DAYLIGHTING AS A DESIGN DETERMINANT: An Elementary School in Hamilton, Ohio

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Abstract:

This project provides a new elementary education facility to replace the current Harrison Elementary School in Hamilton, Ohio. The student make-up of this school is primarily low income children from families surrounding the area. This project produces a quality environment which facilitates learning for all of the primary use classrooms. Daylighting, an issue which greatly contributes to the success of students in the educational environment, is the primary focus and overall design determinant.

Natural lighting is one of the most important aspects of any building, especially educational facilities. "In a typical study (Kleiber, 1973) testing differences between full-spectrum lighting and cool white fluorescent lighting commonly used in institutional settings, it was found that physiological measures indicated that most subjects showed less fatigue after a study session in natural light than in a traditionally illuminated instructional environment." Dr. Lackney also describes various other studies which have been done in order to determine the effect of lighting and learning ability and performance in his article, The Relationship between Environmental Quality of School Facilities and Student Performance. According to a study done by Herschong Mahone Group, Daylighting in Schools, it was discovered that, overall, "students in classrooms with the most daylighting were found to have 7% to 18% higher [standardized test] scores than those in rooms with the least." Not only did the test scores improve, but overall attendance improved and the number of sick days decreased when natural light was combined with improved air quality.

BOORA, a multidisciplinary architecture firm in Portland, Oregon, was able design and build three sustainable educational facilities in rural and suburban areas, which have for long periods of time, been deficient on funding. BOORA creates both sustainable and cost effective solutions for these facilities. In order to accomplish this, they used two simple daylighting techniques: proper orientation and window placement.

BOORA not only was concerned with bringing light in, they also wanted to keep heating and cooling costs down for the money-strapped school districts. In order to accomplish this, they had extensive use of light shelves which reflects summer sun, washing the lightly colored ceiling surface with light, creating one large, ambient-light fixture. These light shelves block only summer sun, reducing heat gain and therefore cooling costs, but allow winter sun in, which reduces heating costs.

Finally, BOORA used daylight as a design feature to create a quality space. At Ash Creek Intermediate school, "the combination of techniques has created light that goes beyond usefulness: it is stunningly pretty. Quality of light is usually analyzed in hard numbers, but on a sunny winter Thursday, Ask Creek seems the brick-and-mortar answer to Tuscany," School district superintendent Forrest Bell says "look at this... this is beautiful light."
Introduction:

Daylighting is defined as “the efficient use of natural light in order to minimize the need for artificial lighting in buildings” (Grinfeld). Buildings, and especially schools, were once designed to provide as much natural light as possible because of poor electric lighting and basic energy costs. Yet, in the mid-1950’s, there was a sharp change in building design from the “finger” plan to the most cost effective plans and compact building envelope. Monica and Alex Grinfeld explain why this change has occurred.

“The advent of relatively cheap electricity in the mid-1950’s together with advances in lighting technology shifted the balance in building design away from the use of natural light towards more reliance on artificial lighting. This change reflected society’s new love affair with technology and the belief that the environment within a building should be, above all, controllable and isolated from the exterior” (Ibid).

This idea that the human has undeniable desire for control has not changed. Yet, the architectural community is now acknowledging the fact that people actually prefer daylit spaces. With design elements from controlled skylights to light shelves, the user can still have this element of control while maintaining their connection with nature.

While studying schools such as Dallas Middle School, Ash Creek Intermediate School and Clackamas High School, all of which are successful daylighting projects in education completed by BOORA, I saw how the new facilities promoted both a psychologically and physically healthier environment. This was accomplished by employing daylighting techniques, both task and ambient, as an essential component to the learning environment. In an education study in the USA, a number of possibilities are defined by Monica and Alex Grinfeld in “Let the Sunshine In” as to why sunlight has been linked to performance. They are as follows:

• “Interviews with teachers indicated that daylit classrooms reduced students’ stress levels and improved their attention spans.
• “Better light levels, quality, distribution and colour balance improved visibility in the classroom and reduced eyestrain.
• “School libraries that are daylit are used up to 50% more than those relying solely on artificial light.
• “Daylight reduces the body’s production of melatonin, a hormone associated with sleep, and so students are more alert in class and thus capable of absorbing new information.”
PROJECT GOALS:

How does one define quality space? A quality space is one which functions as the program specifies. If a space is meant to be used for multimedia presentations, it must have proper projection space, controlled lighting, sound control and sufficient seating. The same applies to classrooms. Classrooms must have ample space for seating, presentation, display space for student work and news and notes, and most importantly, ample lighting. But, this ample lighting must primarily be supplied through daylight and only supplemented by artificial light. Also, lighting for corridors, which are used only for circulation, can be supplied through skylights and/or clerestories.

