Green School Guidelines & Application in Arid Regions

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Abstract

There is a worldwide movement towards sustainability. A stepping-stone towards a sustainability conscience population starts in the education of the younger generation. Focusing on improving education specifically in middle schools in arid regions regarding sustainability will shift and shape youths' interests and lifestyles into an educated community. This sustainability conscience community will continue to make moral sustainable decisions in their future endeavors.

The curriculum implemented will reduce the dropout rate because it is a hand-on curriculum that is interesting and enjoyable for kids. The focus of the curriculum is to rely on outdoor activities to create an outdoor learning environment. The curriculum is based on three different sections: 1) campus-wide adaptable strategies implemented by the students, 2) long term investments implemented by professionals, 3) and hands-on activities that will encourage students to go outdoors and experience real-life problems.

To create this education system, the author will propose design guidelines and applications that will be used to improve middle schools particularly in arid regions to become "Green Schools". This program will validate the sustainable strategies, projects, and efforts done at schools and will also market their school as a model to follow. This will explain what it takes to become a Green School in arid regions and how to achieve these standards.

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Introduction

Education plays a central role in American society. The United States Census Bureau (2015) states that the Unites States population is about 322,928,000 and is projected to increase to 417 million in 2060 (Colby, Ortman, p. 1). Based on the population increase, future generations should become educated on sustainable issues and strategies due to the environmental impact in today's collective consumerist culture. Understanding the implications of climate change can help these generations respond to this crisis accordingly. In order to achieve the common goal of increasing education in the sustainability field, children should be taught this subject early in their education.

Although the United States high school dropout rate has increased throughout the years to 750,000 in 2012, there is still a lot of improvement that should be made because no one at a young age should be deprived of their education (Brown). This curriculum will decrease the dropout rate even more because it is a hands-on learning experience that is engaging and entertaining. It will create a revolution of a new learning environment that will motivate students to engage in a living laboratory with outdoor activities and hands-on assignments.

A sustainability education organization is to be implemented in the United States to teach our future generations and hopefully help them understand the steps they can take to a better future. A reflective curricular activity is necessary to cultivate sustainability studies in children's education. Our future generation should learn about climate change, sustainability, environmental impacts, and the ecological footprint. This educational tool can impact education system in arid regions such as Tucson, Arizona, where it can later be implemented to the county, state, and then modified to adapt all around the United States according to their climate zone. To

celebrate environmental stewardship, sustainability, and action to particularly middle school students in arid regions, the curriculum must be enjoyable, organized, and engaging.

Although there is an increase in environmental awareness, environmental education has been implemented since 1948 at the meeting of the International Union for the Conservation of Nature and Natural Resources (Disinger 1983). Instead of children always seeing the positive image of the world, they should acknowledge both reality and possibility to encourage them to have action on their part in their future studies. A linear model of environmental education by Sterling and Cooper (1992) is the stages this criteria model will follow as seen in *Figure 1*.

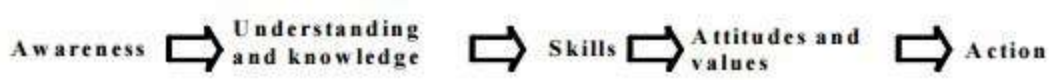

Figure 1 A Linear Model of Environmental Education by Sterling and Cooper (1992).

These stages will be fundamental for an environmental curriculum implemented in the proposed criteria in arid regions to increase environmental awareness in middle schools.

Methodology

The purpose of this report is to provide a list of guidelines and applications that are divided into three section. These sections are: 1) campus-wide adaptable strategies implemented by the students, 2) long term investments implemented by professionals, 3) and hands-on activities that will encourage students to go outdoors and experience real-life problems to become "Green Schools". The guidelines and applications will be analyzed and demonstrated with detailed illustrations of the applications. A qualitative approach is implemented in the report in order to define the stages these guidelines and applications will follow that will be discussed in the literature review. Through a review of literature on environmental education, sustainability, site visits, the assessment of books, online journals, and case studies will evaluate

concepts implemented in the green school guidelines and applications in arid regions. The curriculum will be shaped through the guidance of past case studies and environmental strategies.

Literary Review

The Georgia Department of Education defines environmental education as "a learning process that increases knowledge and awareness about the environment and develops skills that enable responsible decisions and actions that impact the environment. Environmental education promotes interdisciplinary learning, encourages inquiry and investigation, and develops problem-solving skills" (Georgia Department of Education, 2015). The green initiative has started all over the world in elementary education and schools. The Vermon Energy VEEP Education program, for example, is a program whose mission is to, "Promote Energy Literacy: A deep understanding of what energy is and how to use it efficiently, to enable energy usage choices that will result in a sustainable and vital economy and a healthy environment" (Vermont). They host regular workshops on energy efficiency, renewable energy, and climate change. This program also initiates team-based projects to reduce carbon emissions, carbon footprint, and fossil fuels by increasing efficiency, conservation, and renewable generation. The VEEP Educational program is a great educational tool that can be used as model for the green school guidelines and applications arid regions.

Another great local example of sustainability education for the 21st century specific to arid regions is a public charter school called, Changemaker High School (CMHS) in Tucson, Arizona. As in the Vermon Energy VEEP Education program, CMHS focuses on engaging activities that accommodate to arid regions. For example, their Urban Agriculture Lab works in the greenhouses propagating plants, composing, and planting. Through participatory research,

teachers and students also gather data on community safety and health to propose solutions through projects to fulfill the community's need. Their art room consists of students creating paintings that speak to civic engagement as well as global transformation. The Changemaker Lab is designed as a space to create projects through small group meetings and put them into action such as recruiting potential community partners to broaden their learning spectrum. At Changemaker, students are trained to be leaders in their community from their constant ideas put into action, problem solving, and team working skills combined towards a positive change. The school's mission is to prepare their students not only with the core curriculum, but to go above and beyond to engage students in real-world issues. Some of the student-created posters on the wall of the high school read, "Don't Make Excuses: Make Change," "Be the Change you Want to See in the World," and "Once a Changemaker, Always a Changemaker," to continually motivate their students to do their best (School Planning Management). Changemaker High School is an inspiring local example of preparing students to initiate positive change for the greater good by incorporating problem solving, teamwork, and leadership in their core curriculum.

