7-26-2010

Awareness of Daylighting on Student Learning in an Educational Facility

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AWARENESS OF DAYLIGHTING ON STUDENT LEARNING IN AN EDUCATIONAL FACILITY

by

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A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Architecture

Under the Supervision of Professor Katherine S. Ankerson

Lincoln, Nebraska

July, 2010

AWARENESS OF DAYLIGHTING ON STUDENT LEARNING IN AN

EDUCATIONAL FACILITY

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University of Nebraska, 2010

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This study examines how awareness of the interior architecture of a building, specifically daylighing, affects students academic performance. Extensive research has proven that the use of daylighting in a classroom can significantly enhance students' academic success. The problem statement and purpose of this study is to determine if student awareness of daylighting in their learning environment affects academic performance compared to students with no knowledge of daylighting. Research and surveys in existing and newly constructed high schools were conducted to verify the results of this study. These design ideas and concepts could influence the architecture and design industry to advocate construction and building requirements that incorporate more sustainable design teaching techniques.

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Chapter 1

Learning Styles

Studies have proven everyone learns differently, but the one constant is that we are learning all the time. We learn the most when we feel safe, secure, cozy, and challenged (Fielding, 2006). Humans are wired to learn by recognition and pattern development. Successful school curricula are moving from teacher-centered modes of delivery to a learner-centered curriculum. The concept is no longer about delivering information to the students but having the students learn through experiences (Fielding, 2006). Many concepts and factors, such as teaching strategies, curriculum, instructional materials, assessment, classroom management, the organization of the physical environment, and the use of time all focus on supporting the learning-centered way of teaching in a classroom setting (Ehly, 2009)

This new learner-centered curriculum is based on the development of small learning communities. Research shows learners feel a sense of connection and personal identification in smaller numbers. A small learning community is defined as 150 students or less. These groups achieve higher test scores and graduation rates as opposed to a larger group of 180 or more. Most school systems are larger than this, so one way to create these small groups is to adjust the scale of the environment. This can be done by incorporating smaller buildings or clusters of space where color and lighting play an important role in creating spaces (Fielding, 2006). Research has also found the organization of the interior environment can have an impact on the depth of learning (Edwards, Gandini, & Forman, 1998). To help facilitate learning, the environment should eliminate possible distractions, provide maximum access to instructional area and materials, ensure that all furniture and equipment are age appropriate, and provide opportunity for outside environmental experiences (Ehly, 2009).

Developmental Theories

It has been proven learning and development can occur at three different levels or categories: physical development, cognitive development, and socio-emotional development. Physical development refers to motor skills and health-related issues (Tanner, 1990); cognitive development covers how our minds and mental processes change over time (Byrnes, 2001); and socio-emotional development refers to how our concept of ourselves, our relationships with others, and our emotions develop (Erikson, 1963). It is helpful to school officials to understand these various levels of development and how they differ at each age level (childhood, middle school, and high school) so teachers can implement a successful curriculum and adapt their teaching strategy to meet the needs of the students (Murphy, 2006). Although it is important to understand all three levels of student development, this study focuses on students' cognitive development.

The development at each age level is important to note since this influences how one learns. Children learn best during the childhood phase by being both mentally and physically engaged (Rube, Fein, &Vandenberg, 1983). This is also a time for them to start to develop their social relations. Middle school learning is about expanding basic knowledge and skills. By this time, children are physically stronger, more proportioned, and have more coordination. They can think logically and use multiple strategies simultaneously. High school is a time for adolescents to explore and define their identities. This is also a time for experimentation in physical, cognitive, and socio-emotional development (Murphy, 2006). It is important for the high school interior environment to be adaptive and flexible to take into account the students' evolving identities.

Student learning is influenced by many factors, which include noise level, interior classroom design elements, scheduling, time of day, financial concerns, amount of or lack of sleep, and many other similar issues. Some of these items cannot be controlled (scheduling, time of day, finances, etc.), but the classroom's architectural design can be developed to enhance student learning (Ehly, 2009). Information about how children develop and their learning patterns influences the architectural design to create an effective learning environment. This translates into a learning environment that is a safe and secure setting for the childhood years, provides space for specialized physical activities for middle school ages, and accommodates areas to encourage individual interests for students in their high school years. These characteristics are just a few examples of how the interior environment can benefit and influence learning (Reicher, 2000).

Teaching Strategies

Teaching strategies also influence how students learn. Present day teachers are following curriculum changes to spend less time lecturing and focus more on student interaction, integrated technology, and collaboration in the classroom. Lecturing is an effective way to communicate to a large audience, but it lacks student participation and comprehension. Studies have proven student learning is enhanced when they become actively involved in the learning process (Murphy & Alexander, 2006). This active learning allows "students to talk and listen, read, write, and reflect as they approach course content through problem-solving exercises, informal small groups, simulations, case studies, role playing, and other activities -- all of which require students to apply what they are learning" (Barry & King, 1997).

Studies have been conducted by McREL- Mid-continent Research for Education and Learning (2000) over the past thirty years to determine which instructional strategies were most effective for student academic achievement. The mega-analysis study involved all subject areas and grade levels. The results were categorized into nine areas in order from most effective to least effective. They are: identifying similarities and differences, summarizing and note taking, reinforcing effort and providing recognition, homework and practice, nonlinguistic representations, cooperative learning, setting goals and providing feedback, generating and testing hypotheses, and activating prior knowledge. It is noted that none of these strategies work equally well in all teaching situations and with all students. These are only tools that vary in effect with grade level, class size, and teacher implementation of instructional strategies (Murphy & Alexander, 2006).

Interior Environment Characteristics

In addition to the previously mentioned architectural characteristics developed to enhance student success in an educational environment, another important architectural attribute of the new learner-centered type of classroom is a well-rounded mix of indoor and outdoor spaces. These different spaces can accommodate quiet, reflective areas to messy, creative spaces but also include social areas (Fielding, 2006). A study by

Lowenfeld and Brittain (1975) concluded that the use of all the five senses help stimulate a child's ability to observe and explore. Along with this concept was the idea of how interior color and lighting associations with the learning environment. Various studies have been conducted on the topic of color-mood associates to determine if they are learned and how the color design of an interior space affects children to adults (Engelbrecht, 2003).

Impact of Color

A study conducted by Wohlfarth (1985) found that classrooms painted in yellow reduced the blood pressure of the students in that room. The study was conducted in Canada where two schools with similar race and parental incomes were studied. One school served as the control and kept white walls, where the other painted the classrooms a warm, light yellow. This color was chosen to stimulate student arousal levels. Blood pressure was drawn from the students in the morning and again in the afternoon. The data found that students in the experimental school had lower blood pressure in the afternoon than the students who were in the control school. Both schools had the same blood pressure reading in the morning. The study also found that the color affected the student's mood. The students in the experimental school had an increase of self-esteem and a decrease in measures of sadness and aggression. Another added benefit in this school was a decrease in absenteeism.

It has been proven the use of color in an interior space is functional and not just merely for aesthetic purposes. The results of tests show that incorporating color onto one wall in a classroom can relieve eye fatigue (Northeast Energy Efficiency Partnerships, 2002). "Eye fatigue is a medical ailment diagnosed by increased blinking, dilation of the pupil when light intensity is static, reduction in the ability to focus on clear objects and an inability to distinguish small differences in brightness" (Engelbrecht, 2003). Painting one wall in a classroom helps the eye relax as students look up from a task and are drawn to the color. "The wall treatment also helps to relieve the visual monotony of a classroom and stimulate the students' brain" (Engelbrecht, 2003). Although, classroom interior color influences student learning, it is not the main focus of this study.

Interior Lighting

Another architectural interior design feature of today's school is the correct use of lighting. This includes artificial interior lighting as well as daylighing, which will be discussed later. Dunn (1985) found that good lighting contributes significantly to the aesthetics and psychological character of the learning environment. The visual environment affects a learner's ability to perceive visual stimuli and affects his/her mental attitude, and thus, performance. An initial hypothesis is if students felt stimulated in their school's interior environment, they would be more academically successful.

Jago and Tanner's review (1999) cites results of seventeen studies from the mid-1930s to 1997. The consensus of these studies proved appropriate lighting improved test scores, reduced off-task behavior, and played a significant role in students' achievement (National Clearinghouse for Educational Facilites, 2010). A study of fifth and sixth graders in a well-lighted classroom versus a poorly lit classroom had significant increases in scores on the New Stanford Achievement Test (Luckiesh & Moss, 1940).

The benefits of lighting on student learning are only effective if the lighting in a space is designed correctly. A well-lit classroom includes glare control, balanced brightness, higher reflectance ratings, and accent on the focal wall (Benya, 2001). Glare is controlled or prevented by using window blinds or shades, using a lighting fixture that shields the lamp from view, and specifying non-directional fixtures (Northeast Energy Efficiency Partnerships, Inc., 2002). Students are required to read off of many different surfaces, including paper on the surface of a desk to vertical computer monitors. Students often shift their gaze from “heads up” to “heads down,” so it is important to not only illuminate the horizontal surface but also properly illuminate the remainder of the classroom (The Collaborative for High Performance Schools, 2002). Light colored interior finishes such as wall paint, furniture, and ceiling tiles should be used to increase reflectance and balance brightness. Installing a mix of different lighting fixtures (pendant, recessed, and wall mounted) is recommended in the space to help create a uniform lighting level (Best Practices: Lighting the Learning Space, 2008). Below are two examples of how to design lighting for a typical classroom. Computer rooms, media centers, and gymnasiums require different lighting guidelines.