The goals, therefore, of this project are to provide for these “quality” spaces, defined by natural lighting and articulating the daylighting techniques in architectural form. If spaces require a specific light, whether ambient or task, the building will reflect this in both form and layout. Daylighting elements, whether it be skylights, light shelves or sun screens will be used as architectural articulation.

Primary Goals:
- Reduce electric light, replacing it with daylight.
- Provide daylight to all primary use rooms.
- Prevent direct sunlight by redirecting techniques.

Secondary Goals:
- Define and organize an appropriate program for inner city school districts.
- Reduce current class size from the current 30 students per room to no more than 20.
- Site the facility so as to provide for the least amount of noise and distractions.
- Use spatial zoning in order to reduce noise from within the facility for the noise intolerant uses.

Challenges of this project include:
- Providing a smaller scale elementary school for the city of Hamilton.
- Providing equal daylighting throughout all primary use classrooms.
- Providing an efficient floor plan and high quality learning environment.
Precedents:

Durant Road Middle School:

As a school using daylighting for the primary focus of saving energy costs, Durant Road Middle School has been very successful. The building uses the following daylight strategies to light the building's interior:

- Orientation of the building is lengthwise on an east/west axis to optimize placement of the north and south facing daylighting monitors and to reduce heat gain.
- South-facing and north-facing roof monitors provide daylighting to classrooms, cafeteria, gymnasiums, and hallways.
- High-efficiency lighting equipment and controls are used, including motion sensors and light-level sensors to automatically adjust energy-efficient fluorescent lighting as needed.
The Lillis Business Complex:

This is one of the first “green” buildings on the University of Oregon’s Eugene campus. This facility uses daylighting in the following ways:

- Orientation of the building for classrooms to face south.
- South-facing windows utilize light shelves/sunscreens to diffuse the harsh southern light.

Right Above: The classrooms along the southern wall all utilize aluminum mesh light shelves in order to diffuse the light and reflect it into the room.

Right Below: The southern facade uses light shelves to shade the lower portion of the windows from direct sun in the summer time and reflect light into the rooms.
**Existing School:**

Above: Building services are located facing the main street
Below: The few basketball courts make up the entire play area

Above: The west Facade
Below: The view as you pull into the parking lot
Above: The parking area
Below: The landscaping outside of the classrooms

Above: The main entrance
Below: Classrooms facing south
**Site:**

Location:

The new facility is located in Hamilton, Ohio at the University of Miami’s Hamilton branch campus. This site is directly across the street from the existing school located in a vacant field.

Site Context:

Directly adjacent to the new site is an Office building to the West, natural wetlands to the South, The proposed Harrison Adult Education facility to the north, and an academy to the East.

Site Inventory/Analysis:

The site is currently a vacant field with minimal slope. There is an existing mature vegetation buffer along the northern edge, which will remain to buffer the school from the *roadway and help control* the northwest prevailing winter winds. The natural wetlands to the south provide outdoor learning opportunities for science based lessons. The Great Miami river is on block west and directly adjacent to the office structure and wetlands.

This particular site was chosen because of these pre-existing resources. Also, this site is the center of the area in which this school will serve. This provides for the shortest possible commute for any and all students.
Above: The new site looking northeast at the academy.
Below: The new site looking north at the vegetation buffer.

Above: The new site in the midst of the vegetation buffer
Below: The new site looking northwest at the vegetation buffer
Building Space Program:

Primary Classrooms
Kindergarten
- w/ 1 restroom per class
First Grade
30’x30’ = 900ft²
x4 = 3,600ft²
30’x30’ = 900ft²
x4 = 3,600ft²

Second Grade
30’x30’ = 900ft²
x3 = 2,700ft²

Third Grade
30’x30’ = 900ft²
x3 = 2,700ft²

Fourth Grade
30’x30’ = 900ft²
x3 = 2,700ft²

Fifth Grade
30’x30’ = 900ft²
x3 = 2,700ft²

Sixth Grade
30’x30’ = 900ft²
x5 = 4,500ft²

Secondary Classrooms
Multi-handicapped
30’x30’ = 900ft²
x3 = 2,700ft²

Cognitively Delayed
30’x30’ = 900ft²
x3 = 2,700ft²

Learning Disability
30’x30’ = 900ft²
Reading Specialist  
15'x15' = 225ft² 
  x3  = 675ft²