At CMHS, students are not only encouraged to become active members of the community but are required to identify challenges and propose solutions for these challenges. These ideas are presented twice a year where they are judged by local representatives. This project is called Pitch-a-thon. Students at CMHS that have a proposed pitch will, "give report-outs, accounting for funds spent and outlining next steps. Presentations also include foundational research, business strategies and accountability plans. The ideas are creative and diverse, and are grounded in the personal experiences of the students" (School Planning Management). These are some of the launched projects these students have brought into action:

> "One student, who came to this country as a refugee, is organizing a 5K run in support of local refugee relocation initiatives. Another student has successfully launched a project to support teens struggling with body image issues, which she herself battled with as a young teen. Homelessness, food insecurity, sustainability and community health and wellness are other examples of issues being tackled by the students" (School Planning Management).

At CMHS, their education system is focused on action where proposed solutions are launched and processed into a plan. They are engaged in real world issues and are focused on creativity, problem-solving, teamwork, and leadership.

Green School Guidelines & Applications in Arid Regions

The green school guidelines and application in arid regions are separated into three sections: 1) campus-wide adaptable strategies implemented by the students, 2) long term investments implemented by professionals, 3) and hands-on activities that will encourage students to go outdoors and experience real life problems. These three sections are further described under the campus-wide adaptable strategies, long-term investments, community garden, student professional engagement, and professional engagement sections. The campus-wide adaptable strategies are moderate to easy fixes that are accomplished through student engagement. The long-term investments have a bigger impact but require professionals in order to be done and are more expensive. The community garden section explains how the school can grow and consume healthy organic food as well as create an outdoor laboratory through the garden to promote an outdoor learning environment. The final two sections are monthly curriculum topics and activities that will be done by student and professional engagement. These guidelines and applications will be the criteria towards becoming a "Green School" in an arid region.

Campus-Wide Adaptable Strategies

The campus-wide adaptable strategies will improve the school's overall efficiency by reducing energy and water consumption while still having thermally comfortable spaces. These guidelines and applications will create a sustainability conscience schools that are capable of reducing, storing, and producing its own resources such as energy, food, and water.

Reducing Solar Gain

To successfully implement these strategies, we must first demonstrate and identify the major differences between daylight and sunlight. Sunlight is absolutely every wavelength of direct light given off by the sun. Daylight is indirect sunlight rays being reflected off of the clouds. It is critical to understand that reducing solar gain is an important strategy to consider but one must be conscience of daylight as well since it is a strategy that must be implemented as well.

Fully shading windows, doors, and entrances in hot climates is the most effective way to reduce solar load on fenestration because they intercept direct radiation from the sun before it reaches the glass. Incorporating a shading device is crucial because it allows the designer/inhabitant to manipulate desired solar load. Shading devices are most efficient when placed on the South, East, and West Façade. External devices used for shading reduce solar heat gain by up to 80% (2030 Palette). Recessing entrances and glazed openings can also shade and become great balconies, porches, and garages. The optimal strategy to reduce sola gain arid regions is to completely shade the summer sun.

Orientation

The orientation of the building is important to take into consideration to reduce solar gain that exists in arid regions. A building elongated along the East-west direction is the optimal orientation of the building because the shorter East and West sides are exposed to the maximum

heat gain through sunlight and the elongated sides are exposed to much less heat gain as seen in *Figure 2*, increasing the opportunity for potential diffuse natural light on the North façade.

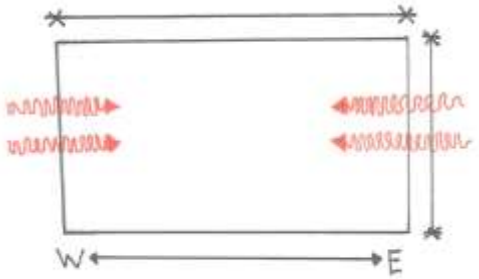

Figure 2 Orientation of Building Elongated in the East-West Direction to Minimize Heat Gain. Illustrated by Ambar A. Gardner.

Size of Window

The sizing of windows is connected to the orientation of where the windows are. Reducing or increasing the size of windows depends on the purpose of the design. Using proper sizing calculations and placement of windows in relation to prevailing wind speeds and direction, natural ventilation can be achieved. The larger the window the greater the solar gain and the smaller the window the lower the solar gain will be as demonstrated in *Figure 3*.

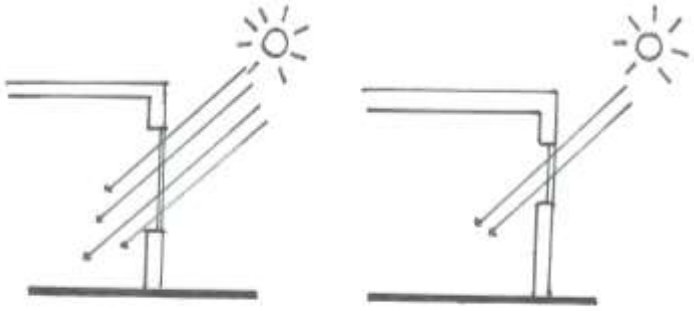

Figure 3 Solar Gain Entering the Space in Response to the Size of Window. Illustrated by Ambar A. Gardner.

Optimal window sizing would be to reduce window size in the East and West facades and maximize window size in the North and South façade. It is also important to not compromise

light. For example, having no windows at all would eliminate solar gain but would also eliminate daylight which is not a good design strategy.

Shading

Simple optimum shading devices for arid regions are horizontal overhangs and vertical fins. Sizing an exact shading device to fully shade windows and doors creates successful shading devices that are both cost effective and energy efficient. Correctly calculating overhangs is the only way to shade efficiently year round by blocking solar gain while having light. Design programs such as SketchUp can allow you to design perfectly shaded overhangs by scaling the designed windows in the program and using the Shading Feature to allow the model to cast a basic shadow at any desired time. To use the Shading Feature in SketchUp, the model's latitude and longitude, cardinal orientation, and time zone must be provided. The appropriate shading devices must be used for the southwest climate. The following shading devices are appropriate for the southwest climate.