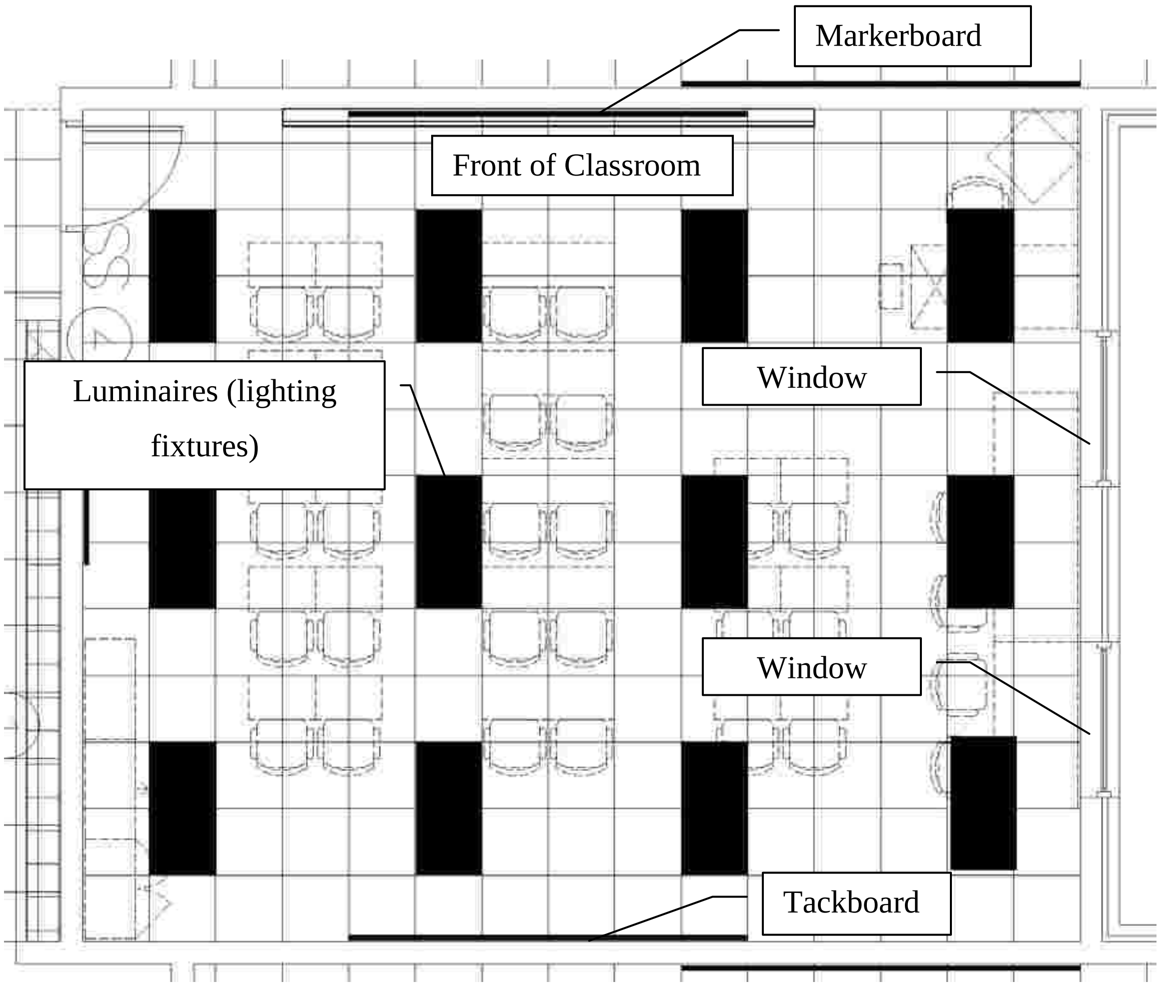


Figure 1.1

This is a floor plan of a typical classroom lighting layout with 2’x4’ fluorescent lighting fixtures oriented parallel to windows for front classroom focus. This layout provides ambient lighting on all surfaces in the classroom, which is not ideal for student learning (Best Practices: Lighting the Learning Space, 2008).

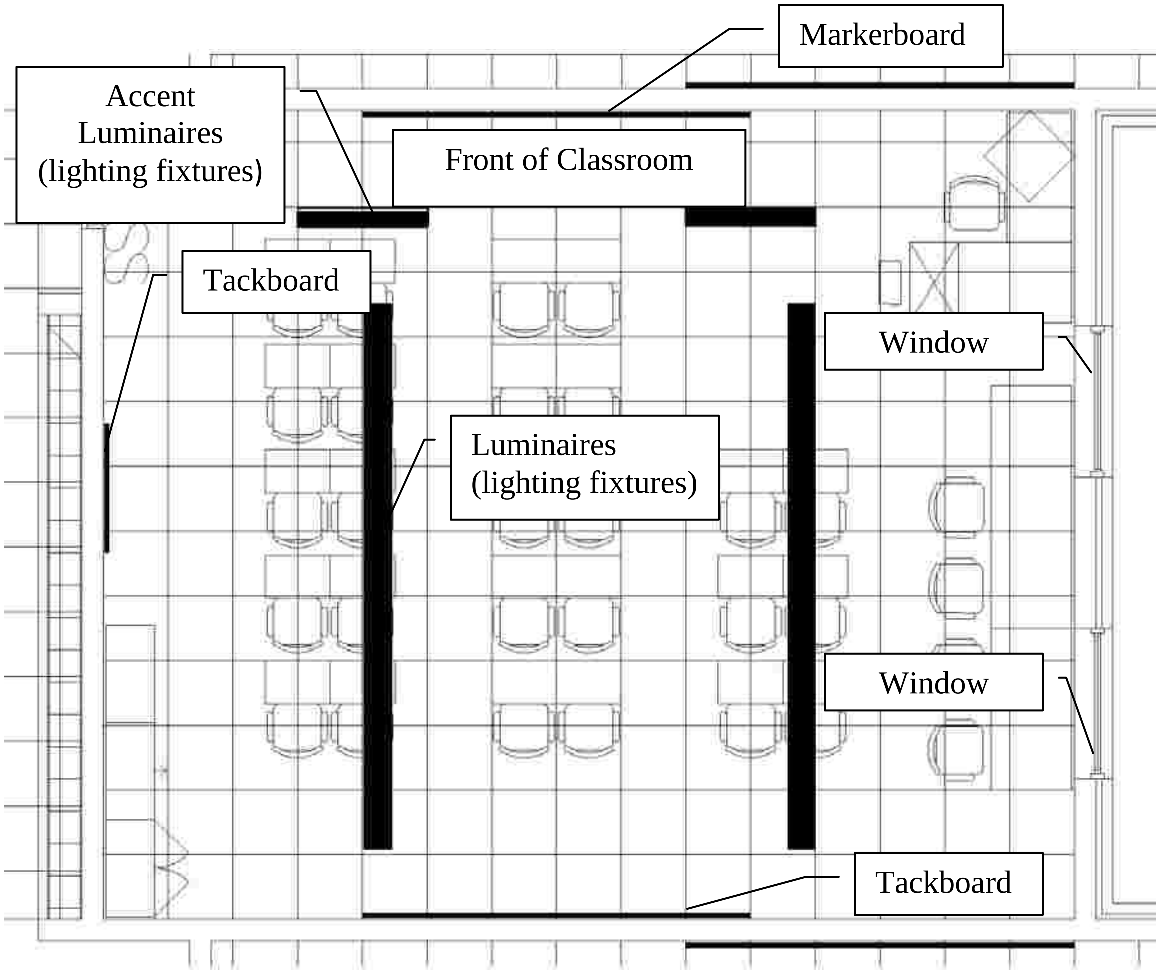


Figure 1.2

This is a floor plan of a correctly designed classroom lighting layout with indirect/direct pendent fixtures running parallel to the windows. This layout provides an even ambient lighting level. Recessed accent lighting is used in the front of the classroom to provide the necessary 100 foot-candles on the focal wall (Best Practices: Lighting the Learning Space, 2008).

Lighting Design Techniques

Different lighting fixtures or luminaires are used together to create the appropriate light quality. Lighting quality is defined as visual comfort, good color, uniformity and balanced brightness (IESNA Lighting Handbook, 2008). Glare, which occurs when brightness from a light source obscures a person's view, is also better controlled by incorporating different luminaires (Best Practices: Lighting the Learning Space, 2008). The elevations below show how different luminaires affect the lighting levels on a wall in a typical classroom.

Recessed parabolic downlight fixtures (2”x 4” fluorescent luminaire)

Figure 1.3

(LaMar Light Company, 2009)

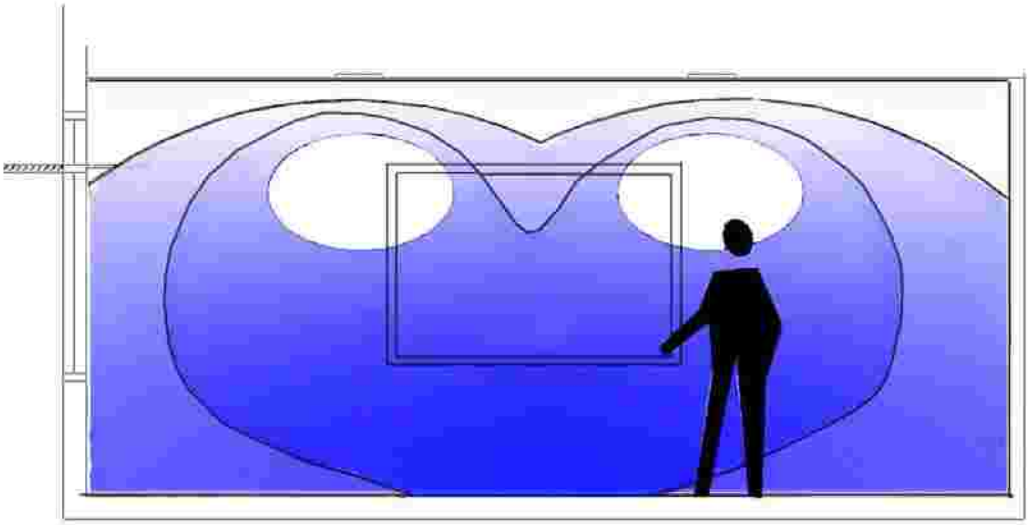


Figure 1.4

With this light fixture, pockets of intense light are reflected at adult eye level on the walls, then distributed around the room with the room corners, ceilings, and floor bases left with a low lighting level. These light fixtures create pockets of darkness and shadows which can inhibit the flexibility of furniture arrangements in a classroom (The Collaborative for High Performance Schools, 2002).

Pendant indirect lighting fixtures

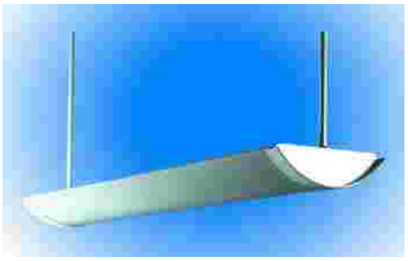


Figure 1.5

(LaMar Light Company, 2009)

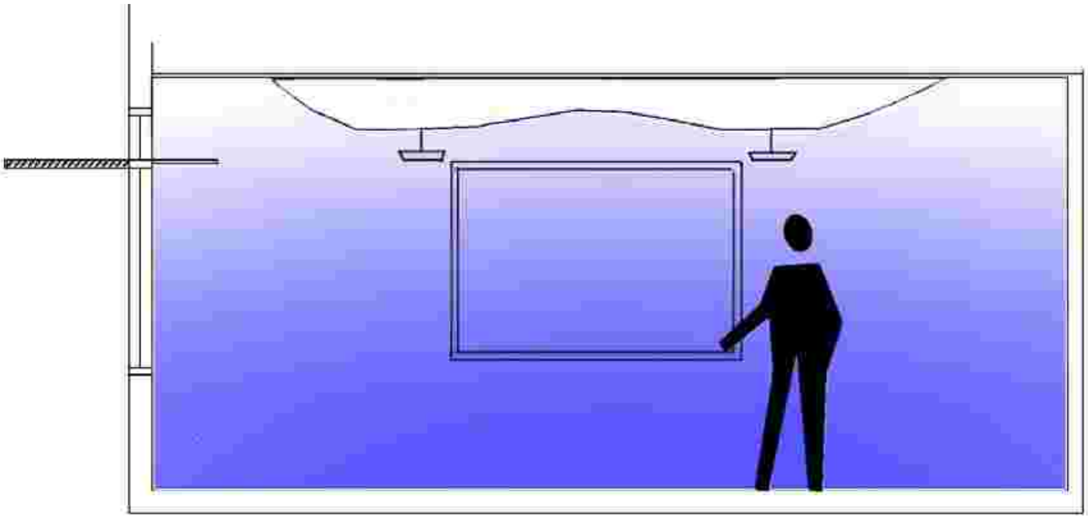


Figure 1.6

With pendant lighting, the light source is reflected off the ceiling then distributed down the walls with low lighting levels at the floor. This gives a more even distribution of ambient lighting but still concentrates the light towards the ceiling and does not provide an adequate lighting level at student desk height (The Collaborative for High Performance Schools, 2002).