Speech  
30'x30' = 900ft²

Vocal Music  
30'x30' = 900ft²

Instrumental Music  
30'x30' = 900ft²

Art  
30'x30' = 900ft²

English as Second Language  
30'x30' = 900ft²

**Administration**

- Main office (2 secretaries & parent waiting)  
  30'x30' = 900ft² 
  15'x10' = 150ft² 
  8'x8' = 64ft²

- Mail Room  
  10'x10' = 100ft²

- Supply Storage

- Teacher Workroom  
  15'x10' = 150ft²

- Teacher’s Lounge  
  30'x30' = 900ft²

- Staff Restroom (1 male, 1 female)  
  15'x20' = 300ft²  
  x2  = 600ft²

**Additional Spaces**

- Computer Lab  
  30'x30' = 900ft²  
  x2  = 1,800ft²
Occupational & Physical Therapist
30’x30’ = 900 ft²

Nurse Clinic
20’x20’ = 400 ft²

Guidance Counselor
15’x15’ = 225 ft²
x2 = 450 ft²

Library
40’x40’ = 1,600 ft²

Gymnasium
- Gymnasium Storage
  74’x50’ = 3,700 ft²
  15’x15’ = 225 ft²
- Physical Education Office
  20’x15’ = 300 ft²

Cafeteria (150 students)
70’x50’ = 3,500 ft²

Kitchen
- Food Storage (cold)
  30’x40’ = 1,200 ft²
- Food Storage (dry)
  10’x10’ = 100 ft²
  10’x10’ = 100 ft²

Student Restrooms (3 boys, 3 girls)
20’x15’ = 300 ft²
x 6 = 1,800 ft²

General Storage
20’x20’ = 400 ft²

Janitor Closet
10’x5’ = 50 ft²

Square Footage
53,589 ft² Net
26,795 ft² Grossage
80384 ft²
+5% Mechanical
84,403 ft² Total
Findings: The hallways with clerestory windows facing south provided ample lighting into the spaces.

Findings: Sufficient light was not available in north facing classrooms. Something more would be needed.

Findings: Natural light was controlled well in the south facing classrooms via simple light shelves and sun screens.
Preliminary Studies: Adult Education

Harrison Adult Education

Proposed as a second phase to the elementary school project, the Harrison Adult Education facility shall provide a place for low income, poorly educated citizens to come after or before work in order to complete their high school diploma or get their GED.

The Harrison Adult Educational Facility was a preliminary study of daylighting techniques and how they can be used throughout the facility in order to create a unique building design. The primary focus of this project was to create a building which shows off the daylighting elements and makes them an architectural feature. The specific daylighting elements used in this design are as follows:

• Light Shelves (Used on the top of South facing Windows)
• Sun Screens (Used on the South facade in order to block direct sunlight during hot summer months)
• Clerestory Windows (Angled down to capture reflected light from the gravel roof)
• North Oriented Glazing on East/West Facades
• Skylights (Used to bring more light to the interior of the cafeteria)
• “Borrowed” Light (Used as clerestory windows for rooms through the corridors)

These daylighting elements were used to create architectural fenestration, massing, and ornamentation. In order to demonstrate to the public that this is a daylit facility, there was no effort to hide these daylighting features in anyway. In some instances, these elements are exaggerated to further show off the daylighting techniques.
Above: The central atrium works as a gallery space and light well for the entire facility. The sun screens and roof overhang are calculated to let no direct light into the space between March 21 and September 21. The south facing large window areas use sun screens and light shelves to control the quality of light entering the space.

Below: The overall design utilizes the planar aspect of light shelves and sun screens and exaggerates them, emphasizing those daylighting techniques. In order to break up the mass of the building, structural elements were exposed and a variety materials were used.
Floor Plan: The primary use spaces (classrooms, library, daycare rooms) are all located on the southern side of the building. Service spaces such as rest rooms and kitchen are placed where the least light will be accessible. The plan is divided into three different zones: daycare (noise), learning (quiet), and group activities (noise).
Above Left: The primary classroom at 6:00am March/September 21
Above Middle: The primary classroom at 12:00pm March/September 21
Above Right: The primary classroom at 6:00pm March/September 21

Below: The offices on the second floor have north facing windows and borrow light from the corridor located to the south. Classrooms and the library utilize light shelves and sun screens to control daylighting.