Horizontal overhangs

Horizontal overhangs are shading devices that are set horizontally above windows. Depending on climate condition and function of the building, a horizontal overhang can either completely shade a window from the winter and summer sun or shade the summer sun and allow direct solar gain from the winter sun as shown in *Figure 4 and 5*.

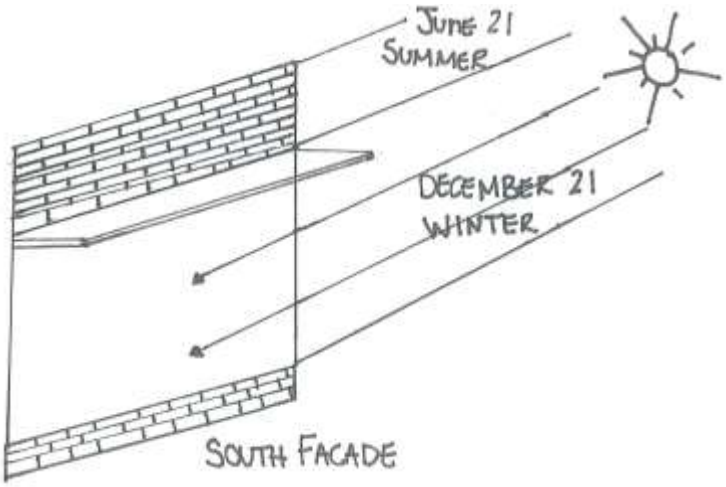

Figure 4 Horizontal Overhang. Illustrated by Ambar A. Gardner.

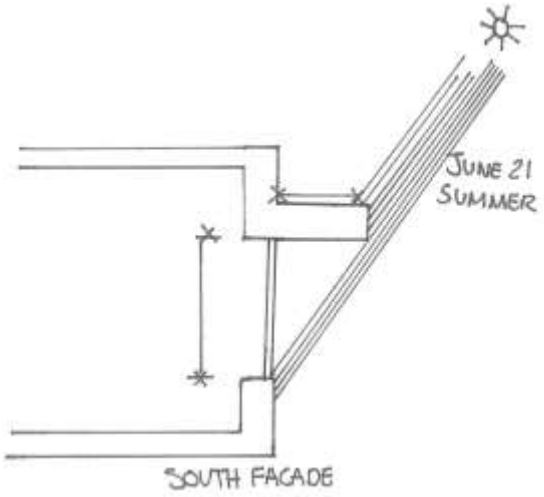

Figure 5 Horizontal Overhang Section View. Illustrated by Ambar A. Gardner.

Horizontal overhangs are optimal for south facing facades. As they strategically block sunlight, while allowing daylight to flood the interior of the space. This also maximizes views to the south.

Vertical Fins

Vertical Fins are shading devices that are set vertically on a window. It is important to recognize that having a mixture of shading strategies can be the most efficient way to perfectly size and shade windows as seen in *Figure 6* where a horizontal overhang and a vertical fin is implemented in the design to shade summer and winter sun.

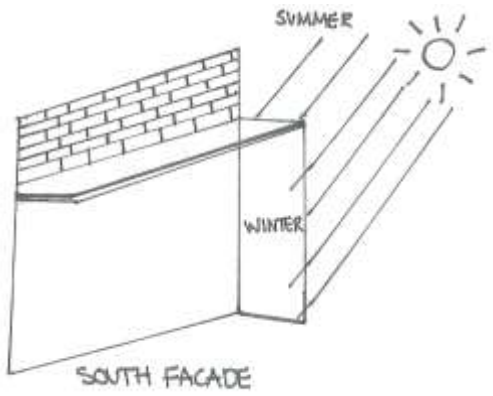

Figure 6 Vertical Fin with a Horizontal Overhang. Illustrated by Ambar A. Gardner.

Vertical fins are most efficient in east and west facades because they block early morning and late afternoon summer sun.

Louvers

Louvers are parallel shading devices that are oriented either horizontal or vertically as shown in *Figure 7 and 8.*

Figure 7 Horizontal Louvers. Illustrated by Ambar A. Gardner

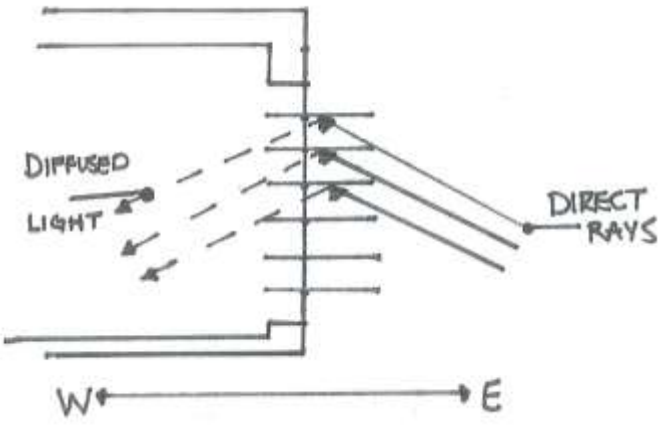

Figure 8 Horizontal Louvers Plan View. Illustrated by Ambar A. Gardner

Figure 8 also shows light being diffused. These outdoor solar shading blades can also be mounted to the façade instead of on the window. There are fixed and motorized sunscreen blade louvers available which are options that vary on price specifically. Operable louvers that are managed electrically have the setback of energy costs and are more expensive than fixed or manually operable louvers. Exterior horizontal louvers are most efficient in a south facing façade.

Vegetation

Vegetation is used for shading and cooling buildings and surfaces as well as blocking winter wind. Surrounded vegetated areas are cooled since water evaporates through leaves to lower its surrounding temperature by beneficial winds. In regards to shading, trees on the east, west, southeast, and southwest sides of a building are most optimal (2030 Palette). Vegetation can be incorporated in the designed shading devices as seen in *Figure 9* or in the landscape surrounding the building as seen in *Figure 10*.