Pendant indirect/direct light distribution

Figure 1.7

(LaMar Light Company, 2009)

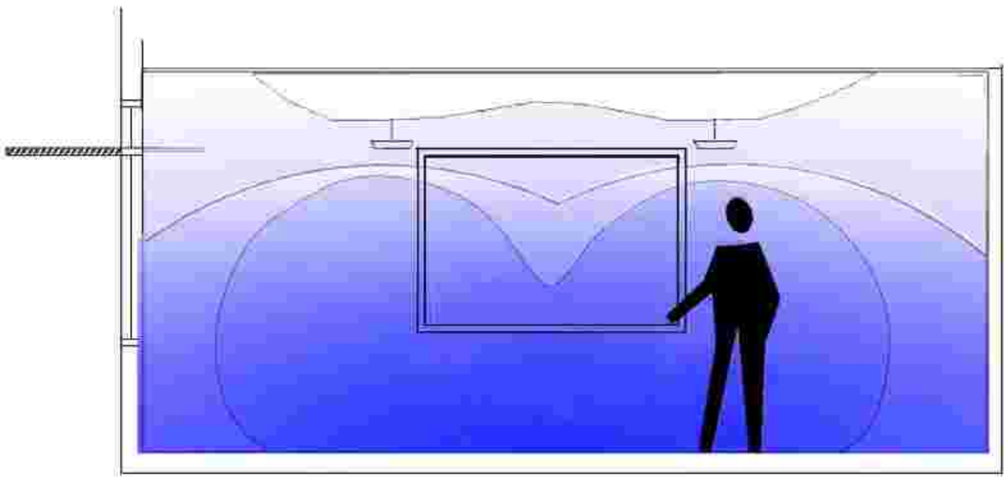


Figure 1.8

Indirect/direct fixtures eliminate glare and light walls more evenly by reflecting light off the ceiling and vertical surfaces instead of directing it down to the floor. Generally, 70 to 90 percent of light is indirect, with the remaining light filtered down through baffles or perforations (shown in the lighting fixture above). These fixtures create an even, ambient lighting level and allow the classroom more flexibility (The Collaborative for High Performance Schools, 2002).

Different types of instructional rooms require different lighting for their intended purpose. The focal wall in a classroom, the wall in which all desks face, should be the brightest. Doing so helps catch and hold students' attention while improving the image of any information displayed on this wall (Learning, Lighting, and Color, 2006). A research study conducted by Fodergemeinshaft GutesLicht (2002) showed that "information presented visually is absorbed faster and retained more reliably than information presented orally." Therefore, it is important that information shown on this focal wall be as visually clear as possible.

A multi-purpose room's focal lighting should be on two or three walls to allow for flexibility and good ambient lighting on all surfaces. This type of room includes shop or art studios, chorus/band classrooms, and other similar type classrooms. However, a computer room should avoid direct lighting and recessed fixtures since both cause a contrast and make viewing the computer screen difficult. Louvers should be avoided here because they make harsh patterns and leave the room too dark. A computer classroom should have indirect lighting for optimum student performance. These lighting design guidelines should be implicated into a school's architectural design to help enhance the interior environment (National Clearinghouse for Educational Facilities, 2001).

Lighting Standards

Many educational standards call for florescent lighting fixtures and a uniform brightness around fifty-five foot-candles in classrooms (Illuminating Engineering Society, 2000). A foot-candle is defined as one lumen of light density per square foot (The Engineering Toolbox, 2005). School systems like to standardize as many architectural items as possible so the replacement process is streamlined. This helps the school not only save on the budget but also on maintenance time (Illuminating Engineering Society, 2000). Reports show that florescent lighting increases hyperactivity among children compared with the use of the full spectrum or incandescent lighting (Tanner, 1999). Tanner (1999) reported a study conducted by Hawkins and Lilley which found that fifty foot-candles are necessary for regular class work and 100 foot-candles are needed for instruction at a chalkboard. Below is the Illuminating Engineering Society of North America (2000) standard recommendation of appropriate foot-candles needed for all school activities:

IESNA Indoor Recommended Foot-candles:

Offices		**Schools**	
Corridors, stairways	10	Reading, note-taking, art rooms, typing	70
Reading, transcribing	30	Laboratories, shops	100
Regular office work	50	Gymnasium - general assembly	10
Accounting, auditing, business machine operation	75	Gymnasium - general exercise and recreation	30
Detailed designing and drafting	150	Gymnasium - exhibits and matches	50
		Library - ordinary reading and stack	30
Pools		Library - study areas and check desk	50
Recreational	30		

Figure 1.9

Achieving these foot-candle levels requires using different types of lighting fixtures, which include the standard fluorescent and incandescent fixtures as well as incorporating daylighting. Daylighting is an architectural design method of using the sun’s rays to illuminate the interior of a building (Daylighting Collaborative, 2010). This is a concept from the 1950s that is becoming popular again in architectural designs because of the “green movement” (USGBC, 2010). The sun’s rays provide between 7,000 to 10,000 foot-candles of light on a sunny day. A completely overcast sky provides between 5,000 to 6,000 foot-candles of illumination. This is one hundred times more light than what is needed, according to the IESNA chart above (Figure 1.9), to sufficiently provide daylighting in a building (Daylighting Collaborative, 2010). The chart below indicates how much light is present under certain weather conditions for comparative purposes (The Engineering Toolbox, 2005).

Condition	Illumination *(foot-candles)*
Sunlight	10,000
Full Daylight	1,000
Overcast Day	100
Very Dark Day	10
Twilight	1
Deep Twilight	.1
Full Moon	.01
Quarter Moon	.001
Starlight	.0001

Figure 1.10

Sustainability

With recent developments and acknowledgement of the "green movement," society is recognizing how our actions affect the environment. This is especially true in the architecture and design industry. Fifteen years ago, a non-profit organization called U.S. Green Building Council (USGBC) was formed to develop guidelines for sustainable buildings and to promote and educate communities on the benefits of sustainability. One of the guidelines the USGBC (2010) established was the effective use of daylighting into the architecture and design of a building. It is proven that lighting, heating, and cooling account for about 75 percent of total commercial energy use, with schools being the largest energy users (U.S. Department of Energy, 2010). With the proper design of daylighting techniques, a school building's energy consumption can be reduced by 26 percent (Herbert, 2005). This is an important topic for schools across the country who have strict operating budgets. Studies have proven that energy features save money, improve the learning environment, and provide dynamic, interactive tools to teach about energy concepts (Department of Energy, 2001).

One issue that arises with the use of sustainable design practices is that the "green" materials, architectural characteristics, and special design fees often add an additional cost to the construction budget (American Institute of Architects, 2010). Even with this initial cost increase, many school systems see the benefits of lower utilities and have the ability to use the sustainable system as an interactive learning tool incentive to build a sustainable daylit building (USGBC, 2010). Studies have proven that in many facilities, the initial cost increase for daylighting implementation can be paid back within thirty-six to sixty months, and over tim,e daylit facilities can save building owners on energy costs (U.S. Department of Energy, 2010).

Daylighting

It is proven that incorporating daylighting techniques into the architecture of a school is beneficial to student learning but is contingent on a carefully planned building that maximizes the different types of lighting. This includes overhead indirect/direct fluorescent luminaires, incandescent accent luminaires, and daylighting (The Collaborative for High Performance Schools, 2002). Daylight design features include roof monitors, clerestories, diffusing baffles, blinds and blind controls, light shelves, light sensors, user-friendly dimming controls and fluorescent backup fixtures, occupancy controls, external shades, teacher and staff training, and maintenance (Kennedy, 2005).

An effective strategy in daylighting a room is to use exterior light shelves. Light shelves eliminate direct lighting into the space by reflecting the light into the room (Innovative Design, 2004). Reflecting the rays of the sun from a surface before allowing the light to enter the interior both softens the light and helps to reduce glare while reducing solar heat gain (Hampton, 2010). Light shelves are most effective if used with 10- foot ceilings to light a space 20 feet deep. Lighting spaces past 20 feet deep are possible, but the ceiling height would need to be raised accordingly or be sloped away from the light shelf (Innovative Design, 2004). The elevations below demonstrate how light shelves reflect the sun's rays indirectly into a room.

