Daylighting as a Design Determinant: Creating an Educational Response to the Environment

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Without the help of some very important people, this thesis would not have happened. I would like to take this time to thank those people.

First Bob Fisher for his support and design sense throughout this year as a studio instructor. I appreciate all the time and effort you have put in to help us all reach our potential.

To Bob Koester for his knowledge and direction into the thesis issues as my advisor. Thanks for always questioning and pushing the design to reach a higher level.

To Alfredo Fernandez for introducing me to the subject of environmentally responsive design. Your classes gave the basics but you created the interest.

To Richard Borrelli for listening to my ideas at the initial stage. Thanks for your expertise in school design and for your support throughout this year.

To my fifth year studio section thanks for always being there when I needed a pick-up. I think each and everyone of us learned from each other and that helped to create a friendly and humorous atmosphere.
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In education, success is often thought of as achieving the highest state of knowledge by both learned ideas and personal experience. Through the personal experience of space I feel that design can be used as a way to educate those who use the spaces. One such way of education is in environmentally responsive design. As an initial starting point to this thesis, I decided to combine two areas of design that interested me. The first stems from my exposure, during internship, to the design of educational facilities at the secondary level. The second was derived from my passion for environmentally responsive design and creating energy efficient buildings. The combination of these two areas of design began to shape my research and create the foundation of exploration into this thesis topic. In order to develop a concept of the building as a teaching tool I chose to focus on Daylighting as the primary design determinant.

Out of these interests the thesis was born:

**Daylighting as a Design Determinant:**
Creating an Educational Response to the Environment
The background

Thesis Idea:

The idea is to create a building that is responsive to the environment. The main focus is to determine how daylighting can influence spaces and form. The idea is then to express these findings into a tangible concept that can show how the building can be a teaching tool for its users. The vehicle which I will use for this exploration will be a new high school for the Fishers, Indiana community.

The Site Context:

The Fishers community is a suburban community just outside Indianapolis. It is an upscale community but still quite small and intimate in nature. The site is located two miles west of the city's core commercial and retail district on 116th Street. The physical characteristics include a suburban greenfield that is being prepared for development. The site is situated on the corner of 116th Street and Eller road. At the present time no pedestrian system is in place to or from the site. The western edge of the site is near the White River. The site offers the opportunity to integrate certain parts of the curriculum into outdoor learning experiences.

The Process:

Through research of precedent, case studies and exploration of daylighting principles, this project will begin to formulate the questions that need to be addressed pertaining to the design of the thesis project. As the process continues through design, alternatives and daylight testing will occur to help assist in design decisions.
The background

The issues and positions:
The objective of this thesis is to make informed decisions regarding environmentally responsive issues in school design and thereby enhance the education of students. The position that I am taking is that architecture can act as an element in environmental education. The daylighting issue that this thesis addresses will direct my design decisions. I feel that this thesis will enhance my personal understanding of daylit spaces as well as create a design standard that I can use in future projects. The issue of daylighting will inform and demand attention to details in order to enforce the idea that these decisions can be expressed to the users of the facility.

The interest:
The interest in this thesis stems from a desire to understand how a building can respond to the environment in a positive way. I have been engulfed in the educational environment as long as I can remember. Growing up with a teacher as a parent has showed me the importance of teaching students in creative ways. To promote creative ways of teaching students, I feel that the environmentally responsive design can be useful to the building and their education. The high school is a good example of how these concerns can be integrated into one building.
The background

Project Overview:
The specific typology of this building is an educational facility. This is a high school that promotes a learning environment based on design decisions made regarding daylighting. The spaces in the building are consistent with other educational facilities, but the ideas behind the building are not as conventional. The facility is programmed to have classrooms, science labs, computer labs, a media center and other pertinent spaces that enhance the learning environment.

The project is intended to create an atmosphere conducive to learning in both traditional and non-traditional ways. Each classroom can become a laboratory. For example, using a daylighting technique to signal particular activities or moods in users, as seen in some of Alvar Aalto’s library designs, can be one tool. Another way is to show students how site planning can incorporate environmentally friendly design solutions; such as, sound erosion control by measuring and comparing sound values throughout the site. These are just a few of the ways that the building can act as a teaching tool.