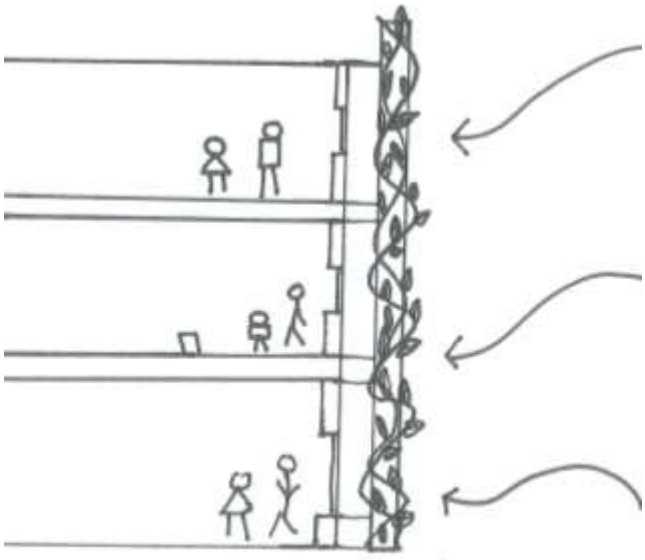

Figure 9 Vertical Shading Blades with Vegetation for Natural Ventilation. Illustrated by Ambar A. Gardner.

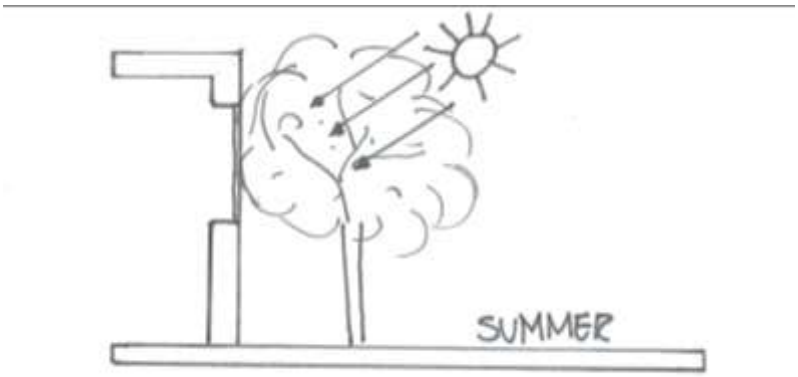

Figure 10 Surrounding Landscape in Building for Shading. Illustrated by Ambar A. Gardner.

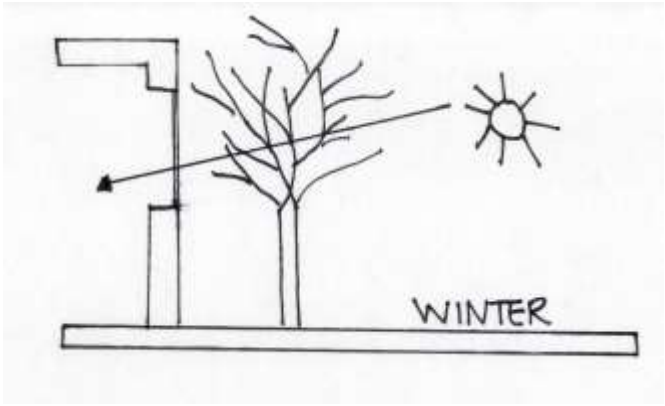

Figure 11 Deciduous Tree Used for Passive Heating in the Winter. Illustrated by Ambar A. Gardner.

Figure 10 is a great example of using deciduous trees for shading and evaporative cooling during the summer. During the winter, the use of deciduous trees allows for solar gain for heating as shown in *Figure 11*.

Daylight

Natural day lighting is a major component in green building design. It influences optical and thermal conditions in a building but it can also counteract by overheating an environment and creating visual discomfort. The sun's movement throughout the day and year is one of the most crucial environmental factors to understand when designing or retrofitting an energy efficient building. Solar Radiation allows for energy generation, passive heating and natural

lighting but can also work against you by overheating an environment and creating visual discomfort.

Secondary Daylight

Secondary daylight is essential for human thermal comfort. An example of secondary daylight is shown in *Figure 12*.

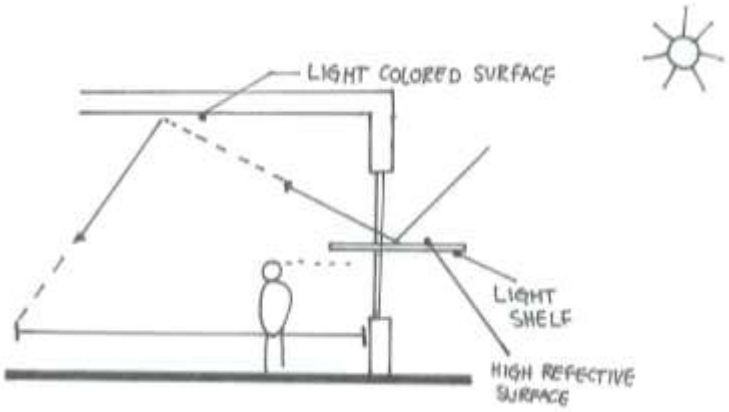

Figure 12 Secondary and Tertiary Daylight. Illustrated by Ambar A. Gardner

Primary daylight would be if the light shelf was nonexistent and solar gain went directly inside the space. Secondary daylight is important and accomplished through the light shelf shown by reflecting daylight into the light colored surface roof. This allows a greater area to be flooded with natural light. Tertiary daylight is then accomplished by the secondary daylight being reflected by the light colored surface further into the space to create human optimum light conditions, and improve the flooding of the space with natural light due to the light shelf that blocks sunlight.

Reducing Energy Consumption

It is important to recognize that before even thinking of investing in long term technology like Photovoltaics and HVAC systems, energy reduction strategies must be implemented first. The most important strategy to reduce energy consumption is by ones behavior. Learning to turn of lights and disconnect appliances when not in use can make a difference. People's daily everyday routine can reduce energy consumption by being resourceful and conscious of the environment. Reducing energy consumption in the space is achieved in many way by using natural daylighting, the most efficient lighting fixtures, and sensors.