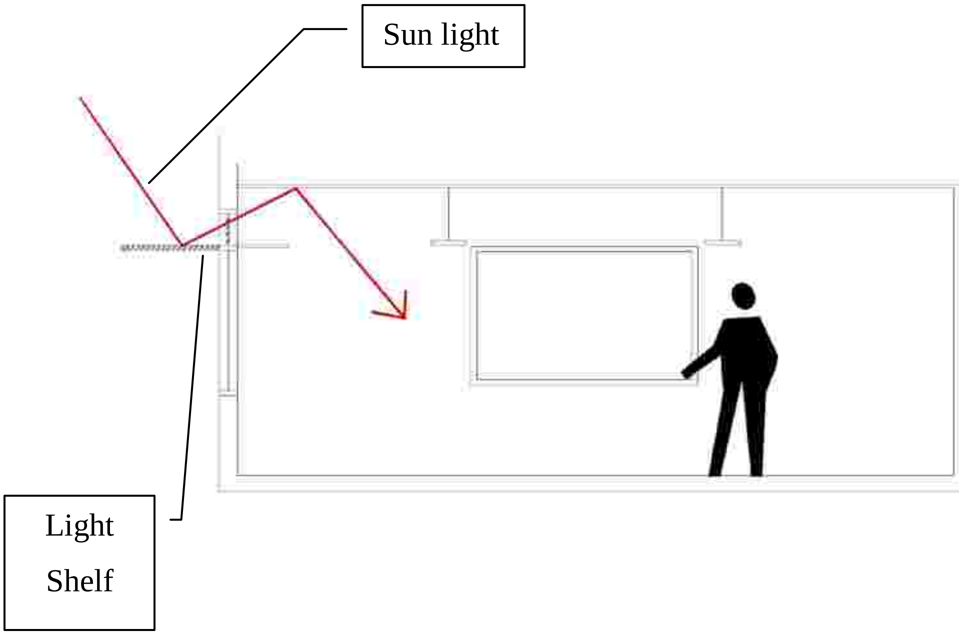


Figure 1.11

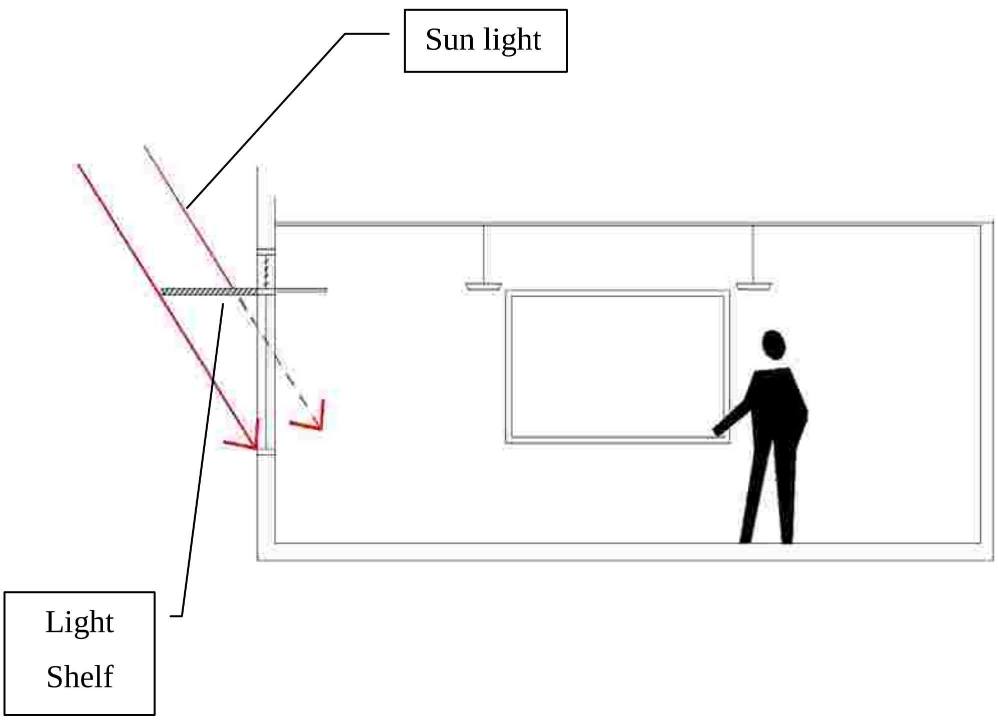


Figure 1.12

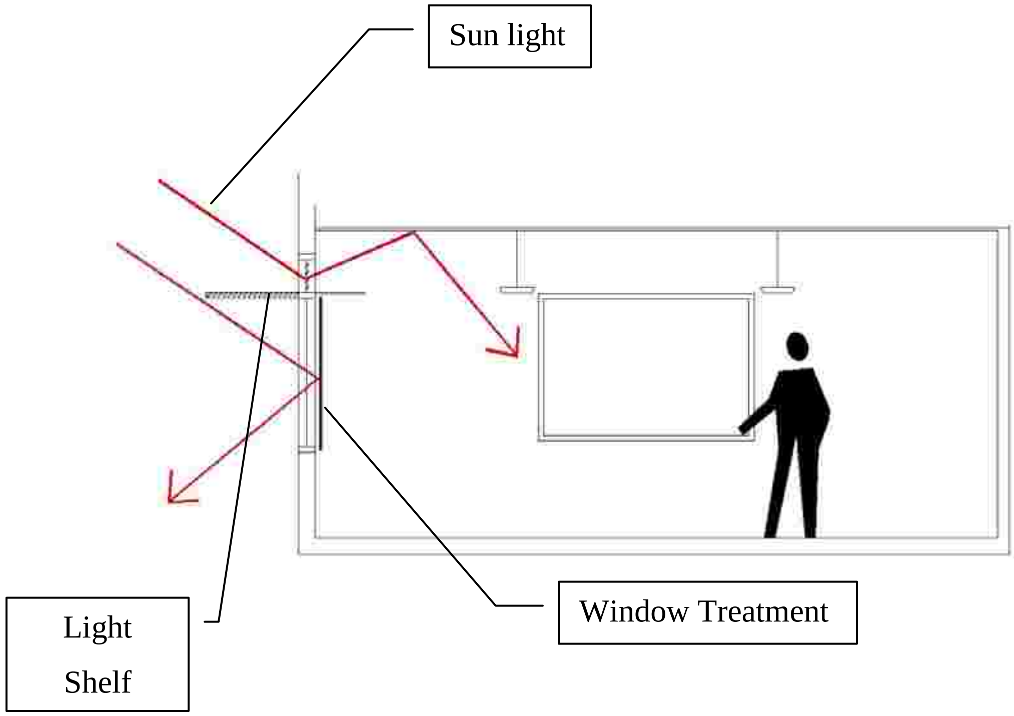


Figure 1.13

Roof monitors are used when interior rooms are not oriented towards the south or to gain daylighting into rooms with no windows. Roof monitors admit daylight and sunlight into the space. Direct sunlight is difficult to control and best avoided by using baffles and diffused glass (Oldroyd, 2005). Light-colored fabric baffles installed parallel to the window glazing allow reflected light to bounce off them and create ambient lighting in the space below (Innovative Design, 2004). The roof monitor should only allow daylight from the north and be four to eight percent of the floor area. To help with light distribution and prevent glare, light colored, reflective surfaces should be installed around the interior of the roof monitor (Oldroyd, 2005).

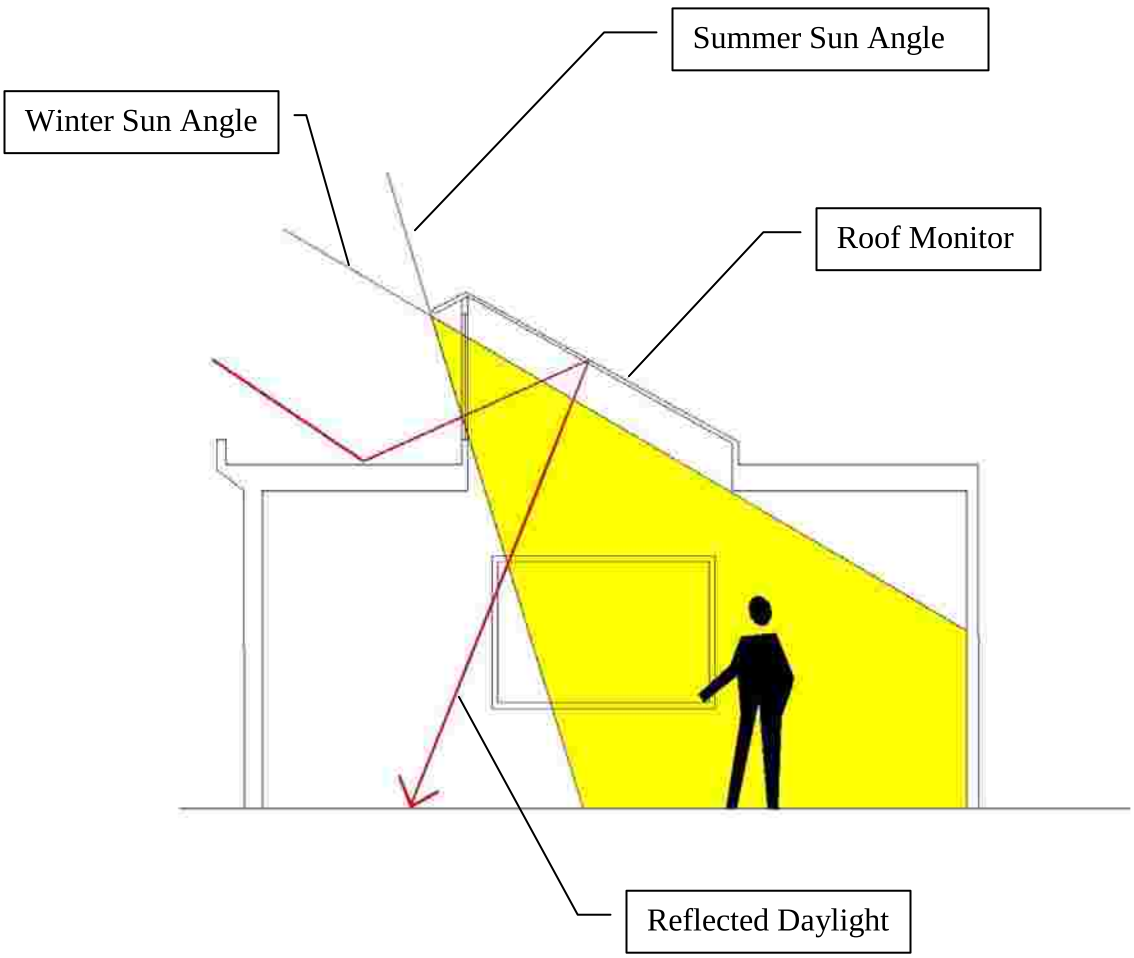


Figure 1.14

Incorrectly planned daylighting can produce solar heat gain, discomfort, increased ventilation and air conditioning loads, and energy use, which contradict the LEED (Leadership in Energy and Environmental Design) design principles (National Clearinghouse for Educational Facilities, 2001). LEED is a points system developed by the U.S. Green Building Council to rate the sustainability of buildings (USGBC, 2010). A well-planned daylighting system has balanced, diffused, glare-free daylight from two or more directions; sufficient and appropriate light levels; operable shading devices to reduce light intensity for computer screens; windows for views to the exterior; and exterior shading devices to minimize solar heat gains in the warm months. For this daylighting system to be the most effective, it must be supplemented with automatic controlled electric lighting that dims according to the rooms' lighting levels (National Clearinghouse for Educational Facilities, 2001).

Although the USGBC has developed a LEED for existing buildings it is limited to the structure's operations and maintenance systems. Most certified LEED buildings are new construction. This can affect the buildings indoor air quality, sound control, color, lighting, and overall aesthetics along with a number of other architectural elements compared to an existing building (USGBC, 2010).

Summary

Based upon the literature review it is known that many different factors contribute to student learning. These factors include learning styles, different developmental theories, teaching strategies, and one's learning environment. Various studies have been conducted on specific interior environmental features of the classroom that contribute to student academic success. The results of these studies indicated that interior room color and the correct use of lighting were important design features that enhance students' academic performance. Although interior room color and lighting are important factors that contribute to student learning, this study focuses strictly on daylighting and students' knowledge on the topic.

Although it has been proven that students improved academically in a daylit classroom, there is a lack of research as to how students perceive daylighting and their learning environment. As stated earlier, a goal of the USGBC is to educate the community about the benefits of sustainability; therefore, a need exists to study whether students are aware of daylighting in their learning environment and how this knowledge is affecting their academic performance. This led to a revised problem statement: How does student awareness of daylighting in their learning environment affect academic performance compared to students with no awareness of daylighting. The results could influence the architecture and design industry to advocate construction and building requirements that incorporate more sustainable design teachings into the LEED rating system.

Chapter 2

Hypothesis

High school students who are aware of daylighting in their educational facility will be more academically successful than high school students with no knowledge of daylighting in their educational facility. It is assumed that all other conditions between the two settings would remain the same: GPA standards, standardized tests, grade level, courses taken, curriculum, and teaching strategy and philosophy.

Independent Variables:

Teaching strategies and curriculum, interior environmental features (daylighting, color, noise, indoor air quality), time of day, and social status

Dependent Variables:

Standardized test scores and attendance records

Chapter 3

Implementation

This study consisted of two parts. The first took place in two different high schools with similar curricula, teaching philosophies, and student body demographics. The control site (Test Site "A") was an existing high school with no daylighting or updated interior architectural features. Test site "B" was a newly built "sustainable" school that incorporates daylighting, improved indoor air quality, noise control, furniture, etc. Standardized test results from both schools were compared. Surveys or questionnaires were distributed to a random sample of the student body and faculty in both locations. This data provided information as to how the students and faculty viewed their educational setting and if they were aware of any issues or concerns about the interior environments that they felt could improve their learning.

The second part of this study revolved around a high school system that moved from an older, existing facility to a newly constructed "sustainable" facility that incorporated daylighting. The student body, faculty, and curriculum remain constant. Standardized test scores from past years in the existing facility were compared against standardized test scores taken at the end of the year in the new facility. The test scores were compared to the national average as a control.   The results demonstrated if there was an improvement in student learning between the school sites.

The results of this study could influence the USGBC to update the LEED rating system to advocate construction and building requirements that incorporate more sustainable design teachings into the architectural design of the building.

Test Sites

Test Site "A" was Capital High School located in Charleston, West Virginia and Test Site "B" was Lincoln County High School located in Hamlin, West Virginia. Both test sites had similar enrollment, curriculum, and teaching philosophies, since both were funded and supported by the West Virginia Department of Education. Below is a West Virginia state map showing the location of both test sites.

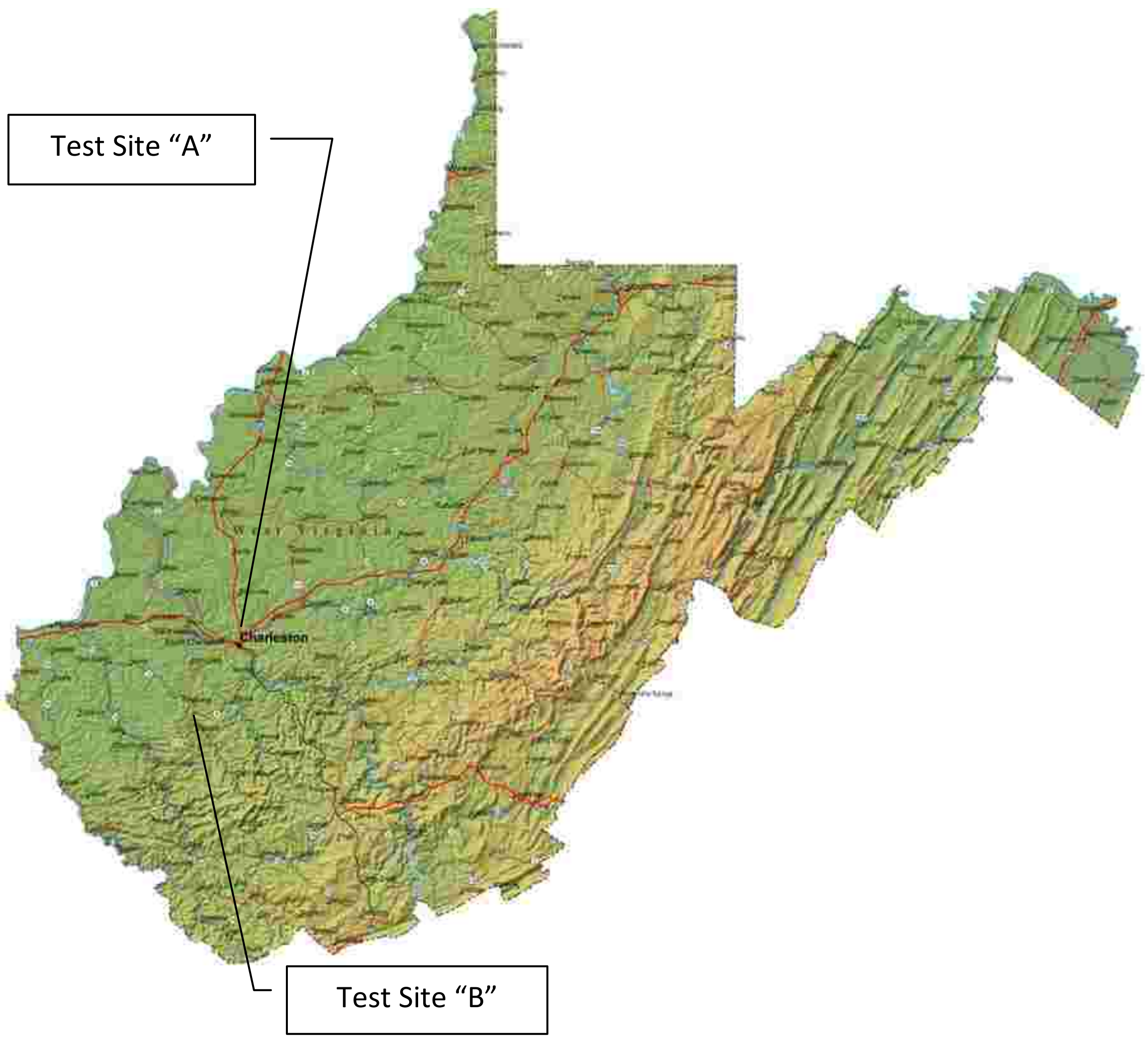


Figure 3.1

Test Site "A"

Test Site "A" was Capital High School, a public high school built in 1989 after the consolidation of Charleston High School and Stonewall Jackson High School, both located in Charleston, West Virginia. This site was located in a rural setting even though it was constructed within city limits. It had a student population of approximately 1,300 (National Center for Education Statistics, 2010). Capital High School was constructed based upon the concept of a campus design. The lower level was divided by an exterior courtyard that separated the freshman students from the other grades. This facility also had two administrative areas. The main administration area was located with the upper level students, and the secondary administrative area was housed with the freshman classrooms. The other building housed the dining/commons area, gymnasium, auditorium, and classrooms for the upper level students. The courtyard area was intended to be a surveillance gathering area for the students to reduce vandalism and instill a sense of community within the student body. Since this facility was designed and built in 1989 it does not incorporate any daylighting techniques. The classrooms were designed with 2'x4' fluorescent lighting fixtures to provide the necessary fifty-five foot-candles (West Virginia Department of Education, 2010). Below are the enrollment statistics on Capital High School (National Center for Education Statistics, 2010).

Students Per Grade

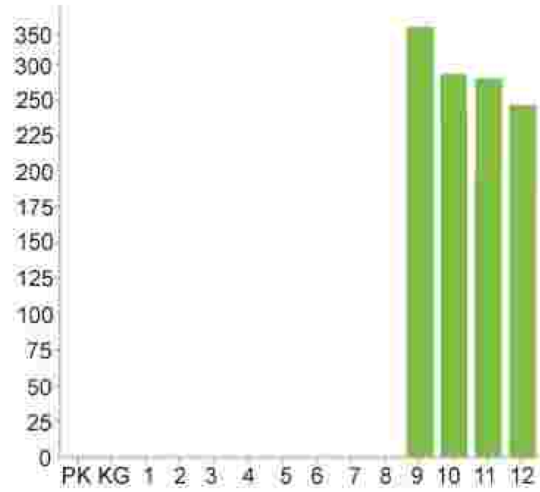


Figure 3.2

Number of Students Per Grade

9th Grade: 399

10th Grade: 318

11th Grade: 301

12th Grade: 258

Student Racial Breakdown

Hispanic: 5

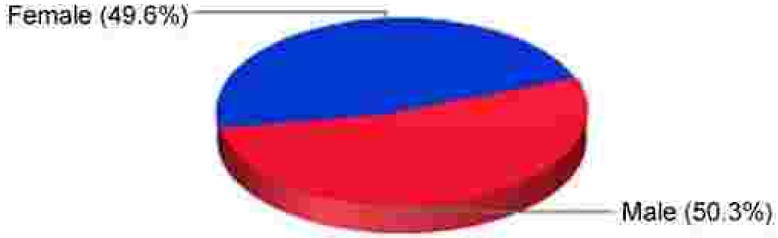
Black: 366

White: 899

American Indian/Alaskan: 1

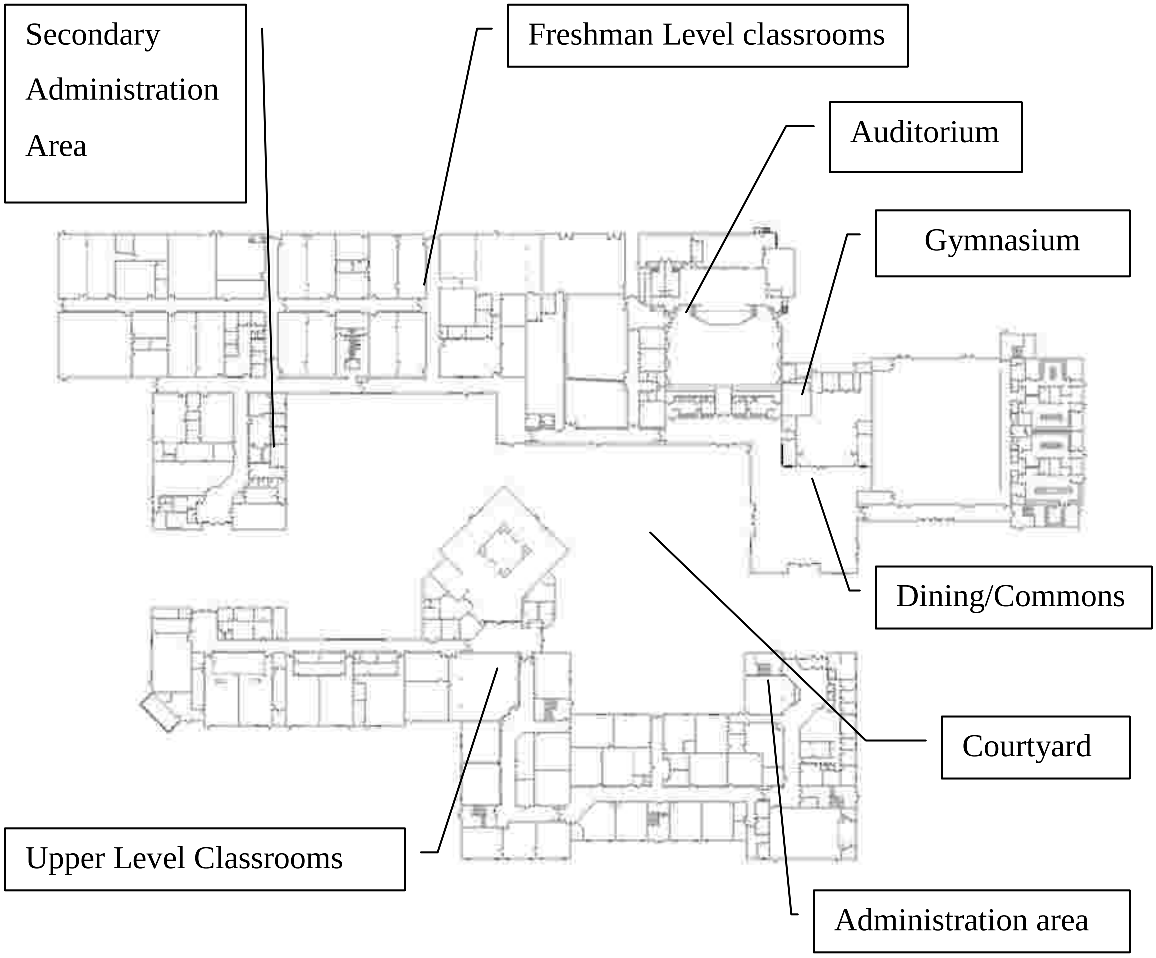
Asian: 17

Student Gender Breakdown



Male: 648 Female: 640

Figure 3.3



First Level – not to scale

Figure 3.4

Second Level – not to scale

Figure 3.5

Test Site "B"

Test site "B" was Lincoln County High School in Hamlin, West Virginia. Lincoln County High School was formed from four former high schools in the county; Guyan Valley High School in Branchland, Duval High School in Griffithsville, Hamlin High School in Hamlin, and Harts High School in Harts. In 2000, due to low standardized test scores and poor school conditions, the state board of education took over the county school system. Almost immediately consolidation was put into action, and Lincoln County High School was built. The school was completed in August 2006. he new $31.4 building provides 217,000 square feet for 950 enrolled students. The graphs below describe the student body.

