e. Students know that in solids the atoms are closely locked in position and can only vibrate; in liquids the atoms and molecules are more loosely connected and can collide with and move past one another; and in gases the atoms and molecules are free to move independently, colliding frequently.

5d. Students know physical processes include freezing and boiling, in which a material changes form with no chemical reaction.

9b. Evaluate the accuracy and reproducibility of data.

9e. Construct appropriate graphs from data and develop quantitative statements about the relationships between variables.

7th Grade Mathematics

1.1 Compare weights, capacities, geometric measures, times, and temperatures within and between measurement systems (e.g., miles per hour and feet per second, cubic inches to cubic centimeters).

1.2 Construct and read drawings and models made to scale.

8th Grade Algebra I

24.1 Students explain the difference between inductive and deductive reasoning and identify and provide examples of each.

24.2 Students identify the hypothesis and conclusion in logical deduction.

24.3 Students use counterexamples to show that an assertion is false and recognize that a single counterexample is sufficient to refute an assertion
I. Relevant California Environmental Principles

Principle I: The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.

Concept a: Students need to know that the goods produced by natural systems are essential to human life and to the functioning of our economies and cultures.

Concept c: Students need to know that the quality, quantity and reliability of the goods and ecosystem services provided by natural systems are directly affected by the health of those systems.

Principle II: The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

Concept a: Students need to know that direct and indirect changes to natural systems due to the growth of human populations and their consumption rates influence the geographic extent, composition, biological diversity, and viability of natural systems.

Concept b: Students need to know that methods used to extract, harvest, transport and consume natural resources influence the geographic extent, composition, biological diversity, and viability of natural systems.

Concept c: Students need to know that the expansion and operation of human communities influences the geographic extent, composition, biological diversity, and viability of natural systems.

Concept d: Students need to know that the legal, economic and political systems that govern the use and management of natural systems directly influence the geographic extent, composition, biological diversity, and viability of natural systems.

Principle IV: The exchange of matter between natural systems and human societies affects the long-term functioning of both.

Concept a: Students need to know that the effects of human activities on natural systems are directly related to the quantities of resources consumed and to the quantity and characteristics of the resulting byproducts.

Concept b: Students need to know that the byproducts of human activity are not readily prevented from entering natural systems and may be beneficial, neutral, or detrimental in their effect.

Concept c: Students need to know that the capacity of natural systems to adjust to human-caused alterations depends on the nature of the systems as well as the scope, scale, and duration of the activity and the nature of its byproducts.

Principle V: Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making process.

Concept a: Students need to know the spectrum of what is considered in making decisions about resources and natural systems and how those factors influence decisions.

J. Resources


APPENDIX E

LESSON: ALTERNATIVE ROOFING EXPERIMENT
Alternative Roofing Experiment

A. Grade span: 7-8

B. Objectives: Students will be able to...
   1. collect data using electronic various electronic resources.
   2. interpret data to make relevant conclusions regarding a physical process.
   3. identify the various parts of a line graph.
   4. describe a living roof system.
   5. list the pros and cons of a living roof system.

C. Lesson Summary
According to Snell & Callahan, a green building maintains a low construction impact, efficiently uses resources, is long lasting, nontoxic, and beautiful (2005, p. 17). As a result, such a dwelling minimizes its impact upon the environment.

Commonly used roofing materials, such as asphalt shingling or porcelain tiles, do not meet all of these requirements. Though they don’t pose much of a construction impact, they are not very durable leading to an inefficient use of resources. Especially in the case of asphalt shingles, which often need to be replaced every 20 to 30 years, many roofing materials eventually find their way to landfills where the chemicals they possess make their way into ground water supplies. Being a subjective measure, beauty will not be considered here. On the other hand, a roof surface composed of soil and plants, also known as a living roof, provides the same services as the synthetic materials while meeting Snell & Callahan’s green building criteria (p. 488).

Living roof systems are made mostly of natural substances easily reincorporated into local ecosystems. The surface immediately adjacent to the top of the house is protected by a water proof lining, which is covered by a series of gravel, mulch, potting soil, and plants (Snell & Callahan, 2005, p. 490). A living roof continues to provide protection from the elements while continuing to contribute to local ecological cycles (p. 488). Thus, it has low construction impact. The plants and soil naturally interact with the physical elements of nature to effectively protect the structural integrity of the building and maintain consistent internal conditions. The evaporation of water from the soil and plants during the summer keeps a house cool. During the winter, the thick layer of soil and mulch insulate the home from the cold. Providing these services while working with adapting to natural conditions is a very efficient use of resources. The rubber skin is very much protected from the damaging effects of the sun, wind and rain. As a result, this water resistant barrier will last a very long time. Since the roof is made of plants, which provide oxygen and is easily absorbed by natural waste cycles should it be replaced a living roof is very non-toxic.

But there are problems associated with a living roof system. First, a living roof is very heavy and requires a very sturdy support system within the load bearing walls of the house. Second, the initial cost is relatively higher than a traditional roof. Thirdly, there doesn’t appear to be many contractors willing or capable of implementing this style of roofing onto a home. But the advantages in the long run make the living roof system worth considering. In this lesson, students conduct a small scaled experiment comparing the effectiveness of a plant in maintaining consistent interior temperatures to that of an asphalt shingle. Prior to the start of this activity, 2 liter bottles need to be constructed for the actual demonstration. The creation of wooden support disks may require the assistance of a person experienced in
the use of a band saw. Though a manual thermometer could be used, probeware connected to available computers will result in more accurate results. Students conduct their experiment, graph the data, and then research the effectiveness of existing living roof systems. They compare all of their observations and findings and formulate a working perception on the viability of a living roof system.

D. Materials

two plastic 2L bottles, two wooden disks able to fit snugly in bottle, ½” wooden dowel (cut into 4 sections, 16 cm each), potting soil, native plant, wax paper, tar paper (same diameter of wooden disk), asphalt shingle (same diameter of wooden disk), 2 computer adaptable temperature probes (such as “GO!” Logger Lite), 2 portable heat lamps, stand to attach lights, computer, masking tape, marker, scissors

E. Procedure

Part I: Pre-lesson Preparations

Time: approximately 60 min.