Natural Lighting

Naturally lighting a space is energy free which is why it is important to take advantage reducing energy consumption. Natural lighting is achieved by utilizing windows efficiently as mentioned in *Figure 12*.

Type of Lighting

Replacing regular light bulbs with LED lighting fixtures will reduce energy consumption. The use of incandescent light bulbs produces internal heat gain into load where LED lighting fixtures produces much less since they are even cool to touch while they are turned on. Using incandescent light bulbs heat the space therefore, the higher and longer the air-conditioning system will have to be on. The replacement of incandescent light bulbs to LED lighting fixtures will reduce the energy consumption of the space dramatically. To see it in perspective, a 60 watts equivalent LED light bulb only uses 8 watts while an incandescent light bulb uses 60 watts. That is about 7.5 times more efficient that an incandescent light.

Sensors

Adding sensors in rooms can also reduce energy consumption by turning off light fixtures when room is vacant. There are two types of sensors: 1) the one that lights up when you walk in

the room, 2) and the one that shuts off when the room is vacant. The most efficient sensor is the one that turns lighting fixtures off when the room is vacant.

Passive Cooling

Passive cooling is accomplished through multiple strategies such as incorporating landscape in the space through evaporative cooling decreasing the local temperature by cooling the air by evaporating water through its leaves as illustrated in *Figure 13*.

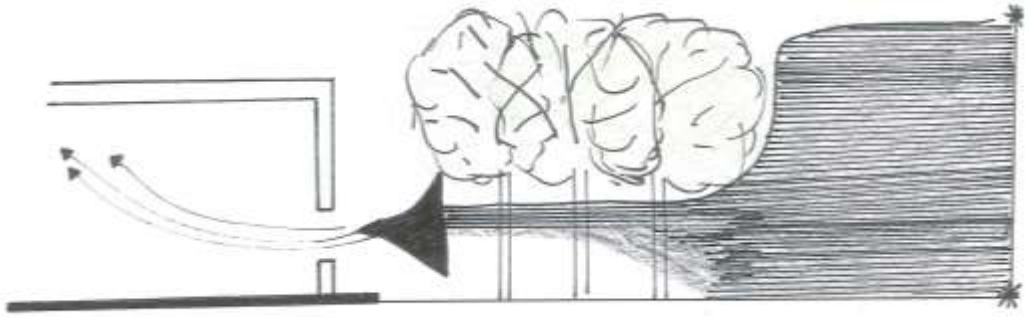

Figure 13 Evaporative Cooling. Illustrated by Ambar A. Gardner.

The landscape also shades the ground surface creating an overall comfortable space. The optimal landscape implemented would be deciduous trees or native plants that don't need as much water.

Infiltration

Seal buildings to eliminate draft and minimize infiltration while keeping ventilation, daylight, and other strategies into consideration. The appropriate timing left on handicap openings can also make a big difference in cooling your space. The least seconds the timing of the door stays open, the cooler the space will be while still taking the individual into consideration.

Location of Shading Devices

Weather stripping a space by using blinds, heavy draperies, operable window shutters can also cool a space. Using blinds is a great strategy if a secondary shading device is implemented as shown in *Figure 13* because blinds without a secondary shading device will trap heat, while a

double skin façade outside of the space will allow natural daylight while cooling the space through shading as it blocks solar gain.

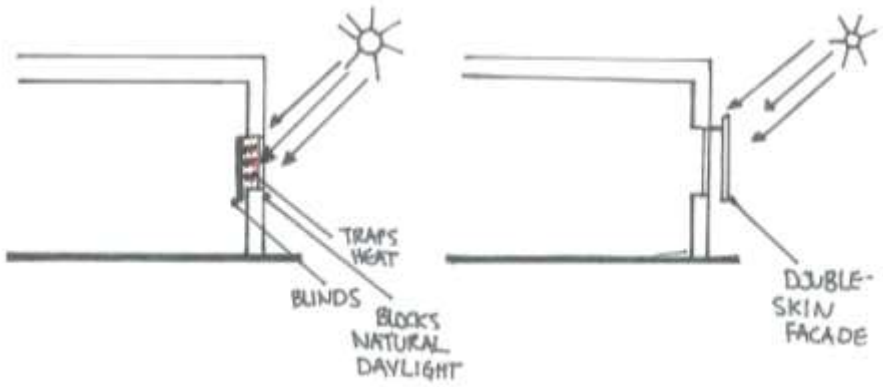

Figure 14 Blinds vs. Double Skin Façade for Passive Cooling. Illustrated by Ambar A. Gardner.

The use of lighter colored material in the floor and roof will be optimal for passive cooling because darker materials attract heat. Tinting on larger windows also helps.

Passive Solar Heating

For passive solar heating, the window to wall ratio should be analyzed. The bigger the window the more heat that's going to go into the space. Locate storage rooms on the side of the building facing the coldest wind to help insulate. Having services on the east and west side of the building buffers habitable spaces from solar gain. Seal buildings to eliminate draft and minimize infiltration. Insulation is also critical for passive heating. Having services on the east and west side of the building also heats the space.

Ventilation

A natural ventilation system can be thought of as a circuit with equal consideration to supply and exhaust windows with openings between rooms. The advantages of ventilation in a space are demonstrated by interior air velocities compared to the reduction of perceived interior temperature. There are multiple methods to achieve natural ventilation such as intercepting wing

walls. Different cases consider different factors and methods to increase natural ventilation, such as the placement of openings and the implementation of wing walls that intercept and increase air flow into the structure. Placing wing walls on the windward façade of the building produces positive and negative pressure zones, which maximize ventilation within rooms as shown in *Figure 15*.

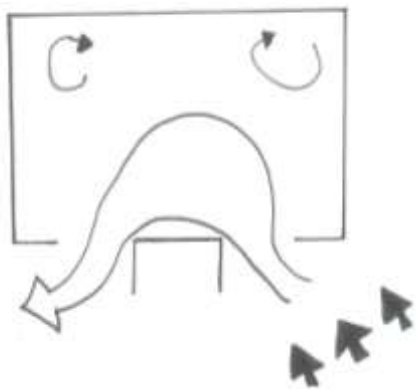

Figure 15 Example of air flow intercepting wing walls (Source: Arens 1989 Document pg. 35).