Students Per Grade

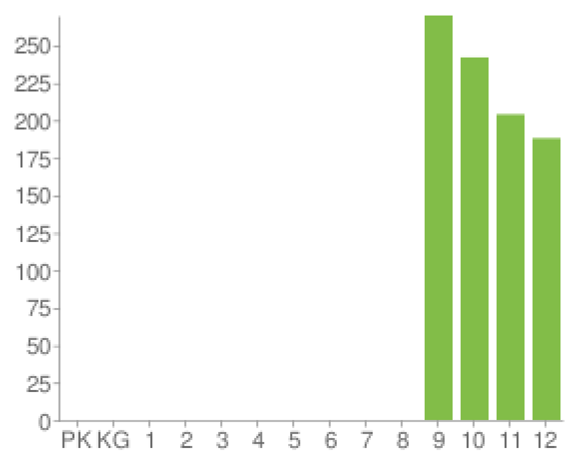


Figure 3.6

Number of Students Per Grade

9th Grade: 270

10th Grade: 242

11th Grade: 204

12th Grade: 188

Student Racial Breakdown

Hispanic: 1

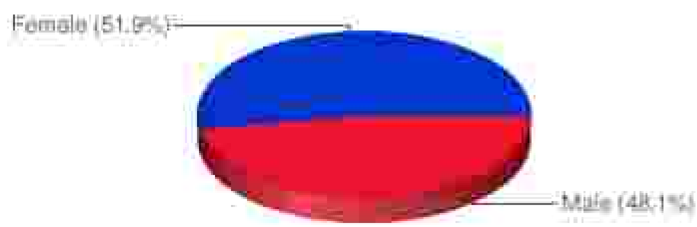
Black: 1

White: 902

American Indian/Alaskan: 0

Asian: 0

Student Gender Breakdown



Male: 435 Female: 469

Figure 3.7

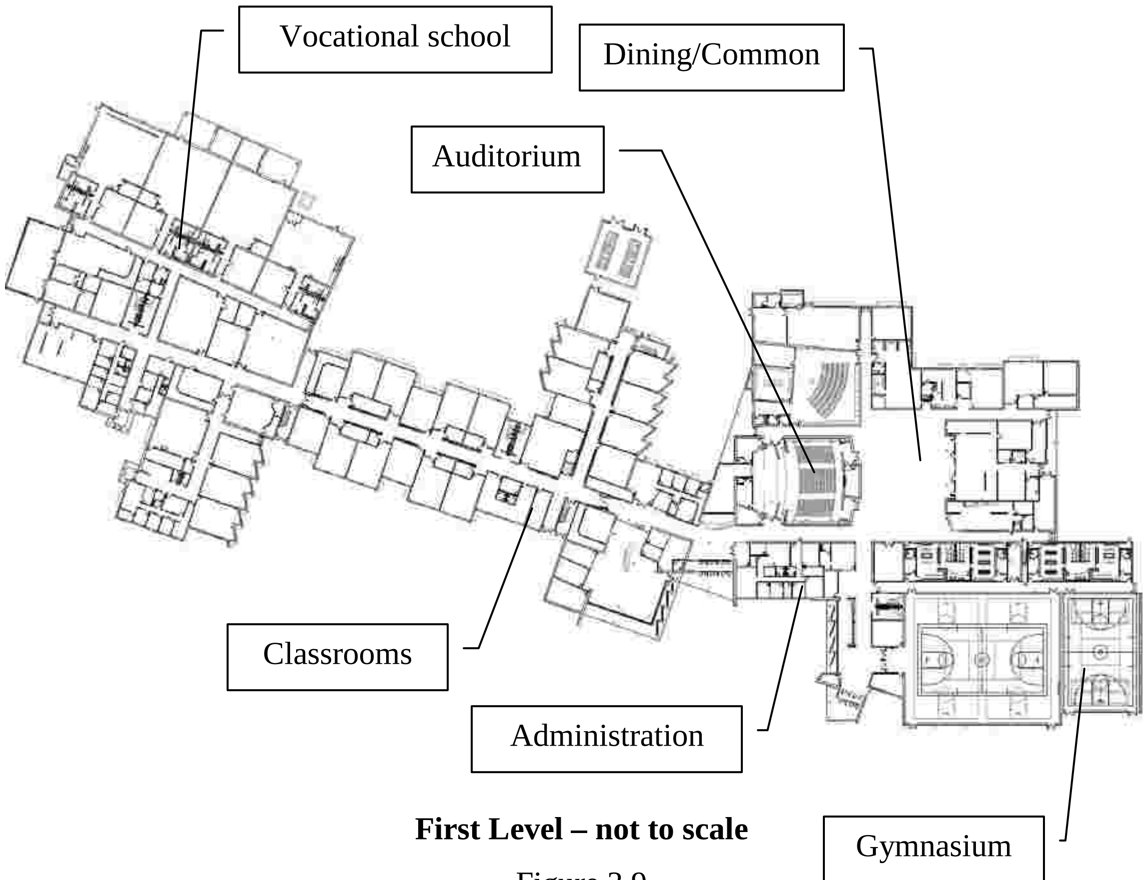
Lincoln County High School was designed with sustainable concepts and applied for LEED certification status but could not gain the title due to budget restraints. The classrooms themselves provided a showcase for state-of-the-art technology. By simply observing how automatic lighting controls enhance natural day lighting in their classrooms, students were able to visualize sustainable design, energy conservation, and technology working in tandem. This school was designed with exterior light shelves and classroom windows orientated to the north and south per daylighting design requirements. The daylighting is enhanced with indirect/direct pendant light fixtures on automatic sensors that adjust to keep the classroom lighting level at fifty-five foot-candles.

The interior design combined concepts from "green" design and bright colors to make a dynamic environment for the students in the shared common areas. The classrooms were designed in a neutral color palate for an optimized learning environment and to enhance the affects of the daylighting. Linoleum flooring was selected along with carpet tiles to help achieve a sustainable building (ZMM, 2010).

The floor plans below represent how each classroom in the high school was designed with exterior walls having full height windows angled towards the south and north to capture the sunlight and redirect its rays to naturally light each room. The pendant direct/indirect fluorescent lighting fixtures were placed on light sensors which calculate the lighting level in each room and adjust the lighting level accordingly. These lighting fixtures were also programmed to automatically turn on when an individual entered a room and shut off automatically when no one was present.

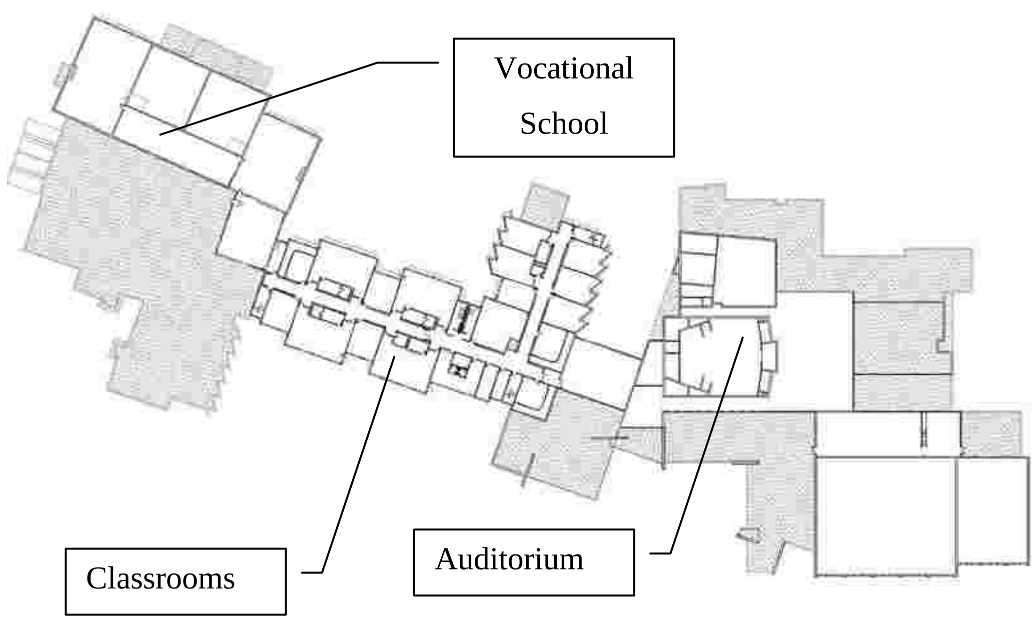
Figure 3.8

The photo above is a typical classroom with full height south facing windows designed per daylighting guidelines (ZMM, 2010)



First Level – not to scale

Figure 3.9



Second Level – not to scale

Figure 3.10

Chapter 4

Methodology

Student and teacher surveys were administered to both test sites at the beginning of May, 2010 before the students were dismissed on summer break so that a full school year would be accounted for in the results. The results were used to determine if the students realized the impact the architectural design of their educational facility had on their learning process. 250 student surveys were delivered to each test site in packets of twenty eight (the average number of students in each class) with one teacher survey. Each school principal placed a survey packet into teachers' mailboxes, at random, for them to administer in their homeroom classes. This enabled a random sampling of each student body and a wide range of students. Fifty extra teacher surveys were placed in the teacher lounge in the hopes to gain more teacher input. Each school had the survey for three days. 175 student surveys were completed at Test Site "A," and 110 were completed at Test Site "B." Ten teacher surveys were completed at Test Site "A," and thirty-two teacher surveys were completed at test site "B." A sample of the student survey is below:

Student Survey: Thank you for taking the time to participate in this survey about how lighting effects student learning. Your answers will be used for a graduate research thesis project that will help architects design better schools. Your answers are confidential and anonymous. They will be released only as summaries in the final report. You do not have to answer any questions that you do not want to answer and you can stop taking the survey at any time. There are no known risks associated with taking this survey. You can help us very much by taking 20 minutes to share your experiences and opinions. You can ask any questions you might have about this research by contacting Alana Pulay at alana.pulay@gmail.com or the UNL Institutional Review Board at nugrant@unl.edu. Thank you for your participation!

Background information: *Please circle your answer*

1. Are you: Male or Female

2. What grade level are you:

   Freshman (9th grade)   Sophomore (10th grade)   Junior (11th grade)   Senior (12th grade)

3. What is your current GPA:

   4.0 – 3.5   3.4 – 3.0   2.9 – 2.5   2.4 – 2.0   2.0 and below

4. What subject are you most academically successful in:

   Math   Science   English   History   Geography   Art/music

Your opinion: *Please circle your answer*

5. Please rate how much you feel you have improved academically over the course of this school year:

   Much Improvement   Some Improvement   Neutral   No Improvement

6. The classroom interior design contributes to your academic success. Classroom interior design includes classroom color, furniture layout and style, lighting, views to the exterior, noise levels, etc.

   Strongly Agree   Agree   Somewhat Agree   Do not agree at all

7. From the following interior classroom design elements, please rank in order (1 being the most important to 8 being the least) the features that you feel contribute the most to your academic success.

   ____ Furniture layout
   ____ Furniture size/design/style
   ____ Views out the window
   ____ Adequate lighting levels
   ____ Low noise levels
   ____ Natural Lighting
   ____ Room temperature
   ____ Wall and floor color

**Please continue onto the next side*

8. In general, you are more academically successful in classrooms containing windows that have natural light versus classrooms that do not have natural light.

   Strongly Agree   Agree   Somewhat Agree   Do not agree at all

9. In general, you like the interior design of Capital High School. Interior design includes colors, furniture layout and style, lighting, views to the exterior, room size and layout, etc.

   Very much   Somewhat   Little   None

10. How familiar are you with the concept of day lighting as an interior design element in a classroom?

    Very much   Somewhat   Little   None

11. How many absences have you had this school year?

    0   1-2   3-4   5-6   6-7   8+

12. Of the options below, please place the number of days missed beside the reasoning for those absences?

    ____ Sick
    ____ No Motivation – just didn’t feel like going that day
    ____ Weather
    ____ Didn’t study for a test that day
    ____ Unappealing school building
    ____ Other

13. What is your favorite subject:

    Math   Science   English   History   Geography   Art/music

Chapter 5

Results

Knowledge of Daylighting:

The student survey results shown in Figure 5.1 indicate that 57 percent of students in Test Site “A” and 48 percent of students in Test Site “B” were very much or somewhat familiar with daylighting concepts. This differs from 43 percent of students at Test Site “A” and 52 percent at Test Site “B” who had little to no knowledge of daylighting.

The teacher survey results shown in Figure 5.2 indicate that 78 percent of teachers were somewhat familiar with daylighting in Test Site “A,” whereas 25 percent of teachers in Test Site “B” were familiar with dayligting concepts. Two percent of teachers in Test Site “A” and 76 percent of teachers in Test Site “B” had little to no knowledge of daylighting.

STUDENT familiarity with daylighting concept	Very Much	Somewhat	Little	None
Test Site "A"	14%	43%	31%	12%
Test Site "B"	8%	40%	35%	17%

Figure 5.1

TEACHER familiarity with daylighting concept	Very Much	Somewhat	Little	None
Test Site "A"		78%	2%	
Test Site "B"	8%	17%	46%	30%

Figure 5.2

The mean and standard deviation results from the student survey at each test site to determine if students are aware of daylighting in their education facility are shown below in Figure 5.3. The analysis of variance revealed that the results do not reject the null hypothesis and are statistically significant.

P value and statistical significance:

The two-tailed P value equals 0.3573

By conventional criteria, this difference is considered to be not statistically significant.

Confidence interval:

The mean of Test Site “A” minus Test Site “B” equals 14.75

95% confidence interval of this difference: From -21.45 to 50.95

Intermediate values used in calculations:

t = 0.9969

df = 6

standard error of difference = 14.795

Review of data:

	Test Site “A”	Test Site “B”
Mean =	41.75	27.00
SD =	24.80	16.15
SEM =	12.40	8.07
N =	4	4

Figure 5.3

Academic Improvement:

The survey results shown below in Figure 5.4 concluded that 73 percent of students in Test Site “A” and 78 percent of students in Test Site “B” felt they had very much or somewhat improved academically over the course of the school year. This differs from 26 percent of students at Test Site “A” and 22 percent at Test Site “B” who felt they had little to no academic improvement over the year.

Number of STUDENTS who felt they academically improved over the year	Very Much	Somewhat	Little	None	TOTAL
Test Site "A"	36	89	33	12	170
Test Site "B"	22	69	21	5	117

Figure 5.4

Test scores:

ACT test results were gathered from both test sites to compare if an improvement in student scores was present after Test Site “B” moved into a day lit facility. ACT is an independent, not-for-profit organization which supplies assessments, research, information and program management for educational and workforce development. The ACT test is a national standardized test to assess high school students’ general education and to record their readiness for college-level work. The PLAN program of the ACT testing system is a program for tenth grade students to build a solid foundation for future academic success. This program also supplies information to the school district to ensure that the correct academic issues are being addressed (ACT, 2010). The chart below shows test results for the past six years at both of the test sites.

Test Site "A"	ACT EXPLORE Scale Score (Score Range 1-25)					ACT PLAN Scale Score (Score Range 1-32)				
Year	English	Math	Reading	Science	Composite	English	Math	Reading	Science	Composite
2004	14.4	14.3	13.8	15.7	14.7	17.1	16.7	16.7	17.8	17.2
2005	14.5	14.4	14	15.9	14.8	17.1	16.9	17	18	17.4
2006	14.2	14.1	13.8	15.7	14.6	17.2	16.7	16.7	18	17.3
2007	14.2	14.2	13.8	15.7	14.6	16.9	16.7	16.9	17.8	17.2
2008	13.9	13.8	13.3	15.2	14.2	16.5	16.2	15.8	16.9	16.5
2009						16.4	16.6	16.3	17.5	16.8
Test Site "B"										
Year										
2004	12.9	13.1	12.5	14.9	13.5	15.5	15.3	15.4	17.2	16
2005	12.6	13.1	12.2	14.8	13.3	15	14.9	15	16.7	15.5
2006	13	13.8	12.7	15.1	13.7	15.3	15.2	15.3	16.5	15.7
2007	13.7	14.4	13.3	15.2	14.2	15.4	15.4	15.3	16.5	15.7
2008	13.3	13.8	13	14.7	13.9	15.7	15.8	15.1	16.3	15.9
2009						15.2	15.6	15.1	16.8	15.8

Figure 5.5

According to the above ACT EXPLORE Composite scores (Figure 5.5), Test Site "B" had an improvement of 0.48 when moving into the new daylit facility in 2007. However, the scores returned to normal in 2008 after being in the facility for a year. Test Site "A" test scores had a constant decline of an average of 0.16 over the years from 2004 through 2008.

The mean and standard deviation results from the ACT EXPLORE Composite Scores at each test site are shown in Figure 5.6 below. The analysis of variance revealed that the results reject the null hypothesis and are not statistically significant.

P value and statistical significance:

The two-tailed P value equals 0.0017

By conventional criteria, this difference is considered to be statistically significant.

Confidence interval:

The mean of Test Site "A" minus Test Site "B" equals 0.860

95% confidence interval of this difference: From 0.430 – 1.290

Intermediate values used in calculations:

t = 4.6101

df = 8

standard error of difference = 0.187

Review of data:

	Test Site "A"	Test Site "B"
Mean =	14.580	13.720
SD =	0.228	0.349
SEM =	0.102	0.156
N =	5	5

Figure 5.6

ACT PLAN English Scores

Year	Nation	All (WV)
2002	16.1	16.7
2003	16.1	16.7
2004	16.1	16.7
2005	16.1	16.9
2006	16.9	16.7
2007	16.9	16.3
2008	16.9	16.3
2009	16.9	16.3
Change 08-09	0.0	0.0

2002-2009 ACT PLAN English Mean Scale Scores (aggregate of all tenth grade students): Shows the National mean scale score and West Virginia mean scale score

Figure 5.7

The chart above illustrates that there is a slight decline in ACT PLAN English scores in the state of West Virginia for the past eight years while the national average ACT PLAN English Scores have risen or remained constant. The means for the National and West Virginia scores are both at 16.5 points. The test scores from the year 2006 to 2007 had a 0.4 point drop in the West Virginia scores whereas the National scores remained constant at 0.4 points above the average. In 2009, the National average score remained constant at 0.4 points above average, and the West Virginia scores remained constant at 0.2 points below average.

The mean and standard deviation results from the ACT PLAN English Scores at each test site are shown in Figure 5.8 below. The analysis of variance revealed that the results do not reject the null hypothesis and are statistically significant.

P value and statistical significance:

The two-tailed P value equals 0.6711

By conventional criteria, this difference is considered to be not statistically significant.

Confidence interval:

The mean of Test Site "A" minus Test Site "B" equals -0.075

95% confidence interval of this difference: From 0.0446 to 0.296

Intermediate values used in calculations:

t = 0.4337

df = 14

standard error of difference = 0.173

Review of data:

	Test Site "A"	Test Site "B"
Mean =	16.5	16.575
SD =	0.0428	0.238
SEM =	0.151	0.084
N =	8	8

Figure 5.8

Classroom interior design influences:

The chart below displays the classroom interior design elements that students felt most influenced their academic success. The results of the surveys indicate that 32 percent of the students in Test Site “A” and 21 percent of students in Test Site “B” felt low noise levels influenced their academic success above the rest of the listed classroom architectural interior design elements listed on the survey. A close second interior environmental feature that students thought influenced their learning was room temperature. 21 percent of students surveyed in both test sites felt they learned better in an environment that had a comfortable room temperature

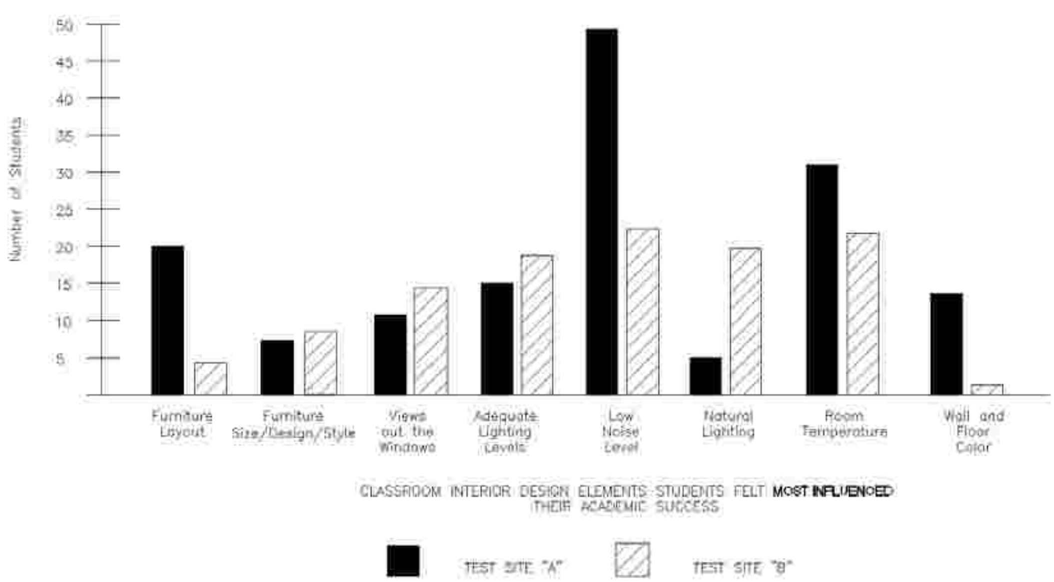


Figure 5.9

. The survey results also demonstrate that 28 percent of students in Test site "A" and 47 percent of students in Test Site "B" felt the wall and floor colors did not contribute to their academic success along with classroom furniture layout and views to the exterior. Refer to Figure 5.10 below for graphical representation