1. Using the pattern in Figure 1, cut out equal numbers of plywood, tar paper, and asphalt shingle pieces, two pieces of plywood and one piece of the asphalt shingling per group of students.

2. Using a pair of scissors, measure 20 cm from the bottom of two plastic, 2L bottles and cut off the tops. Refer to Figure 2 for assistance.

3. At approximately 4 cm below the cut edge of each bottle, make four holes with the scissors. The holes should be arranged in pairs on opposite sides (see Figure 3). Insert each of the four dowel pieces through adjacent pairs of the holes.

4. Place one of the circular pieces onto the dowels in one of the bottles. Then place a piece of plastic over the top of the wooden circle in the bottle.

5. Repot a plant over the plastic cover on the plywood circle in the first bottle. If possible, use a plant species native to the local climate. Once the plant has been placed in the bottle, use the scissors to puncture a small hole approximately 1 cm below the wooden circle. If the activity isn’t going to take place for some time, make certain to water the plants regularly.

6. Place a second wooden circle on the dowels in the other plastic bottle. Cover the wooden circle with the tar paper, then top it off with the piece of asphalt shingle. As with the first bottle, make a small hole 1 cm below the wooden circle.

7. Repeat this procedure to meet the needs of the classroom, a pair of bottles for each group of students, one with a plant and one with a piece of shingling.

8. Place the bottles in an area receiving regular amounts of sunlight.

9. Just prior to the activity, insert temperature probes into the computers. Set up the temperature sensing program to label the line graph as “Living Roof” and “Shingle Roof.” Using masking tape and a marker, label the corresponding temperature probe with the corresponding measurements being recorded by the computer. See Figure 4 for an illustration on the completed set-up for the lab.
Figure 1: Wood Circle Pattern

Use this circle as a pattern for assembling Living Roof Lab

Figure 2: Cutting the Bottle

20 cm

Cut off bottles top as pictured

Figure 3
Insert wooden support dowels through holes in bottle.

Top View
Figure 4: Living Roof Lab Set-up

Living Roof Model

Soil with plants
Plastic barrier
Temperature Probe
Wood Disk

Asphalt shingle and tar
Temperature Probe

Shingled Roof Model

Figure 5: Pictures of Living Roof

Jackson Hole & Greater Yellowstone Visitor Center
Jackson Hole, Wyoming

Photos taken by author
Part II: Temperature Comparison
Time: approximately 60 min.

1. Show students pictures of homes having shingled roofs and living roofs (Figure 5). Explain to the class how living roofs are increasingly being utilized in homes across the country. Ask students why this might be so. What advantages would a living roof have over a shingled roof? The experiment they are about to perform will help compare the effectiveness of this method against traditional shingled roofing.

2. Have groups obtain their “roofed” plastic bottles (created in Part I), one of each type.

3. Hand out the worksheet, Living Roof Lab (Figure 6). Assign a laptop and two temperature probes (to be used with relative software on the computer) to each group. Explain to the students they will be measuring the effectiveness of a living roof versus the traditional asphalt shingle in maintaining internal temperatures within a house.

4. Students will insert a temperature probe through the single hole beneath the wooden circle in both bottles. Make sure the probe is not touching the plastic of the bottle or the wooden circle.

5. Arrange a lamp over both of the bottles. Instruct students to record the initial temperature inside each bottle.

6. Turn on the lamps. Require students to record the temperature of each bottle every 30 seconds for 15 minutes. When finished, students will save their computer generated graphs and use them to complete the Alternative Roofing Experiment worksheet.

7. While students are working on the experiment, they will need to think about the following questions:
   a. As the experiment goes on, do you notice any differences between the two bottles? Why is this so?
   b. Based solely on the data measured in this experiment, which type of roofing method would be best for maintaining internal temperatures in a house? Why?

8. Depending upon the accessibility to the internet within the classroom, have students research the websites listed on the worksheet. Otherwise, schedule time in a school computer lab or library for research.

9. When students have finished their measurements, they may take their bottles apart. Suggestion: Keep the shingled pieces of wood for future use. The grass and soil can be composted and reused for other planting projects.
Living Roof Lab

Objective: Compare the air temperature changes experienced between asphalt roofing material and plants in soil.

Procedure:
1. You may do this experiment in a group of 2 or 3 students.
2. Obtain two bottles, one representing a living roof system and the other a shingled roof. Also acquire a computer with two temperature probes. Probe one should be placed in the shingled sample; probe two should be placed in the living roof (soil and plant) sample; **make sure the lamp is turned off.** Answer questions #1 & 2 of the Analysis Questions below.
3. Run the temperature probeware program. On the computer, move your cursor to the green “Start” button. Then turn on the lamp and allow the computer to record the data. Information from the temperature sensors will be collected for 10 minutes. During that time, watch what happens to the temperatures.
4. When the data has been collected, turn the lamp off and answer #3-5 of your Analysis Questions.
5. Using your cursor, click on the “Save” icon. Save your data with your last name followed by the words “living roof.”
6. Using your cursor, click on the word “Experiment” on the menu bar. Then click on “Erase Latest Run.”
7. Answer the remaining Analysis Questions. Turn your work into your teacher when finished.

Analysis Questions: Answer the following questions.

1. Based on what you see, write a hypothesis for this experiment.
2. Define the manipulated and responding variables in this experiment.
3. On your graph, which variable is represented by the x-axis?
4. On your graph, which variable is represented by the y-axis?
5. Which of the two lines had a greater slope? Explain why this happened in one sample and not the other.
6. Based on your graph, summarize the results of your test.

7. Check out some of the various living roof systems already being used. Research some of the following internet resources. Cross out the letter of the web sites you investigated.

8. Based on what you read and saw on the websites, what are some of the benefits or pros of having a living roof system? List at least three.

9. Based on what you read and saw on the websites, what are some of the problems or cons of having a living roof system? List at least three.

10. Would you want a living roof system on your house? Why or why not?
Part III: Discussion of Results
Time: approximately 60 min.