Wing walls are features that may increase natural ventilation drastically.

Although openings on different walls have the ability to increase natural ventilation within a room, an opening on one wall of the building can increase interior air flow and air change rate by 100 percent; while cross-ventilated rooms with openings on opposite walls can increase average interior velocity by 15 percent (Cooling Buildings by Natural Ventilation, 11.02-37). In order to create a room with proper natural ventilation, two openings will be made on the windward façade of the buildings with two wing walls. Openings on the windward walls are to be implemented carefully in order to maximize efficiency. One opening on the windward wall causes the ventilation to depend on fluctuation of the wind as seen in *Figure 16*.

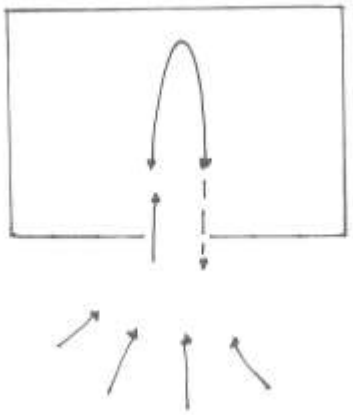

Figure 16 One Opening on the Windward Wall. Illustrated by Ambar A. Gardner.

Two openings placed far apart increases ventilation, due to an increased pressure between the openings; while openings on same wall, with placement of wing walls, maximize air flow because positive and negative pressure zones are created and better distribute airflow as seen in *Figure 17*.

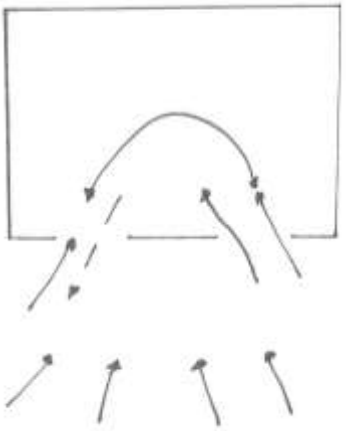

Figure 17 Two Openings on the Same Wall to Better Distribute Airflow. Illustrated by Ambar A. Gardner.

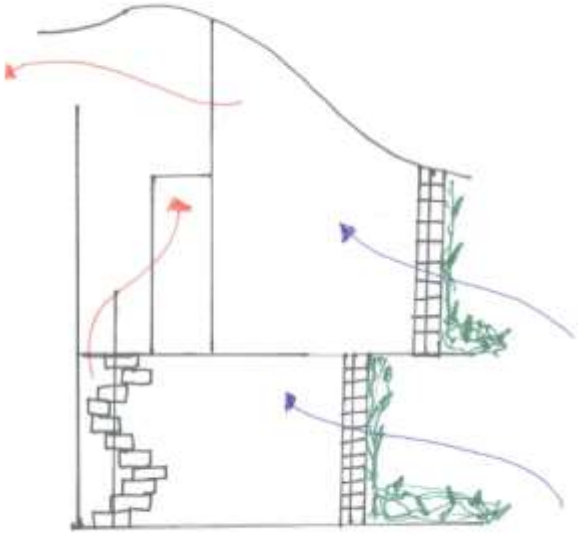

Figure 18 Cross Ventilation. Illustrated by Ambar A. Gardner.

In order to maximize the potential for cross-ventilation within the room, two openings will be made on the windward façade of the room with wing walls placed similarly to *Figure 14*. To conserve and maximize interior space of the room, the area between the two wing walls will serve as a storage room for occupants. By taking advantage of natural win currents, a space can be cooled by providing fresh air as seen in *Figure 18* through the process of cross ventilation.

Air-Quality Ventilation

Air-quality in a building is extremely important especially in a school. The use of non-toxic materials and having a smoke-free property is essential for the health of its occupants. Since a community garden is encouraged, it is also important to take into consideration that the species must be grown in a chemical-free environment, avoiding insecticides and other chemicals. The ACH (air changes per hour) must be evaluated in any space to ensure that the air is changing per hour and is equivalent to the amount leaving the space and entering the space to a total of 63%.

Water Reduction

As discussed in energy efficiency, it is also very important to take water reduction into consideration before implementing water harvesting strategies: we reduce first. Reducing water usage is essential for every building particularly in arid regions where water is a valuable resource and drought conditions are expected. There are two ways to reduce water. One is through behavior such as reducing water use through the individual's regular routine. This can be through hygiene such as turning off the faucet while brushing one's teeth, showering faster, and replacing shower heads to low flow shower heads. One's behavior should be pushed towards reducing water in their regular everyday routines. There are also other examples of reducing water. For example, a cheap way to reduce water consumption in toilets would be to displace enough water out of the toilet in the tank and add a brick to it. This allows the same pressure to flush and reduces the amount of water used per flush. Having native plants in the landscape as well as salt tolerant plants is also an efficient way to reduce water use outdoors. Having an efficient irrigation system can also save a lot of water.

Water Harvesting

Water harvesting can be achieved in many different ways. Capturing, slowing, and treating storm water are the main components of water harvesting. Water can be harvested by the use of rain gardens and water catchment systems.

Rain Gardens

Rain gardens divert, slow, and filter storm water runoff from parking areas. A great example of a rain garden is seen at the College of Architecture, Planning, and Landscape Architecture's Underwood Garden seen in *Figure 19.*

Figure 19 College of Architecture, Planning, and Landscape Architecture Rain Garden. Take by Ambar A. Gardner.

Water Catchment Systems

Water catchment systems such as cisterns revert water from roof and incoming rain providing clean water and reducing storm water runoff. This water can be used for potable water supplies as well as landscaping. It is important to have effective filtration and disinfection methods to guarantee the quality of the water.