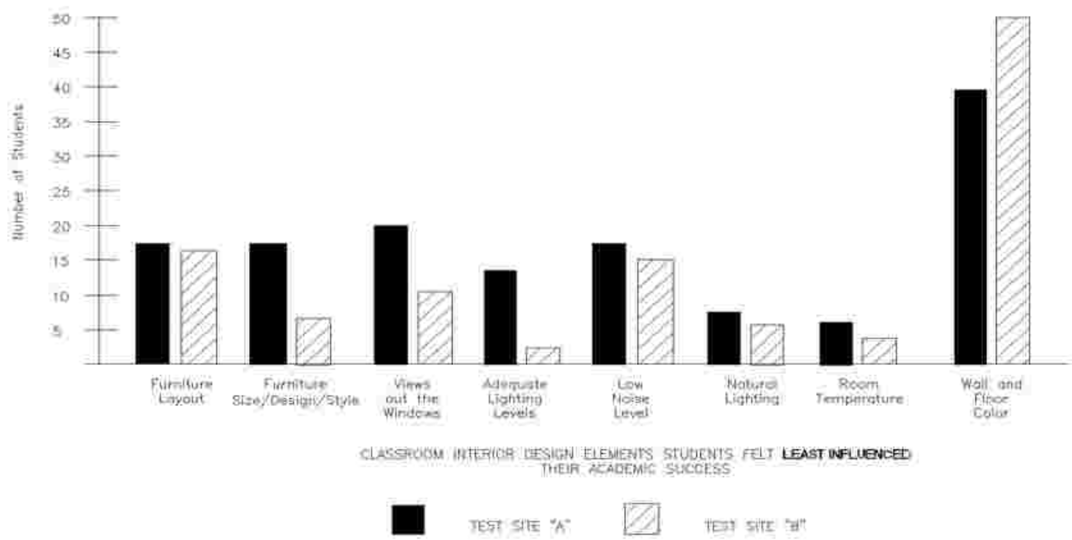


Figure 5.10

. The results from the teacher surveys also indicate that they felt the students were more academically successful in classrooms with low noise levels and comfortable room temperature. Refer to Figure 5.11 below for the teacher survey results.

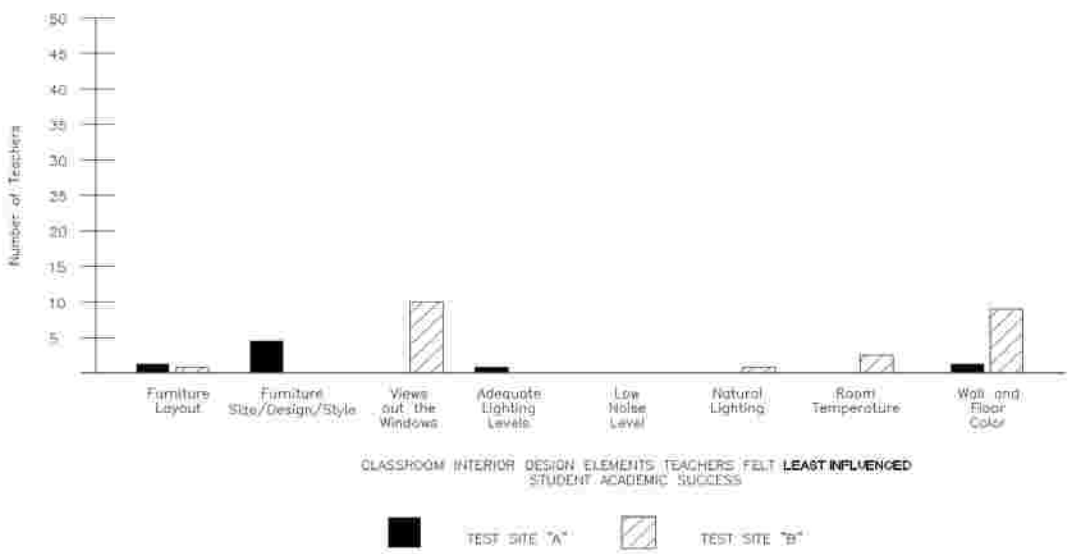


Figure 5.11

At Test Site "B," the teachers felt that adequate lighting levels were not influential to the students' academic success, whereas the teachers at Test Site "A" felt that views to the exterior did not influence the students' success rates. These results differed between both test sites. Test Site "B" teachers were vocal on their opinions of how lighting and the interior design of the school influenced the student learning.

Voluntary remarks from teachers at Test Site "B" on the teacher survey indicate that day lighting and views to the exterior were important for student academic success, but they were contingent on the fact that there were no exterior distractions for the students. One comment from a teacher at Test Site "B" stated, "Too much day lighting impacts my students – glare on computer screens, directly in the eyes, on TV's, etc." Another voluntary comment stated, "Views out the windows are sometimes distracting to students – snow, other students, etc." Figure 5.12 below displays the teacher survey results.

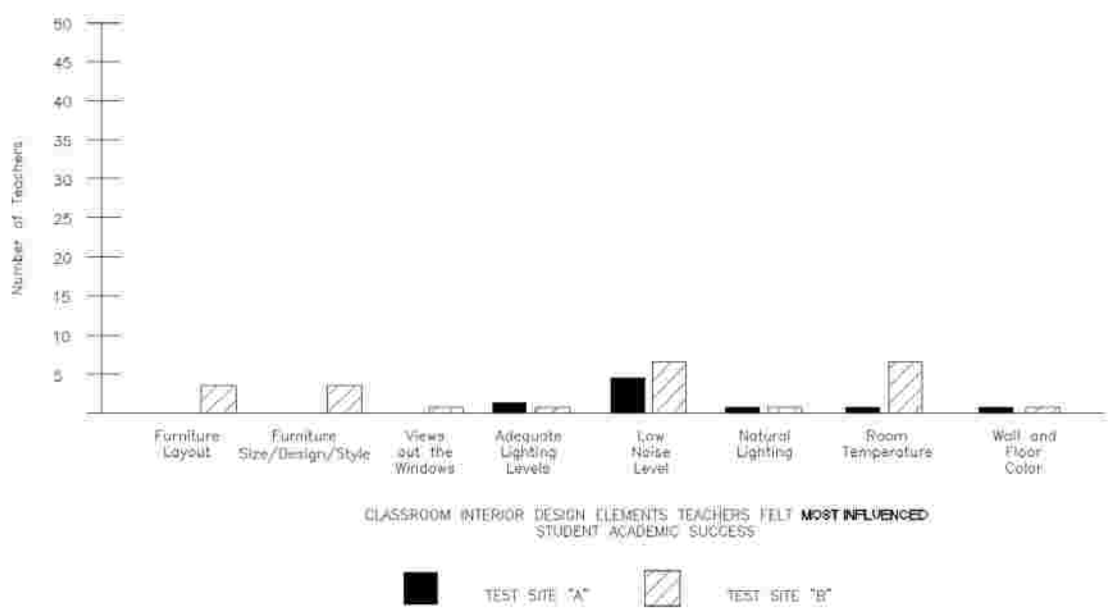


Figure 5.12

Chapter 6

Conclusion

The statistical analyses of the ACT scores between the schools were inconclusive. The results did indicate a positive increase in test scores in Test Site “B” upon moving to a daylit facility but the scores returned to normal the year after. This increase could have been caused by other factors such as the “newness” of the facility, change and addition of teachers, or a new consolidated student body. Follow up research needs to be done to verify these results at Test Site “B”.

The student and teacher survey results concluded that the percentages of students who were aware of daylighting versus the percentage of students who were not familiar with daylighting were almost equal. However, there was a slight increase in students and teachers at Test Site “B” who were not aware of daylighting, even though the school was designed with daylighting techniques. This would lead one to believe that Test Site “B” was not using and teaching the study body about the sustainable features built into that school facility according to the LEED (Leadership in Energy and Environmental Design) design principles and USGBC (U.S. Green Building Council) recommendations. From the surveys, one would assume that since the teachers were unaware of daylighting concepts, they were not educating students about the philosophy behind daylightings’ intended design purpose. Since the teachers were not aware of daylighting, they might not be using the sun to its fullest potential to aid in student academic success (Chapter 1, page 18). They could be using window treatments such as shades and blinds or blocking the windows with furniture which would inhibit daylight from entering the room and interfere with student academic success.

The survey results indicated that students and faculty were more concerned about their personal comfort than the sustainable design features, specifically daylighting, that have been designed into their educational facility to assist students' academic success. The results also demonstrated that there is little knowledge on the subject of daylighting in sustainably designed buildings. A guideline the USGBC established with the LEED rating criteria was educating the community about sustainable practices. Teacher, faculty, and staff at a sustainably designed school, such as Test Site "B", should be incorporating sustainable concepts and ideas into their curriculum as part of the LEED requirement (Chapter 1, page 17). An example would be teaching about energy systems and conservation in science classes, writing reports about daylighting techniques in English classes, and teaching the background of sustainability in history.

To advocate sustainable architectural design, the USGBC could update the LEED rating system to include a section and point criteria which encourages architects and designers to allocate teaching strategies into their educational facility designs. These teaching strategies could include seminars or handouts which describe the different sustainable techniques designed into that educational facility. Teachers would be given this information at the start of each school year to encourage them to incorporate the sustainable aspects of the building into their lesson plans (Chapter 1, page 3). Student learning is most successful when students are immersed into the lesson by learned-centered modes of delivery (Chapter 1, page 1). Using the architectural elements of their educational facility as a teaching strategy would accelerate student learning.

Documentation of the architectural design characteristics could be displayed throughout the facility using wall plaques or signage. These would explain how and why that particular architectural design feature was used and the benefit to the end user. An example would be wall signage by a daylit window which explains why the window was placed in that location and how positioning the window in such a way increases the sunlight into the interior space (Chapter 1, page 18). It could also explain how the window placement reduces the building's energy consumption and helps improve student learning by providing sufficient and appropriate lighting in the classroom. This includes the correct ambient overall lighting levels plus accent lighting on the focal wall, which relieves student eye strain and helps students concentrate (Chapter 1, page 6).

These learner-centered teaching strategies would only be effective if school officials recognized and honored this way of teaching. A responsibility of the architect and design team would be to educate the community of the benefits the students gain by attending class in a daylit educational facility. The community support, along with support from school officials, would help advocate designing and building sustainable educational facilities which in turn aid in student academic performance.

The research found that more students and faculty in the daylit facility were not aware of daylighting than students in an educational facility not designed with daylighting techniques. This could be caused by various reasons. A need exists to study this topic further to discover if educational tools, such as signage or seminars, would help promote student and faculty awareness of daylighting which, in turn, could help students' academic performance.

Chapter 7

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