1. As a result of the experiment, students should notice the temperature in the bottle with the grassy roof as being lower than the one with the shingled roof, as shown in Figure 7.

Figure 7: Sample Data as recorded by GO! Data Logger probeware

![Graph showing temperature change over time with shingled and grassy roof samples.]

The shingled roof sample showed a greater increase in temperature while exposed to the heat lamp.

Both samples cooled quickly when the heat lamp was turned off.

2. Discuss the answers to the questions in Part II with the class.

3. Ask the class what they found while performing their research. Discuss the following factors:
   1. Weight of the roofing materials on structure of house
   2. Maintenance requirements.
   3. How often does it need to be replaced?
   4. Up front costs
   5. Long term costs
4. Survey the class for their response to the final two questions on the worksheet. What type of roof is preferred by the class? Discuss the responses by the class.

F. Answers to Discussion Questions

Part II: Alternative Roofing Experiment
b. The bottle with the grass on top should be a bit cooler inside than the shingled bottle.
   Water, located in the soil, is a great absorber of heat energy. As the water absorbs the heat, the water evaporates taking the heat away from the roof. In addition, plants transpire water vapor as result of photosynthesis, which also sends water and heat away from the roof.

   c. Since the experiment showed lower temperatures in the living roof model, a living roof is more effective at maintaining internal home temperatures and saving energy.

Part III: Discussion of Results
As a result of their research, students should have found the following information:

   a. Living roofs weigh more than shingled roofs. As a result, less money and materials are needed to support a shingled roof. New methods for living roof construction are decreasing the overall load, but the soil and extra materials for the living roof will still be heavier.

   b. If the living roof is set up appropriately, the only maintenance needed will be to maintain the plants growing in the soil. If native plant species are used, very little extra watering will be needed. A shingled roof does not a lot of maintenance. Occasionally, shingles will need to be replaced and leaks filled.

   c. If constructed correctly, the living roof will never have to be replaced. Sections of plywood may have to be replaced, but soil and plants can be reused to cover the roof. Shingled roofs need to be replaced every 10 to 50 years, depending upon the grade of shingles purchased. If plywood needs to be replaced, the overlying shingles will also have to replaced. Shingled roofs provide more waste then living roofs.

   d. Up front costs for a living roof are higher than a shingled roof.

   e. Due to replacement cost and energy consumption, shingled roofs cost more in the long run than living roofs.

G. Interdisciplinary Applications:

   Language Arts: After researching the two types of roofing materials, students could write a comparison/contrast essay, or a persuasive essay, related to the information they found.

   Social Science: Students could research numerous roofing methods used by other cultures. Gold and other metals were and still are utilized because they reflect much of the intense sunlight found in the region. Students could also investigate roofing methods used by native societies and pioneering cultures. People migrating across the American west utilized sod as a roofing material, very similar to the living roof used in this experiment.

   Science: The activity could be expanded to test other types of roofing materials, such as steel and clay tiles. A lesson on how plants transpire water could be included. Students simply need to place a plastic bag over a plant. The following day, students could measure the amount of liquid water accumulated in the bag. Such a lesson would also be a fine visual
for discussing the various states of matter, or how to survive extreme conditions in the wild should one become lost or stranded.

Mathematics: Students can calculate the percent difference between the temperatures in each of the bottles. From this data, students can calculate figure out how to calculate energy efficiency and possible savings in energy costs due to different roofing materials. Students could also compare short term and long term costs of using shingled and living roof methods.

H. Relevant 7th & 8th Grade Content Standards for California

7th Grade Science

7b. Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project.

7e. Communicate the steps and results from an investigation in written reports and oral presentations.

8th Grade Science

3d. Students know the states of matter (solid, liquid, gas) depend on molecular motion.

9a. Plan and conduct a scientific investigation to test a hypothesis.

9b. Evaluate the accuracy and reproducibility of data.

9c. Distinguish between variable and controlled parameters in a test.

9d. Recognize the slope of the linear graph as the constant in the relationship y=kx and apply this principle in interpreting graphs constructed from data.

9e. Construct appropriate graphs from data and develop quantitative statements about the relationships between variables.

7th Grade Language Arts

2.1 Write persuasive compositions:

7th Grade Mathematics

1.1 Compare weights, capacities, geometric measures, times, and temperatures within and between measurement systems (e.g., miles per hour and feet per second, cubic inches to cubic centimeters).

I. Relevant California Environmental Principles:

Principle I: The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential hoods and ecosystem services.
Concept a: Students need to know that the goods produced by natural systems are essential to human life and to the functioning of our economies and cultures.

Concept c: Students need to know that the quality, quantity and reliability of the goods and ecosystem services provided by natural systems are directly affected by the health of those systems.

Principle II: The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

Concept a: Students need to know that direct and indirect changes to natural systems due to the growth of human populations and their consumption rates influence the geographic extent, composition, biological diversity, and viability of natural systems.

Concept b: Students need to know that methods used to extract, harvest, transport and consume natural resources influence the geographic extent, composition, biological diversity, and viability of natural systems.

Principle III: Natural systems proceed through cycles that humans depend upon, benefit from and can alter.

Concept a: Students need to know that natural systems proceed through cycles and processes that are required for their functioning.

Concept b: Students need to know that human practices depend upon and benefit from the cycles and processes that operate within natural systems.

Concept c: Students need to know that human practices can alter the cycles and processes that operate within natural systems.

Principle IV: The exchange of matter between natural systems and human societies affects the long-term functioning of both.

Concept b: Students need to know that the byproducts of human activity are not readily prevented from entering natural systems and may be beneficial, neutral, or detrimental in their effect.

Principle V: Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making process.

Concept a: Students need to know the spectrum of what is considered in making decisions about resources and natural systems and how those factors influence decisions.

J. Resources

APPENDIX F

LESSON: YOU'VE GOT THE POWER!
You’ve Got the Power!

A. Grade span: 7-8

B. Objectives: Students will be able to...
   1. describe how mechanical energy is transferred into electrical energy.
   2. compare and contrast various forms of alternative fuels or energy sources used to generate electricity.
   3. compose an essay supporting decisions regarding energy choices.
   4. analyze data in the form of a circle graph.
   5. observe a working electrical circuit involving a photovoltaic cell.

C. Lesson Summary
   “Burning coal is the most polluting way to generate electricity” (Montana Environmental Information Center, 2008, para. 1). Power plants burning this fossil fuel are responsible for 40% of the mercury, a neurotoxin, entering the air in the United States annually (para. 4). Other pollutants such as sulfur dioxide, nitrogen oxides, and other particulates generated from the burning of coal can damage plants, water sheds, and aggravate respiratory problems (para. 5). The burning of fossil fuels is also partially responsible for the emission of greenhouse gases causing climate change. With all of the problems coal burning plants cause, it is still the main source of electrical energy generated in the United States. There are other, less environmentally damaging, sources of electricity worth considering. This lesson provides the opportunity for students to investigate these methods.

   First, students review how electricity is generated and delivered to individual buildings. After a circle graph of the commonly used forms of electrical generation is created, students will observe how a turbine works. A hand-cranked, AC generator is obtained from a science supply company. When turning the crank, a coil of copper wire rotates within a series of magnets. The magnetic forces move the electrons along wires creating an electrical current. With the exception of photovoltaic cells, all forms of electrical generation require some form of turbine to create a current. A separate model is assembled to demonstrate the effectiveness of solar power as a source for electricity. In addition to a lamp and a fan, the assembly is also equipped with a double switch and a motor to demonstrate how an electric meter functions. As energy is being consumed, the dial on the motor rotates in a clockwise manner. However, current photovoltaic systems are being attached to the general power supply as way to supplement energy supplies. When the residential solar panel is generating electricity for “the grid,” the motor on the meter spins in the opposite direction. Individual households are charged for the number of times the dial rotates clockwise. But when the motor spins the other direction, customers are credited for the amount of electricity they contribute. Individual energy bills can quite feasibly be nullified.

   The lesson progresses into a research based project. Groups of students are established and assigned one of several alternative energy sources. As a result of this research, presentations outlining the main principles of these methods are given. Students will record the findings of their classmates, notably the pros and cons of each technique for obtaining electrical current, in the form of a graphic organizer. They finally assess these various electrical resources and develop conclusions about the form of electrical generation they find most effective.
D. Materials
   Hand cranked AC electrical generator model (can be obtained by major science equipment companies), copies of Alternative Energy Project, white board or overhead projector, paper and colored pencils for creating circle graphs
   For solar panel demo: 1 2V solar cell, copper wire, 1 AA battery, two way switch, light bulb with socket, motor & gear box ("2 in 1" Gearbox, available from Elenco Electronics Inc., Model #21-130), a piece of plywood and screws for mounting

E. Procedure

   Part I: Sources of Energy
   Time: 90 minutes

1. Ask the class and discuss responses to the following question: How does your home get electrical energy? Possible responses include the use of fossil fuels, solar power, and wind turbines.

2. Provide the following data for the sources of electricity in the U.S.:

   Current Fuel Mix for U.S. Electricity Generation
   - Biomass: 7%
   - Coal: 49%
   - Nuclear: 20%
   - Natural Gas: 14%
   - Hydroelectric: 7%
   - Oil: 2%
   - Other Renewable: 1%

   Instruct students to construct a circle graph showing this information. Then ask the following questions relative to the data:
   a. What percent of our country's electricity comes from fossil fuels?
   b. Are there problems with using some of these fuels to generate electricity? What are they?
   c. Are there benefits with using some of these fuels to generate electricity? What are they?
   d. What is meant by “Other Renewable” resources? Can you list some renewable resources?

3. Display for students an AC electrical generator, available through most science lab companies. The model should include a light, which will emit light when the crank on the generator is turned. Explain to the class how electrons are moved when the copper coil is rotated in the center of the series of magnets. The electrons travel down the wire and through the light bulb to emit light and heat.

4. Most of the electricity entering homes today comes from large generators formed in this fashion. Ask students how the generators get turned. On an overhead projector or white board, record student responses. Answers should include water from dams, wind turbines, and steam generated from burning coal or nuclear power. Students should be able to briefly discuss their answers.
5. Electrical power can also be generated from the sun. Display for students a model of an electrical system set up on solar power; Figure 1 diagrams how such a circuit could be created. Flip the switch in order to turn on the light bulb from the battery. The gearbox will also make the arrow spin in a clockwise direction. Explain to the class how the electric company records the amount of electricity being used in your home; they count the number of times the dial has turned. See Figure 1 for a basic illustration of said circuit.

6. Turn on a heat lamp and aim it onto the solar cell in the model. Flip the switch to connect the second circuit, so the light bulb is now being powered by the solar cell. At the same time, the dial on the gear box will now be spinning in an opposite direction. Explain to the class how the chemical activity of the silicon in the solar cell transports electrons across the wires. Ask students to observe the dial operating on the solar power; as a homeowner, would you be paying for this energy, or does the electric company owe you for this output? Since the dial is moving counterclockwise, the electric company would have to credit your account; your electric bill would decrease.

![Figure 1: Diagram of Parallel Circuit](image)
- the switch enables the user to use two different electrical sources

- Motor with gear box: cut a note card into a circle and number the edge clockwise from 1-10, then slip the circle over the axle extending from the gear box and use small pieces of tape to keep it stationary
- Using the remainders from the note card, cut out an arrow and attach it to the end of the axle using clay or tape

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Part II: Alternative Energy Project

Time: About 45 minutes to introduce project
   Approximately 1 week for research and preparation of presentations
   About 2 hours for student presentations

1. Hand out the worksheet, Alternative Energy Project (Figure 2), and review the directions.

2. Organize students into groups of three to four. Assign one of the eight research topics to each group: solar power, nuclear power, wind power, biomass, hydrogen, hydroelectric, tidal power, and fossil fuels.

3. Provide appropriate class time to complete the requirements of the project. Depending upon the number of resources available to your class, approximately one week will be needed for students to research and explore their topic.

4. After students have had time to research, organize, and prepare, have each group report their findings to the class. Require students to note the pros and cons of each energy source for home electrical production. Instruct students to use a T-chart to organize information. For example:

   Hydroelectric Power

<table>
<thead>
<tr>
<th>PROS</th>
<th>CONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable resource, as long as water is flowing</td>
<td>Very expensive to construct</td>
</tr>
<tr>
<td>Very efficient energy output</td>
<td>Siltation decreases amount of energy output over time</td>
</tr>
<tr>
<td>No pollutants are emitted</td>
<td>Dams greatly alter habitat and can negatively affect biodiversity and local ecosystems</td>
</tr>
</tbody>
</table>

5. If it can be arranged, display visual aids and information for mass viewing (for example, show projects in local library).
One of the major problems facing our planet is the generation of clean electrical energy for a growing global population. There are many ways to provide electricity to meet human needs, but the use of each source comes at a cost. For this project, you will analyze one of these energy sources and present your information to the class.

In Groups of 3-4, you will research and produce a visual displaying an alternative source of energy for technological use by humans. Your group will select one of the topics below:

- Solar Power
- Hydrogen Power
- Fossil Fuels
- Nuclear Power
- Hydroelectric Power
- Wind Power
- Tidal Power
- Biomass (Biofuels, not fossil fuels)

For the topic chosen by your group, you will research the following information:

1. **Cost**
   - a. How much does it cost to install or build this system?
   - b. What are the operating costs for this energy system?

2. **How are these energy sources converted into electricity?**
   - a. What is the primary source of energy?
   - b. How is this source translated into electricity?
   - c. How is electricity acquired by the human population?

3. **Pros and Cons of obtaining electricity from these alternatives?**
   - a. How do these methods affect the local and global ecosystem?
   - b. What effects are considered positive for the environment?
   - c. What effects are considered negative for the environment?

4. **How efficient is this source of energy?**
   - a. How is energy “wasted” as the source is converted into electricity for the home?
   - b. What problems exist in transporting electrical power to homes?

5. **Current Status/Research**
   - a. Is this energy source currently being utilized to generate electricity?
   - b. How many people are accessing this resource?
   - c. Who is using or could use this energy source for electricity?
   - d. Is there research to make this source more available or less harmful to the environment?

6. **Overall Summary**
   - a. Is it, or will it be worth using this energy source for electrical generation? Support your answer.
   - b. Do you this source of energy as being a major supplier of electricity in the future? Explain.

After completing your research, your group must organize your information and present it to the class. The presentation will be about 4-7 minutes long. In addition to each group member speaking, your presentation must also include a visual aid and discussion of the six major topics regarding your energy source. The visual aid can be a poster, model, or demo. It should display how your selected energy source is converted into electricity.
Part III: Assessment
Time: 45 minutes

1. Once all of the presentations have been completed, ask students to write a brief essay answering the following questions:
   a. If you could choose, which of the energy sources would you like to see the U.S. use the most? Explain why.
   b. If you were to build or purchase your own home and choose your energy source, which energy source would you choose? Explain why.

The essay should be at least four paragraphs long and include an introduction, conclusion, and two body paragraphs.

F. Answers to Discussion Questions

Part I
   a. Adding up the percentages from oil, coal, and natural gas, 65% of our electricity results from the burning of fossil fuels.
   b. They are finite, at some point we will run out of fossil fuels. The burning of these substances releases large quantities of pollution.
   c. Relative to other energy sources, fossil fuels are still cheaper in terms of dollars.
   d. Renewable resources are those provided by recurring natural cycles. Aside from hydropower and biomass, electricity can be generated from the wind and tides. The sun is technically not renewable, but its source is outside of Earth’s atmosphere and is in readily available supplies.

Part II:
   a. Answers will vary amongst groups, depending upon topic and information gained through research.

Part III:
   a. Answers will vary depending upon student choice of topic.

G. Interdisciplinary Applications:

Language Arts: In addition to the presentations, students could write a short research paper comparing and contrasting between various methods for delivering electricity to individual homes. They could also develop an informative brochure on how to save electricity in the home, or explaining the alternative energy sources.

Social Science: Students can associate the various types of fuel sources, especially oil and hydroelectricity with various aspects of history. They could research the Reclamation Act and its effects on the developing western United States. In addition, students could analyze the history and effects of individual dams in our country or those specific to California. Students could also look into the social effects of pollution derived from these energy sources.
Science: In addition to the concept of electricity and how it is formed, a discussion on work and power could be demonstrated. Different forms of kinetic and potential energy could be observed while using the described models. Students can also observe the different types of energy and how it is transferred from one form to another; it is neither created nor destroyed, the law of conservation of energy/mass.

Mathematics: Students could request, from their parents, a copy of their electricity bill (a worksheet could be developed, or confidential information could be blacked out). They could then analyze and learn how an electric bill is calculated. A presentation by a representative of a solar power company could show students how their firm determines the number of solar panels would be needed to cancel out household electric bills.

H. Relevant 7th & 8th Grade Content Standards for California

**7th Grade Science**

7b. Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project.

7e. Communicate the steps and results from an investigation in written reports and oral presentations.

**8th Grade Science**

2e. Students know that when the forces on an object are unbalanced, the object will change its velocity (that is, it will speed up, slow down, or change direction).

2f. Students know the greater the mass of an object, the more force is needed to achieve the same rate of change in motion.

3d. Students known the states of matter (solid, liquid, gas) depend on molecular motion.

9e. Construct appropriate graphs from data and develop quantitative statements about the relationships between variables.

**7th Grade Mathematics**

1.1 Compare weights, capacities, geometric measures, times, and temperatures within and between measurement systems (e.g., miles per hour and feet per second, cubic inches to cubic centimeters).

1.2 Construct and read drawings and models made to scale.

2.4 Relate the changes in measurement with a change of scale to the units used (e.g., square inches, cubic feet) and to conversions between units (1 square foot = 144 square inches or \([1 \text{ ft}^2] = [144 \text{ in}^2]\), 1 cubic inch is approximately 16.38 cubic centimeters or \([1 \text{ in}^3] = [16.38 \text{ cm}^3]\)).
I. Relevant California Environmental Principles:

Principle III: Natural systems proceed through cycles that humans depend upon, benefit from and can alter.
Concept a: Students need to know that natural systems proceed through cycles and processes that are required for their functioning.