Resourcefulness

The resourcefulness of the building is an important factor in the building's overall efficiency. The building's walkable location and proximity to public transportation can reduce the carbon footprint of vehicles driving there every day. Automobile parking spaces are also essential in the productivity of a building, especially a school. A school's building must have a safe place for bicycle, skateboard, and scooter storage to encourage these types of transportation. The use of regional materials in the building will also dramatically reduce the total carbon footprint used to build and maintain the building. Another way to be resourceful is to lower the indoor comfort temperature at night to reduce energy consumption (night flush ventilation).

Having recycling bins in every room, hallway, and outdoor space is essential for a clean and renewable environment. It is important to have a system to transport the recyclables to a recycling station.

Long-term Investments

While applying the campus-wide adaptable strategies to the space, long-term investments must be considered to improve the overall efficiency of the school. These investments involve professional instalment and are costly. The following strategies are long-term investments that must be done to the building to improve the overall efficiency.

Heating and Cooling

For heating and cooling, an energy efficient HVAC system must be purchased as well as economizers when not in use. High-efficiency heaters and boilers are also a great purchase.

Insulation

Vegetation can also be used to increase roof insulation as seen in *Figure 20* called a green roof.

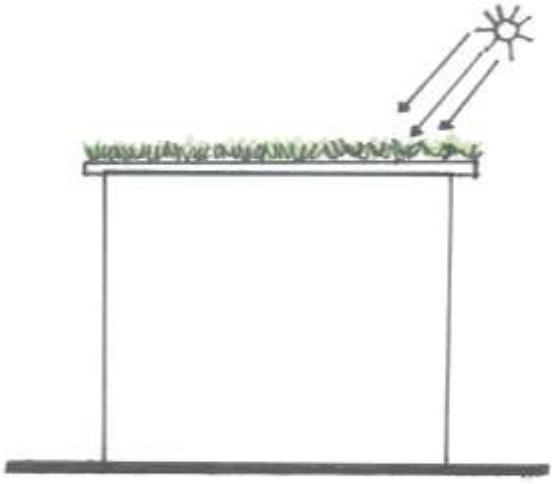

Figure 20 Earth sheltering, sedum roof for high efficient insulation. Illustrated by Ambar Gardner.

The roof has a high surface area exposed to solar gain which maximizes areas for conduction for heat if a green roof is implemented. This strategy reduces ambient air temperatures and energy

consumption inside the space. Green roofs are also efficient for noise control that is definitely a factor in schools.

Energy Generation

As mentioned in water reduction, it is important to reduce energy consumption before considering generating energy. Energy generation is achieved through on site renewable energy. Energy generation is important to suffice the energy consumption in the area.

On-site Renewable Energy

Photovoltaic Systems are extremely efficient in the southwest. It would be a great investment to install and appropriately calculate the placement of photovoltaics for maximum energy generation because a school is usually closed at night. That means that there is no need to purchase a battery (the most expensive part) to generate electricity at night. Photovoltaics installed in the southwest are most efficient when angled at 30 degrees as seen in *Figure 21*.

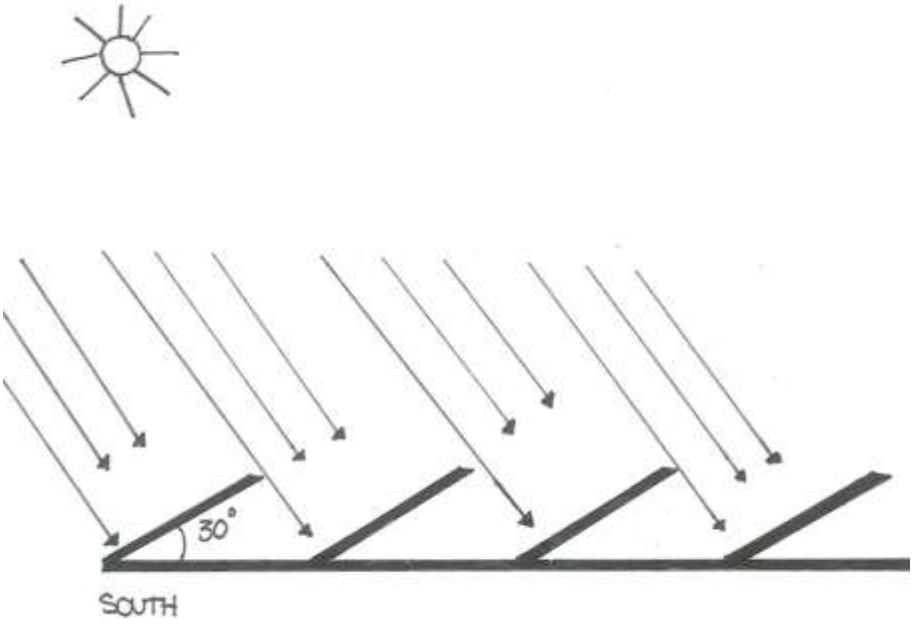

Figure 21 Appropriately calculated placement of photovoltaics for maximum energy generation. Illustrated by Ambar A. Gardner.

Solar Hot Water Collector System

A solar hot water collector system is used from glycol heat exchangers connecting to a large-capacity gas-fired water heater that not activate while the sun is up. An image that explains the process is seen in *Figure 22*.