Above: The daycare wing has clerestory windows which get light from rays bouncing off of the gravel roof below.
Harrison Elementary: Preliminary

The preliminary design for the elementary school consisted of a very simple plan with the larger gathering spaces anchoring the west end and the classrooms pulling off of those spaces towards the east. The long hallways were used as oversized light wells, pouring light into the space. In order to utilize this light, all of the classrooms have clerestory windows into the corridors, allowing the light to flood into them.

Initial problems with this preliminary scheme include massing and equality light in the classrooms. With the large gathering spaces anchoring the building on one end, there became large masses on one side of the building and a much smaller scale portion on the other. This particular building layout prevented there from being any type of transition between the site and the large masses on the west end. In order to provide a transition, these masses should be more central to the building, allowing the smaller scaled classrooms to surround them.

With this preliminary design, which includes some classes with windows to the north and some to the south, providing equal daylighting in those spaces became difficult. In order for no classroom to be a better environment than another, it is very important for the amount as well as the quality of daylighting to be equal. In order to solve this problem for the final design, all primary use classrooms (kindergarten through sixth grades) shall be oriented east and west.

Above: The classrooms bump out in order to break up the long stretch of facade on both the north and south sides.

Above: The cafeteria and the Gymnasium anchor the west end, but have no way of bringing the building down to a human scale.
Above: To the left are the large gathering spaces (Cafeteria and Gymnasium), centralized are a courtyard to bring light into the administration wing which is also central to the building for security purposes, and the media center. The primary use classrooms are located on the exterior, while the specialty classrooms are placed in the center section. Light is brought in through skylights and clerestory windows facing the hallways.

Below: This section is through the non-bumped out classrooms. Here, one can see the use of light sleves, and sun screens on the south facade. Overhangs are utilized in the corridor clerestories to block out direct sunlight preventing heat gain.
Harrison Elementary: The Result

Proposed as the first phase of the overall project, the Harrison Elementary School shall replace the existing facility which is in a state of disrepair. The primary focus of this new elementary school is to provide a better learning environment through controlled daylighting. The primary classrooms (those that compose the K-6 grade classrooms) all have equal daylighting. There are no overly bright nor overly dark classrooms.

Equality in daylighting is accomplished by placing these classrooms to the exterior and facing them east and west. With the proposed site and the scale of the new school, north/south orientation was not chosen for the classrooms. With some classes facing north and some facing south, equality could not be achieved. Because of this, the new facility takes a counterintuitive approach to the orientation of the classrooms and places them all facing either east or west. Depending on the time of day, in order to get daylight into the rooms on the opposite side of that the sun is on, the panels are placed away from the building so as to reflect light into the classrooms. When the sun is on the same side of the building as the panels, the panels act as sun screens, blocking direct light. Light is then reflected into the classroom through a light shelf as well as a lightly colored ground surface located adjacent to the building outside of the rooms.

Like the Harrison Adult Educational Facility, the primary focus of this project was to create a building which shows off the daylighting elements and makes them an architectural feature. Taking cues from the preliminary study, the Harrison Elementary School does not hide the daylighting elements in anyway. Where a daylighting feature is used, it is used as architectural articulation. Similar to the preliminary study, the specific daylighting elements used in this design are as follows:

- Light Shelves (Used on the top of south facing Windows)
- Sun Screens (Used on the south facade in order to block direct sunlight during hot summer months)
- Clerestory Windows (Located parrallel to hallways, filling them with natural light)
- Vertical Panels east/west Windows (Positioned to reflect light in as well as block direct light depending on the time of day)
- Skylights (Used to bring more light to the interior of the Gymnasium)
- “Borrowed” Light (Used as clerestory windows for rooms through the corridors)

These daylighting elements were used to determine architectural building orientation, fenestration, massing, and ornamentation. In order to demonstrate to the public that this is a daylit facility, there was no effort to hide these daylighting features in any way. In some instances, such as the use of vertical panels on the East and West facades, these elements are exaggerated to further show off the daylighting techniques.
Building Sections:

Section A-A
Scale: 1/32" = 1' - 0"

Section B-B
Scale: 1/32" = 1' - 0"
North/South Elevations:

South Elevation
Scale: 1/32” = 1’-0”

North Elevation
Scale: 1/32” = 1’-0”
East/West Elevations:

East Elevation
Scale: 1/32" = 1'-0"

West Elevation
Scale: 1/32" = 1'-0"
Light Shelf/Sun Screens:

Light Shelf/Sun Screens
Scale: 1/2" = 1'-0"
East/West Vertical Panel System:

Scale: 1/2"=1'-0"
Above and Left: The approach to the building consists of both the vertical panels as well as the light shelves and sunscreens on the library's south facade. These daylighting elements were not hidden in any way. These elements are used both for practicality reasons as well as aesthetic ones.