Principle V: Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.
Concept a: Students need to know the spectrum of what is considered in making a decision about resources and natural systems and how those factors influence decisions.
Concept b: Students need to know the process of making decisions about resources and natural systems, and how the assessment of social, economic, political, and environmental factors has changed over time.

J. Resources

APPENDIX G

LESSON: GO WITH THE FLOW
Go with the Flow

A. Grade span: 7-8

B. Objectives: Students will be able to...
1. measure the density of regularly shaped objects.
2. determine the relative density of an object based on its ability to float.
3. predict changes in density as a result of changing temperatures.
4. describe the process of convection.
5. explain how convection currents can be used to save energy.

C. Lesson Summary
Density is the amount of mass within a given unit of volume, or:

\[
\text{density} = \frac{\text{mass}}{\text{volume}}
\]

In other words, density is a measure of how compact matter is within a given space. Particles of matter within a substance can be arranged very tightly, high density, or they can be loosely spread out over an equal area, low density. This physical property can be altered with temperature. As energy is added, the particles within a given substance begin to move faster and increase their distance from each other. Thus, when matter is heated, the density of a substance will decrease because the constant mass is being distributed over a greater volume. On the other hand, when energy is taken away from a substance, the temperature is decreased, its particles move less and contract; the mass of the substance takes up a smaller quantity of space. The relative density of a substance can be determined by observing its ability to float on another substance. A low density object will float in a higher density substance. The density of water is 1 g/mL. If a substance, such as dry wood, floats on water, the density of that substance must be lower than 1 g/mL. In contrast, any substance with a density greater than 1 g/mL will sink in water.

Knowledge of density can assist with the proper planning of in-home heating and cooling systems. Some homes are constructed with a central heating/cooling unit, which blows both warm and cold air through the system of vents. Warm air will float on denser cold air. Thus, if heated air was distributed through the ceiling of a house during the colder, winter months, much of the air would continually rise never reaching the floor of the building. Likewise, if the vents were located near the floor, the cooled air would have a hard time reaching through the warm, less dense, summer conditions. In either case, a homeowner spends extra money and excessive energy to establish their interior environments. A heating/cooling system where warm air rises from the floor and cool air sinks from the ceiling would be most ideal, decreasing the amount of energy needed to maintain consistent internal, structural temperatures.

This lesson contains a series of activities where students measure density, graph its changes, and apply their findings to the efficient use of heating and cooling systems. In Part I, the Density Investigation, students measure the density of various substances. They graph their data and make predictions regarding the relative buoyancy of each. In Part II, Changes in Density, students take a given data set and produce two line graphs. One of the graphs will reveal how density changes when volume is increased; the other line will show how density is altered when mass is increased. Using their observations from Parts I and II, students make
predictions about natural phenomena in Part III. A closed convection system is created in a tank full of water. With the assistance of food coloring, students will be able to see the warm water rise and cooler water sink. In addition, a sealed plunger of air is heated and cooled to demonstrate changes in volume with temperature. To assess student learning on the subject of density and their ability to apply it to real-world scenarios, students are asked to sketch an efficient home heating and cooling system for a house. Students should be able to recognize the need to vent warm air from the floor and cooler air from the ceiling.

D. Materials
Density cubes (come as a kit from Flinn Scientific including pine, PVC, polypropylene, aluminum, copper, brass, oak, acrylic, steel, oak), triple beam balance, ruler, 10 gallon fish tank, ice pack, 4 bricks, hot plate, food coloring, Density Investigation worksheet, Changes in Density worksheet, plastic plunger with rubber stopper (Boyle’s Law Apparatus)

E. Procedure
Part I: Density Investigation
Time: approximately 100 min.

1. Review with the class the concepts of volume and mass. Remind students mass is the amount of matter contained within an object and is measured using a balance. Volume is the amount of space an object or substance occupies. This property is measured by multiplying the length, width, and height of a regularly shaped solid, such as a cube. The volume of liquids is measured using a graduated cylinder.

2. Hand out the Density Investigation lab sheet (Figure 1). Review the procedure and definition for density. Density is the amount of matter in a given space. It is a measure of how “compact” matter is. The equation for density is

\[
density = \frac{mass}{volume}
\]

Students will record answers onto their data chart, construct a bar graph, and answer the questions as related to their data.

3. Put students into groups of two or three. Each group will obtain a balance, ruler, graduated cylinder, and a calculator.

4. Assign a number to each type of block. For the sake of clarity of these instructions, the following assignments have been made:

   Item 1 = oak
   Item 2 = pine
   Item 3 = polyvinyl carbonate (PVC)
   Item 4 = polypropylene
   Item 5 = aluminum
   Item 6 = copper
   Item 7 = brass
   Item 8 = acrylic
   Item 9 = steel
Density Investigation

Objective: Students will calculate the density of various solid substances. Based on a substance's density, students will predict whether an object will sink or float in water.

Directions
1. Use a balance to find the mass for each of the cubes listed below. Record your findings on the chart.
2. Measure the length, width, and height of each block in centimeters. Then find the volume of each block by using the following formula:
   \[
   Volume = \text{length} \times \text{width} \times \text{height}
   \]
   Record your answers on the data chart.
3. Determine the density of each block using the formula for density.
   \[
   \text{density} = \frac{\text{mass}}{\text{volume}}
   \]
   Record your answers on the data chart.
4. Use the chart below to construct a bar graph and answer the questions that follow.

Data Chart

<table>
<thead>
<tr>
<th>Substance</th>
<th>Mass (g)</th>
<th>Volume (cm$^3$)</th>
<th>Density (g/cm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Oak</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polypropylene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Analysis Questions

1. Wood products float on water. Using your data for pine and oak, describe the density of wood as compared with water.

2. Using your answer for questions #1, what other products should float on water? How can you tell?

3. Describe the density of air as compared with water.
With the assistance of the class, demonstrate and measure the density of corn oil. First measure the mass of a graduated cylinder. Then place an amount corn oil into the cylinder. Measure the mass of the cylinder and the corn oil together then subtract to find the difference and thus the mass of the corn oil. Simply measure the volume of the corn oil from the graduated cylinder then calculate the density. Inform the students they will need to find the density of water in a similar fashion. Have the nine density blocks lined up and labeled on a table/counter top. When groups have been formed and their equipment passed out, allow students to measure the mass and volume of the various blocks, recording their answers onto the data chart.

5. When students have completed their mass and volume measurements, facilitate a discussion on how they found the mass and volume of water. In the end, they should have first measured the mass of the empty graduated cylinder, then place a measurable volume of water into it. Then they should have found the mass of the graduated cylinder and the water. The mass of just the water will equal the difference between the mass of the empty graduated cylinder and the graduated cylinder filled with water. Students should use the same sample of water to measure the volume in the graduated cylinder.

6. Once students have completed their bar graphs, obtain one sample of each density block and a tank of water. Starting with water, review student measured densities of each item. As each item is discussed, reveal to the students the name of the material each item is made from and place it in the tank of water. Students should get close to the following measurements:

   Density of water = 1 g/mL  
   Density of pine = 0.38 g/mL  
   Density of PVC = 1.34 g/mL  
   Density of polypropylene = 0.90 g/mL  
   Density of aluminum = 2.88 g/mL  
   Density of copper = 8.26 g/mL  
   Density of brass = 8.83 g/mL  
   Density of acrylic = 1.22 g/mL  
   Density of steel = 9.41 g/mL  
   Density of oak = 0.77 g/mL

Display the following questions on an overhead projector for discussion as the blocks are being dropped into the water.

   What samples float in the water?  
   What relationship can be determined about buoyancy and density?

Students will observe items with a density less than that of water, 1 g/mL, will float in the water. Items with a density greater than 1 g/mL will sink in water. In addition, the greater the density a block has, the faster it appears to sink to the bottom of the tank. A substance will float when placed in a substance of greater density. The greater an object’s density, the less buoyant it will be when placed in another substance.
Part II: Changes in Density
Time: approximately 45 min.

1. Review the observations students made in Part I. Each of the blocks measured in Part I had the same volume, but different masses. Density is how compact matter is arranged within a substance. Like a pair of identical suitcases, one suitcase may have more stuff in it than the other. The suitcase with more stuff packed in it is more dense than the identical suitcase with less stuff in it.

2. Hand out the worksheet titled Changes in Density, Figure 2. Allow the students some time to complete the assignment.

3. Discuss the answers to the Changes in Density sheet with the class.

4. While reviewing the line for Graph A, have students relate this information to their data for the density blocks. They will observe how the density of the blocks was larger as mass increased while volume remained constant. For Graph B, students will observe an increase in volume results in a decrease in density should mass remain constant.

5. End Part II by asking the class, “What happens to a substance if its volume increases and density decreases?”

Part III: Increasing the Volume of Air
Time: approximately 60 min.

1. Take a volumetric plunger and set it at 50 mL. Place a rubber stopper over the tip to trap the air inside. Place the plunger into a chest full of ice or a freezer a couple of hours prior to performing Part III of the lesson.

2. Review with the class how density changes when mass and volume has been altered. Ask the class, “How can the volume of a substance be altered? How can a substance expand and contract?” Discuss a couple of the answers before proceeding with the experiment.

3. Begin the Volume of Air Demonstration. Set up a butane burner, a mesh beaker stand, a 100 mL beaker, and a thermometer. Pour water into the beaker. Set the filled beaker on the stand and begin boiling the water with the butane burner.

4. Retrieve the volumetric plunger from the ice chest. Immediately push the plunger until it stops. Forcing the plunger to go any further will pop the rubber stopper off and release the air trapped within. Once the plunger has reached its stopping point, read and record the volume of air in the plunger. Also, measure and record the temperature inside the ice chest, which should be approximately 0°C. Before taking the plunger back to their table, the students will place approximately 50 mL of ice from the chest into the beaker. Place the thermometer and the plunger into the beaker of water. The temperature of the water should be close to 100°C. Periodically remove the plunger from the boiling water with a tongs and check the volume of the air inside. The volume of the air inside the plunger should increase over time.
Changes in Density

Directions: Calculate the density in each of the charts using the data provided. Then plot the data on the appropriate graphs on the back side of this sheet. Answer the questions below.

Graph A

<table>
<thead>
<tr>
<th>Mass (g)</th>
<th>Density (g/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
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<tr>
<td>20</td>
<td></td>
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<tr>
<td>15</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Graph B

<table>
<thead>
<tr>
<th>Volume (mL)</th>
<th>Density (g/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
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<td>15</td>
<td>15</td>
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<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Analysis Questions

1. What is a directly proportional relationship?

2. What is an inversely proportional relationship?

3. As the volume of a substance increases, what happens to its density?

4. As the volume of a substance decreases, what happens to its density?

5. As the mass of a substance increases, what happens to its density?

6. As the mass of a substance decreases, what happens to its density?

7. Which of the two graphs represents a directly proportional relationship?

8. Which of the two graphs represents an inversely proportional relationship?
Graph A: Density vs. Volume

Graph B: Density vs. Mass
5. While performing the demonstration in Step 4, begin heating water in the fish tank (see Figure 3). Place each corner of the 10 gallon fish tank upon the four blocks of wood. Place a small hot plate between two of the wood blocks under the narrow end of the tank. Fill the tank with water. The water should be about two inches from the top. Submerge the miniature table and chair to the bottom of the tank. On the end of the tank opposite of the hot plate, tape a bag of ice to the side of the tank so the majority of the bag sits in the water. Turn the hot plate on low. **DO NOT TURN THE HOT PLATE UP TO HIGH!** Also, the top of the hot plate should be at least 2 inches from the bottom of the tank. If the tank gets too hot too quickly, the glass of the tank will shatter or the plastic holding the tank together could melt. Allow the water to heat and cool on opposite ends while students complete the lab.

Figure 3: Convection Model

6. Review the result of the Volume of Air Demonstration. In the end, students will observe the volume of a gas increases as temperature increases. Relate these observations with the information from the previous two parts of the lesson. As volume increases, the density of a substance will decrease. In turn, as the density of substance decreases, that substance will become more buoyant.

7. Have the class gather around the fish tank system. Point out to the students how one end of the tank is being heated and the other is being cooled. Again, relate the situation to what they just saw with the plunger. Explain how the tank represents a room in a house. The water represents the air in the room. Place a few drops of food coloring near the bag of ice. Students will see the food coloring drop nearly straight down to the
bottom of the tank. The coloring will then creep its way along the bottom of the tank until reaches the warm spot over the hot plate. Students will track the warmed water rising to the surface and deliver the coloring back to the ice pack. Explain to the students how the varying temperatures have created a convection current. Warm air rises and cold air sinks.

Part IV: Assessment and Connection
Time: 45 minutes

1. Ask students to review what was learned during the previous parts of a lesson.

2. Hand each group a sheet of paper and some drawing utensils. Ask each group to draw an outline of a house. Each group will then design a heating and cooling system maximizing on the effects of convection to save energy. Drawings should include a heating and cooling source, and how the various air masses are delivered. Students will need to be able to explain their system and how it saves energy to the rest of the class.

3. Ask groups to briefly present their ideas to the class in a 1 to 2 minute presentation. After each presentation, post the designs in the room. When all of the presentations are completed, ask each student to analyze each plan and choose the one they think will work best and explain why. The heating and cooling designs should show heat being delivered to the house from the bottom and cool air supplied through the ceiling.

F. Answers to Discussion Questions

Part I: Density Investigation
The pine, oak, and polypropylene will float in water because their density is less than 1 g/mL, the density of water. Substances with a lower density will float on top of substances with a greater density. Or, substances with a high density will sink in substances with lower densities.

Part II: Changes in Density
Volume is inversely proportional to density; as volume increases, density decreases, and vice versa, provided mass remains constant. Mass is directly proportional to density; as mass increases, density increases also in a linear relationship. In the latter case, volume remains constant.

Assessment
Student answers will vary, but should utilize the concept of convection currents. Vents in a home should be so warm air rises from the floor and cool air sinks from a source in the ceiling. Decisions regarding the most effective system should be justified based on knowledge gained from research and lab/demonstration activities.
G. Interdisciplinary Applications:

**Language Arts:** In addition to the presentations, students could write a short research paper comparing and contrasting between various home heating/cooling systems. Research could be completed on-line. Students could analyze cost and effectiveness in saving energy relative to investigated strategies.

**Social Science:** The concept of density can be related to California’s gold mining history. At one time, miners delivered their ore to mills where it was crushed then bathed in mercury. Most of the rock was less dense than mercury, so it would float. However, gold is more dense than mercury and would sink to the bottom where it could be collected in a more pure form. A visual aid using foam beads (representing residual rock), water (acting as the mercury) and coarse sand painted gold in a jar could be used.

**Science:** The concept of convection could also be related to numerous natural processes, including the development of weather systems, plate tectonics, or the circulation of nutrients in Earth’s oceans. Various groups could be assigned each topic to research. The groups would design a visual aid showing how convection is utilized in each of these processes. Students could also predict what might happen to Earth should convection in any of these situations ceases to function. The lesson can also act as an example of changing molecular motion as energy in a substance is increased or decreased. A lesson on coastal wetlands could be performed. Less dense freshwater will float on top of oceanic saltwater. Students could examine how organisms have adapted to this habitat.

**Mathematics:** Practice problems related to calculating density could be included as part of the lesson (see Density Word Problems).

H. Relevant 7th & 8th Grade Content Standards for California

**7th Grade Science**

7b. Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project.

7e. Communicate the steps and results from an investigation in written reports and oral presentations.

**8th Grade Science**

2d. Identify separately the two or more forces that are acting on a single static object, including gravity, elastic forces due to tension or compression in matter, and friction.

8. All objects experience a buoyant force when immersed in a fluid.

8a. Students know density is mass per unit of volume.

8b. Students know how to calculate the density of substances from measurements of mass and volume.

8d. Students know how to predict whether an object will float or sink.

9e. Construct appropriate graphs from data and develop quantitative statements about the relationships between variables.
7th Grade Mathematics
1.1 Compare weights, capacities, geometric measures, times, and temperatures within and between measurement systems (e.g., miles per hour and feet per second, cubic inches to cubic centimeters).
1.2 Construct and read drawings and models made to scale.
2.4 Relate the changes in measurement with a change of scale to the units used (e.g., square inches, cubic feet) and to conversions between units (1 square foot = 144 square inches or [1 ft²] = [144 in²], 1 cubic inch is approximately 16.38 cubic centimeters or [1 in³] = [16.38 cm³]).

8th Grade Algebra I
24.1 Students explain the difference between inductive and deductive reasoning and identify and provide examples of each.
24.2 Students identify the hypothesis and conclusion in logical deduction.

I. Relevant California Environmental Principles:
Principle II: The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.
Concept b: Students need to know that methods used to extract, harvest, transport and consume natural resources influence the geographic extent, composition, biological diversity, and viability of natural systems.

Principle III: Natural systems proceed through cycles that humans depend upon, benefit from and can alter.
Concept a: Students need to know that natural systems proceed through cycles and processes that are required for their functioning.
Concept b: Students need to know that human practices depend upon and benefit from the cycles and processes that operate within natural systems.
Concept c: Students need to know that human practices can alter the cycles and processes that operate within natural systems.

Principle IV: The exchange of matter between natural systems and human societies affects the long-term functioning of both.
Concept b: Students need to know that the byproducts of human activity are not readily prevented from entering natural systems and may be beneficial, neutral, or detrimental in their effect.

Principle V: Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making process.
Concept a: Students need to know the spectrum of what is considered in making decisions about resources and natural systems and how those factors influence decisions.

J. Resources
REFERENCES


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