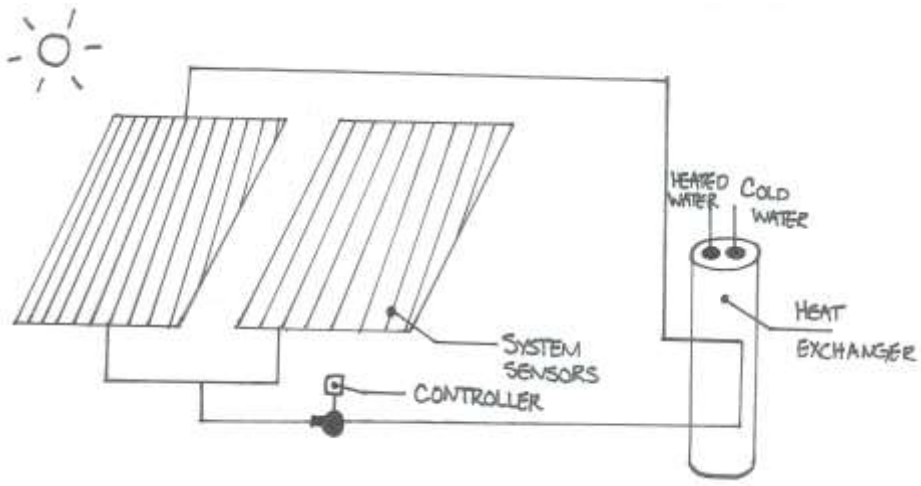

Figure 22 Solar hot water collector system. Illustrated by Ambar A. Gardner

Water Reduction

Having an effective water system design is essential to reducing water. Having an efficient leak detention system and repairing system can reduce an abundant amount of water. Some of these fixtures can cost more money because they are new technologies but are definitely worth it in the long term. For example, water-efficient plumbing fixtures such as retrofitted dual flush toilets, waterless urinals, low-flow and sensored faucets, low-flow showerheads are essential to reducing water use in buildings. There are also ways to reduce water through the HVAC system.

Community Garden

Serving healthy food schools is essential for an overall pleasing education. Eating healthy can benefit a student tremendously when it comes to concentrating and having enough energy to function throughout a school day. If a community garden is implemented in the school, the food

grown can be implemented in the school lunch menu and also save the carbon footprint it takes to transport food from outside vendors.

Curriculum

Student Professional Engagement

"Tree-athon": Students required to plant a tree every month where one student is chosen a week to maintain it. Teacher must give a lecture on passive cooling and shading to allow students to collectively decide where they will plant the tree to benefit from the highest efficiency (such as watering, weeding, protecting it from extreme weather, etc.).

"Watts-up": Students required bring an electricity bill from their home to calculate the monthly total of kWh, the amount due, the cost per kWh, and the amount of water consumed throughout the month in gallons.

"Green Police": Students will be chosen weekly to become the green police in their school. This role involves monitoring recycling activities, make sure trash is where it belongs, and to help their fellow classmates avoid littering and turning off lights that aren't in use. This role will allow every student to participate in creating a norm for sustainable practices and enforcing them amongst others.

This role won't encourage sustainable policies such as recycling at school but in their community as well.

"Bike and Walk to School Day": Pima County's department of environmental quality (pdeq) have established walk and bike to school days for kids, usually accompanied by an adult, these events help children and parents/teachers (grown-ups in general) explore alternative modes of transportation; combining that with a curriculum or lesson, the effects will be astounding in building a more conscious future.

"Community Garden": Build a community-led garden to grow fresh fruits and vegetables that can be served during lunch or donated to the local community bank. Throughout this outdoor laboratory experience, the students will learn basic gardening skills, learn how to compost, and learn about science and nature while having the pleasure to grow your own food in the process.

"Re-use it or lose it": Teacher must give a lecture on how to recycle and your school must have a set recycling program.

"Buy Local": Teacher must give a lecture on how buying local benefits their community economically and environmentally.

"Fieldtrips": Schedule monthly field trips. (Biosphere II, Community Gardens, Local Hikes, etc.)

Tucson's Downtown Historic Districts – Students will visit Tucson's Downtown Historic Districts such as El Presidio District and El Barrio District.

"Volunteer with a Peer": Teacher must require two hours a month volunteering service that is done individually or collaboratively.

"Shading": Teacher must give a lecture on shading. Students must create effective shading devices that are both cost effective and energy efficient by studying shading devices with respect to the southwest climate conditions.

<u>Professional Engagement</u>

"Guest Lecturers": Recruiting local guest lecturers that are making a difference in the community throughout the school year is critical to maintaining diversity of knowledge in a variety of subjects and allow students to collaborate with professionals. Lecturers will be divided into sections of expertise such as a utility company (electric & water) to inform ways to reduce

energy and water consumption in their community. Local organization leaders are a great source of teaching leadership skills as well as guidelines towards starting an organization.

Results and Discussion

After conducting this research, green school guidelines and applications in arid regions were illustrated and successfully put together. The guidelines and applications are divided into sections that include campus-wide adaptable strategies, long-term investments, community-garden, and a curriculum for student professional engagement. These guidelines and applications will create a revolution of a new learning environment that can be spread worldwide. *Figure 23* illustrates the guidelines towards becoming a green school in arid regions.

Green School Guidelines & Applications in Arid Regions		
Reducing Energy Consumption	**Campus-Wide Adaptable Strategies**	Student Professional Engagement
	Reducing Solar Gain	Orientation
		Size of Window
	Shading	Horizontal Overhangs
		Vertical Fins
		Louvers
		Vegetation
		Passive Cooling
		Location of Shading Devices
	Daylight	Secondary Daylight
		Tertiary Daylight
		Natural Lighting
		Artificial Lighting
		Sensors
	Passive Solar Heating	Infiltration
	Ventilation	Air Quality Ventilation
	Water	Water Reduction
		Rain Gardens
		Water Catchment Systems
		Resourcefulness
		Community Garden
	Long-term Investments	
	Heating and Cooling	Insulation
	Energy Generation	On-site Renewable Energy
		Solar Hot Water Collector System
	Water	Green Roof

Figure 23 campus-wide adaptable strategies and long-term investments.

Limitations

There were several limitations in this study. The time frame for this project is a limitation. Cost of implementation is also a limitation because a public school might not have the funds to purchase materials and hire professionals for the guidelines and applications mentioned above.

Recommendations

Research can continue to move forward by implementing these strategies in a school and recording the results through energy audits, grade differences, dropout rates, and overall success of the school. After recording the improvements, these records of success can help promote these guidelines and applications to other schools in arid regions to introduce a revolution of a new learning environment. Further research can be implemented in regards to creating simplified calculations on the implementation of design strategies such as calculations on the optimal degrees a photovoltaic should be placed depending on the time of the year. Simplified calculations can also be made to the implementation of overhangs and sizes of windows. The use of lab equipment such as an overcast sky simulator, wind tunnel, and simple equipment such as a dry/wet bulb thermometer can also be used in the curriculum to practice potential design strategies in models.

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