The project entails a variety of spaces for both the learning environment and can host other activities relevant to the community in which it resides. This facility will be a high school that hosts 800 students with room to grow into 1200 students.
Site Characteristics:
The site for this design will be located in a semi-suburban setting. The site is located in the town of Fishers, Indiana.

In locating a site for my thesis, I explored suburban Indianapolis school districts that were planning on expanding their educational facilities to include new construction for their respective communities. I chose the Hamilton Southeastern School District because I saw potential for this site related to my thesis topic. The district is planning on developing this site for a future freshman center.

The physical characteristics include a 75 acre plot of farmland with a tree line on the western and southern edges of the site. The site extends north to 116th street, east to Eller Road, south to the tree line and west to the other tree line. The western edge is near the White River with a small street bordered by a few houses situated on the river's edge. Across Eller Rd. sits another cornfield, yet smaller in size. Adjacent to the smaller cornfield is a large housing development.

The Fishers community is just outside Indianapolis and has a population of 37,835 (census 2000). It is an upscale community but still quite small and intimate in nature. There is a major commercial and retail district for the city on 116th St. near the interchange to I-69. The site however, is located on a plot of land west of this commercial area.
Site Analysis:
The site's location is full of potential for both optimal daylighting conditions and also for the curriculum to engage the natural environment.

The features of the site allow for the major axis of the building to be oriented east-west. This will provide optimal daylighting conditions. This orientation will allow for spaces to receive southern, northern and overhead light. There is a natural shading device provided at the southern edge of the site with the tree line that already exists.

The adjacencies to the site help to influence the building positioning because of the major traffic flow, the large housing development that could house potential students, and being close to the river's edge.

The River and the Wooded area will help integrate the class environment with the natural environment. I can envision outdoor classrooms, nature trails, river water testing and an outdoor daylighting lab.
the program

<table>
<thead>
<tr>
<th>Assigned Spaces</th>
<th>Square Footages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Office</td>
<td>3,584 sq.ft.</td>
</tr>
<tr>
<td>Classrooms (25 @ 896 sq.ft./room)</td>
<td>22,490 sq.ft.</td>
</tr>
<tr>
<td>Computer Labs (2 @ 1024 sq.ft./room)</td>
<td>2,048 sq.ft.</td>
</tr>
<tr>
<td>Science Labs (8 @ 1025 sq.ft./room)</td>
<td>8,200 sq.ft.</td>
</tr>
<tr>
<td>Special Projects Room</td>
<td>896 sq.ft.</td>
</tr>
<tr>
<td>Art Room</td>
<td>1,280 sq.ft.</td>
</tr>
<tr>
<td>Life Skills Room</td>
<td>2,384 sq.ft.</td>
</tr>
<tr>
<td>Choral Room</td>
<td>2,112 sq.ft.</td>
</tr>
<tr>
<td>Band Room</td>
<td>5,412 sq. ft.</td>
</tr>
<tr>
<td>Industrial Arts Room</td>
<td>5,984 sq. ft.</td>
</tr>
<tr>
<td>Media Center</td>
<td>6,144 sq.ft.</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>8,320 sq.ft.</td>
</tr>
<tr>
<td>Staff Lounge</td>
<td>512 sq.ft.</td>
</tr>
<tr>
<td>Work Room</td>
<td>512 sq.ft.</td>
</tr>
<tr>
<td>Auditorium</td>
<td>17,963 sq.ft.</td>
</tr>
<tr>
<td>Gymnasium</td>
<td>16,080 sq.ft.</td>
</tr>
<tr>
<td>Locker Rooms (2 @ 3640 sq.ft./room)</td>
<td>7,280 sq.ft.</td>
</tr>
<tr>
<td>Assigned Bathrooms (8 @ 544 sq.ft./room)</td>
<td>4,352 sq.ft.</td>
</tr>
<tr>
<td>Total</td>
<td>117,553 sq.ft.</td>
</tr>
</tbody>
</table>
Net Assigned

Gross Square Footage
Academic Building  Efficiency Ratio
65% assignable to 35% unassignable

Calculation: 127,413 sq.ft./.65 = 180,850 gsf

Net Unassigned Space
Distribution for 35% of gsf expressed in typical percentages:

Circulation 20%          180,850 gsf x 0.20          36,170 sq.ft.
Mechanical 5.5%          180,850 gsf x .055         9,946 sq. ft.
Public Toilets 1.5%      180,850 gsf x .015         2,712 sq.ft.
Janitor's Closet 00.5%    180,850 gsf x .005       904 sq. ft.
Unassigned Storage 00.5%  180,850 gsf x .005       904 sq.ft.
Walls, Partitions, Strucure 7% 180,850 gsf x .07     12,660 sq.ft.

Total                                63,296 sq.ft.

Outdoor Spaces include:
Outdoor Classrooms
Football Field with Track and Field
Soccer Field
Tennis Courts (6)
Practice Fields (3)
Baseball Diamond
Softball Diamond
Precedence:
As I began a focused research on daylighting techniques, I chose to read through documents that contained case studies of schools that were under the typology of high performance. These schools are excelling in a wide variety of sustainability issues. The schools that I chose to focus on had already achieved a high level of success in daylighting issues. A few of these schools are outlined according to contributions to daylighting and techniques that were successful to their buildings.

Clackamas High School:
This Oregon High School is a two story building that introduces exterior and interior light shelves and skylights to reach the second floor. The high school was oriented on an east-west axis, had a narrow building mass, and also incorporated courtyards to allow sun penetration and optimal daylighting conditions.

Durant Road Middle School:
Natural Daylighting was planned for by orienting the building on an east-west axis to take advantage of maximum southern exposure. The main concept I thought was important was their use of facing single sloped roof monitors in the classroom wings. This then allows both northern and southern light into every classroom.
Adam Joseph Lewis Center at Oberlin College:

This center at Oberlin College is an environmental studies facility. The facility engages the students into a role as managers of the systems of the facility as well as students of environmental education. The facility took advantage of reflected light as their major lighting source. The building also has strategically placed windows to affect how light is distributed throughout spaces. All classrooms and offices in the Center have windows on at least two sides to provide pleasant and ample lighting. The classrooms also have light level sensors and motion sensors so that electric lighting is only used when people are present in the room. Again the facility is oriented along an east-west orientation in order to take full advantage of passive solar gains from the south.

The Center has a unique approach to environmental studies where the building is an actual learning laboratory. The students conduct tests on all aspects of the building from energy use to cistern water levels. As for daylighting as a teaching tool, the lighting levels are monitored by the students in the program. The data monitoring system is an interactive learning tool for the students by revealing how energy flows through the facility.
Daylighting Techniques and Principles:

**Basic Principles:** The sources I have read all suggest that optimal daylighting is achieved by certain basic principles. The first is that the building should be oriented in an east-west axis to allow the spaces to receive southern and northern light. The next stated that in order for daylight to penetrate deep in the space that a narrow floor plate is suggested. One story buildings are also suggested for optimal conditions to penetrate all spaces. Additional features are recommended in order to create a uniform distribution of the light, to reduce glare, to reflect light deeper in the space and for user control.

**Light Shelves:** These are to be used to reflect direct beam light and turn it into a uniformly distributed light reaching deeper into the space. Light shelves are both on the exterior and interior to provide effective reflection of direct light into the space. A design recommendation that relates to light shelves is that they shall be placed above eye level, but below the top of the window in order for them to reflect the light, but not interfere with views.
Daylighting Techniques and Principles:

**Roof Monitors and Skylights:** There are many different configurations of utilizing overhead lighting. Roof monitors and skylights increase the uniformity of light into the space since the light overhead is much brighter than the light at the horizon. A strategically placed roof monitor or skylight can allow light to penetrate areas of the space that the perimeter side lighting cannot reach. An aspect to consider when using this application is that heat gain and loss in the skylight area needs to be monitored or vented.

**User Control:** Although daylighting is very beneficial to the users as well as the building's energy efficiency, it is common to see controls placed within the daylighting systems so that the users can control how much light penetrates the space. For specific functions it may be necessary for the user to adjust the lighting levels. Some common techniques used on the interior include: shades, louvers or blinds to allow the user to control the lighting level and allow control of direct beams and glare that may filter into the space at certain times of year. On the exterior it is wise to consider using overhangs or trees to provide shading into every classroom.
"Is it possible to design buildings so well and so carefully that they do not cast a long ecological shadow over the future that our students will inherit? We now know that such things are possible—that buildings can be designed to give more than they take." -David Orr, Director of Adam Joseph Lewis Center
the process

Space Relationships
the process

Concept 1 - using a two-story structure with wings around a central space.

Concept 2 - using a three-winged approach with one story classroom spaces.

Concept 3 - furthering concept 2 and looking at roof monitors which were facing the interior of the building.

Roof Monitor Study of south facing only monitors.

Roof Monitor Study of facing monitors where light is only brought in from either the north or south.

Roof Monitor Study where light filters into the monitors from both the north and south. This became the option for testing.
The site plan went through many studies and changes over the project. This is a diagram of the placement of the main features on the site.

A zoning diagram of how space relationships work on the site.

This was a conceptual site plan from the mid-project review. The site plan eventually became a well organized representation of building and site.

This model began to show the idea of raising each classroom wing four feet to capture more daylight and to create outdoor amphitheaters.

This model also studied how to extend the facility towards the river and also to create a cascading feeling that will integrate into the overall site plan.

This model shows the fenestration of the lobby area/main entrance.
From the light penetration study, I found that the classroom spaces have high levels of daylight entering the space. I also found that at times it will be necessary to have controls placed in the windows at times where glare could become a problem at the desk level.
The study also showed how the light penetrated into the corridors. A bar of light is projected on the corridor wall. The location of the light corresponds with the time of year as well as time of day. I envision this to be a learning opportunity to teach about light penetration.
“I was after an explanation of how and why I perceived the world around me, so that I could put that understanding to work in the design of environments which would have predictable and positive effects on those who experienced them.” -William Lam from *Perception and Lighting as Formgivers for Architecture*
the results

Site Axonometric
the results
the results
the results

EAST ELEVATION

WEST ELEVATION
the results

NORTH ELEVATION

SOUTH ELEVATION
the results

SECTION 1

SECTION 2
the results

PARTIAL SOUTH ELEVATION

WALL SECTION THROUGH SOUTH WALL @ LIGHT SHELF
the results
the results
the results

Section Model through Lobby:
the results

classroom section

top lighting
roof monitors allow southern and northern indirect light to infiltrate the interior of the classroom.

high angle sun

shading
light shelf and roof overhang provide horizontal shading from high angle sun. horizontal blinds are provided for user control.

light shelf
ambient and direct daylight bounces off external and internal light shelves for a higher level of indirect lighting.

low angle sun
the results

Courtyard Perspective

Amphitheater Perspective

Lobby Perspective
the results

Main Entrance Perspective
"One of the most essential things you need to do for yourself is to choose a goal that is important to you. Perfection does not exist - you can always do better and you can always grow. – Les Brown
Reflection of Exploration:

As the project concluded, the thesis was still prevalent in the
decisions and the outcome of the building. This project allowed me to
apply the principles of daylighting as a design determinant. Daylighting
is something that is very helpful to the building’s sustainability. Paying
attention to this issue enhances the overall performance of the building.
I have found that through this project, daylighting can help shape the
form of the building as well as the spaces that it penetrates.

In the design of this facility, I was able to learn how to influence
space by allowing adjustments to be made to the land forms as well as the
daylighting scheme. Through these decisions, the spaces became more
open and actually helped to highlight the daylighting scheme as the
prominent feature of the facility. The facility was expansive in program,
yet I feel that the organization was one of its strongest points. As the day-
lighting became more influential the building became more and more
consistent. This project became an integrated scheme with the entire
site becoming an integrated piece of architecture as well as the building
becoming an integral part of the big picture.

I would like to take the lessons learned from this experience and
use them in a professional setting. I strongly believe that architecture is
a teaching tool that can educate others about environmentally responsive
decisions.

Although this package is the final product, there is so much
more that I would have like to explore. Some lingering questions will be
on how to integrate the larger volumes as an expression of daylighting,
the development of the courtyards and break-out spaces as well as a more
ceremonial ramping system on the interior.
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