Right: The vertical panels and the supporting columns give the building a rhythm and help break up the long flat facades. The music rooms jut off of the east end in their own unique architectural expression.
Harrison Elementary School: Interior

Left: The media center is flooded with light from the south facing windows as well as clerestory windows on the north and east. The southern windows utilize sun screens and light shelves on the top which not only reflect light into the space, but help scale the room down along that wall.

Below Left: The main office is located direct adjacent to the entrance in order to control access to the facility. The room is lit using borrowed light through glass walls which help separate the room from the corridors as well as control noise.

Below Right: The cafeteria uses clerestory windows on the south and west sides as well as large windows on the north overlooking the play area. In order to help define the space as well as spread light throughout the building, glass walls are used between the structural and ornamental columns.
Left: Outside the cluster of classrooms (third and fourth and fifth and sixth), there is a gathering space which is used as an oversized lightwell and can be utilized for grade-wide lessons, display area, and gathering space.

Below Left: Outside the kindergarten and first grade classrooms is another atrium type space. Here, the scale is brought down by the lower ceiling height on either side. This space will primarily be used for gathering, lining up, and display space.

Below Right: This is a typical classroom, square in size (30'x30'). Outside the windows is the vertical panel system which helps reflect light into the space. A light shelf is used along the wall in order to reflect light deeper into the classroom. These light shelves also help to scale down the room along the window wall.
**Conclusion:**

**Reflections**

Daylight is very important to humans for both psychological and physical well being. Builders of the past might not have known about these psychological and physical benefits to having natural light, but it was important that all buildings prior to the invention of electric light have openings in order to provide light. Unfortunately, compact building envelopes and tight budgets have overruled the need for natural light in building design. The architectural community is beginning to move back to daylighting, realizing that, not only is it preferred by the user, but it causes the user to be more productive in his or her activities throughout a daylight building.

This project was particularly difficult. With a preconception that daylighting elements and daylit buildings as a whole are not attractive, it was a challenge to overcome these obstacles and make the daylighting elements an attractive design feature. Upon designing this elementary school and the adult educational facility, I looked for ways to produce a unique architectural expression.

Once daylighting the building took over as it should have as the primary design determinant, the building formed itself. Certain things such as building layout, fenestration, and openings came inherently with the daylighting. The daylighting elements although practical in their function, also became the entirety of the facility's ornamentation.

Daylighting can produce an attractive building and does produce quality learning and living environments. It is not necessary, as shown in the Harrison Elementary School, to have mechanically and electrically controlled daylighting elements. Not only would these high-tech devices malfunction at some point in time and need to be repaired, but every user from their inception through the life of the building would need to be trained on how to use them. Daylighting can be very simple and inexpensive and should be considered for all new construction. Proper orientation, window size and placement, and an appropriate building envelope can all provide a high quality daylit building at little or no extra cost.

**Considerations**

While this project may have been successful in its own right, there are still many things which could have been done or explored. If more time were available for this project, one might continue to explore these vertical east and west panels to find the optimum placement, size and materials. Would they work better if perpendicular panels were placed coming off the building and reaching to the panels (creating a type of waffled panel system)? Because these east and west vertical panels are currently limited to a single story structure, the question should be asked as to how might a north to south orientation work when it comes to a multi-story structure? Would it be possible to get equal and ample light into those east and west facing rooms? Could a panel be devised to place on the northeast, northwest, southeast and southwest corners which could bounce light into these rooms?

There are questions which could still be answered. But, the most important thing to take away from this particular project is that daylighting can be achieved in all facilities. It can produce a high quality environment. Daylighting can be attractive. And, most importantly, daylighting can be affordable when simple techniques are used, making it a building feature desirable for any and all types of facilities.
Selected Works:


Libby, Brian. “BOORA Architects Proves that Green Strategies like Daylighting can Help Kids Learn – While Staying within Educator’s Budgets.” Metropolis. March 2003. 101-105


Additional References:


