Introduction to Daylighting

Presented by: Christopher Meek, FAIA, IES
Date: 19 May 2020
Before we begin...

**During the Webinar**
- Attendees will be muted
- Please use the chat feature in the control panel to submit questions to LDL staff
- The presenter will pause to address questions every ~10 minutes
- Please participate in the online polls.

**Following the Webinar**
- Please take the short survey
- A recording and the slide deck will be posted on LDL’s webpage
- Reach out to LightingDesignLab@seattle.gov with comments or questions.
It takes a village...
LDL’s Four Core Service Areas

- **EDUCATION & TRAINING**
- **TOOLS & RESOURCES**
- **TECHNOLOGY EVALUATION**
- **INFORMATION AGGREGATION**
Introduction to Daylighting Design
19 May 2020

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The Integrated Design Lab
The Discovery Commons

@ the Bullitt Center
DAYLIGHTING DESIGN IN THE PACIFIC NORTHWEST

CHRISTOPHER M. MEEK
KEVIN G. VAN DEN WYMELENBERG
FOREWORD BY JOEL LOVELAND

http://www.washington.edu/uwpress/search/books/MEEDAY.html
What is Integrated Lighting Design?
General Motors Building, Detroit, 1917; Albert Kahn and Associates
“Silos”

Architects

Lighting Designers and Engineers

1941
Our Pattern of Light and Dark

- **Ancestral**
- **Modern**

**Axes:**
- **Y-axis:** Brightness
- **X-axis:** Midnight, Dawn, Noon, Dusk, Midnight

Legend:
- Blue line: Ancestral
- Orange line: Modern
ARCHITECTS POLLUTE
Daylight and the Sky as a Light Source
Daylight Variability

Figure 6-9 – Example of Daylight Variability
Daylight Illuminance = Sky C + External RC + Internal RC
Daylight Illuminance = Sky C + External RC + Internal RC
The Experience of Direct Sunlight in Buildings

Illumination Patterns of Direct Sun
Building as a Luminaire
Design Rules of Thumb: Sidelighting and Toplighting
Glare/Thermal Control Strategies: Exterior to Interior

- Automated Exterior Shading Systems
- Fixed Exterior Architectural Shading Systems
- Exterior Fabric Awnings
- High Performance Glazing
- Operable Windows
- Automated Interior Shading Systems / Double Skin Systems
- Manual Interior Shading Systems
Automated Exterior Blinds

Photocell and Weather Station Control

Courtesy: Markus Klopf / Warema
Fixed Exterior Architectural Shading

Giadrone MS, NAC Architecture
Glazing: *Light and Thermal Properties*

**U-Value**

**What it is:** U-value measures a glazing system's insulating ability. The lower the U-value (expressed as a number between 0 and 1), the better the insulation.

**What to look for:** Regardless of whether you live in a heating or a cooling climate, go for windows with the lowest U-value you can afford. Single-pane windows have a U-value of around .90, while the most sophisticated Heat Mirror glazing systems have values as low as .11.

**Visible Light**

**What it is:** Visible light transmittance (VT) measures the amount of light that passes through a window. Clear glass has a VT rating of .90, meaning that it admits 90 percent of visible light. Add multiple panes and low-E coatings and that number starts to go down.

**What to look for:** To maintain good light transmittance and visibility, choose glass with a VT of .6 or above, which will appear clear to the naked eye. Lower VTs indicate tinted windows, which can cut down on solar heat gain but will also reduce visibility, especially at night.

**Solar Heat**

**What it is:** The solar heat gain coefficient (SHGC) measures the amount of the sun's heat that passes through a glazing system.

**What to look for:** Lower numbers are best in warm climates where cooling costs dominate, while higher numbers mean more of the sun's heat will radiate indoors. For low solar heat gain, look for numbers in the .40 range; for high heat gain, look for .70 and above.

Courtesy: This Old House Magazine
LSG: *Light to Solar Heat Gain Ratio*
Ensure Visual Comfort
Interior Blinds

Provide Complete Opacity, Maintain Diffuse Daylight
Daylight Performance Varies Widely
SKYLIGHTS: Geometric Basics
SKYLIGHTS: How Much Glazing Area?

Total Annual Energy Savings from Skylights Lighting, Cooling and Heating (all fuels converted to kWh)

- SUNNY CLIMATES
- OVERCAST CLIMATES

From: SKYCALC  www.h-m-g.com
SKYLIGHTS: Light Diffusion

Transparent (Clear) Glazing

Translucent Glazing
SKYLIGHTS: Light Diffusion

Light Scattering Through Pigment/Fibers

- Insulated Glass Sandwich Panels
- Laminated Glass PVB Inter-Layers
- Fiberglass Panels
- Acrylic (White Pigment)
- Polycarbonates

Image: Schott Glass  Image: Kalwall  Image: Polygal
SKYLIGHTS: Light Diffusion

Light Scattering Through Refraction

- Prismatic Lenses
- Tubular Skylights
Concepts for Controls Integration
Controls Integration:

Daylight “Harvesting” Controls Concept
Controls Integration:

46 Photoelectric control

Figure 3 Operation of a “differential switching” photoelectric control as the daylight illuminance at the control point changes
Controls Integration

Hardware Components
Luminaire Level Lighting Controls (LLLC)

Daylight and Occupancy Control for Energy Efficiency: Integrated Sensors, Embedded Controls, Wireless Networking,

https://www.designlights.org/lighting-controls/download-the-qpl/
Tools and Resources—Daylighting Pattern Guide

Optimizing Daylight Performance
Introduction

New Buildings Institute in partnership with the University of Idaho and University of Washington has developed a freely available interactive tool for the design of proven daylighting strategies in a variety of building types. Users will be introduced to the Daylighting Pattern Guide while exploring the inter-relationship of sky, site, aperture, and space planning. The guide uses a combination of built examples and advanced simulation to set the stage for substantial reductions in lighting power consumption and overall energy use through successful daylighting design.

http://patternguide.advancedbuildings.net/home

Courtesy: Meek & Van Den Wymelenberg
# Common Space Types & Daylighting Design Challenges

| Pattern # | Pattern Name                  | Building                | Ceiling Height | Plate Depth | Window Height | Window Pattern | Window Area | Sliding Horizontal | Sliding Vertical | Roller blinds | Mini blinds | Shading Dynamic | Shading Static | Skylights | Skywell | Colorful Roof | Parapet Clerestory | Clerestory Monitors | Courtyard / Air Shaft | Sun Penetration | Space Programming | Sky Condition | Skyline | Time of Sun | Multiple Views |
|-----------|-------------------------------|-------------------------|----------------|-------------|--------------|----------------|-------------|--------------------|-----------------|--------------|------------|----------------|----------------|-----------|--------|--------------|--------------------|--------------------|--------------------|-----------------|--------------------|-----------------|---------|-------------|---------------|----------------|
Geographic and Climate Diversity
Daylight Pattern Guide

http://patternguide.advancedbuildings.net/home

Patterns and Search Page

Table of Contents and Sort Field

Thumbnail images and pattern and sub-pattern descriptions for all or sorted pattern contents.

Courtesy: Meek & Van Den Wymelenberg
Daylight Pattern Guide

http://patternguide.advancedbuildings.net/home

Pattern Overview Page

Pattern Title
Indicates the pattern title and number.

Pattern Overview Filmstrip Overview
Indicates the geometric or temporal variations explored in each pattern and the position of each simulation case within the larger pattern sequence.

Pattern Overview Narrative
Provides overarching design considerations inherent with each daylighting challenge.

HDR Actual Photo
High dynamic range photograph of the physical space

Courtesy: Meek & Van Den Wymelenberg
Typical Pattern Page Layout and Common Elements

Daylight Pattern Guide

http://patternguide.advancedbuildings.net/home

Courtesy: Meek & Van Den Wymelenberg
Simulation/Validation Tool: IDeAs Office Building  (EHDD Architects)

HDR Photo from Site Visit

Visualization from Radiance Model
Luminance Data from Site Visit

Luminance Data from Radiance Model

(Images both scaled 10-2500 cd/m²)

Courtesy Meek
Pattern 17: Daylight from Top and Side: Classroom
Section Depth, Sidelighting and Toplighting

Overview

One of the perennial challenges in classroom daylighting is providing balanced illumination at the "back" of the classroom, opposite the perimeter glazing. Historically this was accomplished by maintaining shallow section depths (less than 24'-0") and creating relatively high ceiling heights (greater than 12'-0") with large window areas. However, many contemporary classrooms have section depths of greater than 30'-0" with ceiling heights at less than 11'-0". Once an interior section depth exceeds 25'-0" the contrast between perimeter zone and core of the building begins to increase substantially during daylight hours. Since the human eye tends to adjust to the brightest location within a space this can cause the perception of darkness in the interior section, and glare due to the lack of luminous uniformity across the section. To address this condition, a second (or multiple) source of daylight can be added where possible to provide supplemental illumination and to wash the "back wall" with light.

In this case we explore a range of classroom section designs that include: sidelighting only, north-facing transparent roof monitors, south-facing diffuse roof monitors, diffuse horizontal skylights, and increased perimeter glazing. It is important to note the presence of translucent glazing in all top-lighting configurations where direct beam sunlight has the potential enter the classroom during hours of instruction. For this simulation diffuse glazing is simulated at a 50% visible light transmission.

There are three primary goals for the effective daylighting of classrooms. The first is to control direct sunlight during all occupied hours. The second is to provide balanced luminance on interior surfaces, especially between the perimeter and key interior surfaces within the classroom. The third is to provide sufficient ambient daylight illumination for visual tasks. Since classrooms are predominately used during daylight hours, they provide an excellent opportunity for lighting power savings from daylight responsive controls.

The case study example is Chartwell School, designed by the EHDD Architecture. The site receives a range of sky cover including coastal fog and heavy cloud cover with periods of clear skies. For this reason we show each design case under both overcast and clear skies. The ambient illumination criterion is shown at 300 lux.
17.1(o): Daylight from Top and Side: Classroom
Perimeter with no clerestory

Vertical windows on one side are insufficient to effectively illuminate this 30'-0" deep classroom under overcast sky conditions. North-facing perimeter glazing with an 8'-0" head height provides effective daylight illuminance at only about one-third of the classroom area. The contrast from perimeter glazing and the interior surfaces of the classroom is very high, increasing the likelihood of glare. Commonly this results in the deployment of blinds and a substantial reduction in daylight performance.
17.2(o): Daylight from Top and Side: Classroom

Perimeter Glazing

Vertical windows on one side are insufficient to effectively illuminate this 30'-0" deep classroom. North-facing perimeter glazing with an 12'-0" head height provides effective daylight illuminance at about two-thirds of the classroom area under overcast sky conditions. The contrast from perimeter glazing and the interior surfaces of the classroom is very high, increasing the likelihood of glare. The increase in vertical glazing does contribute to increased luminance at the "back" of the classroom.
17.3(o): Daylight from Top and Side: Classroom
Perimeter + window

The inclusion of a small vertical window at the "back" wall provides balancing illumination and washes the teaching wall with daylight. The combination of these vertical windows is sufficient to illuminate approximately three-quarters of this 30'-0" deep classroom under overcast sky conditions. The contrast from perimeter glazing and the interior surfaces of the classroom is managed across the section of the space. It should be noted that, due to circulation requirements, it is uncommon for classrooms to have the potential to be side-lit from opposite vertical walls.
17.4(o): Daylight from Top and Side: Classroom
Perimeter + skylight

The inclusion of a pair of translucent (light diffusing) 3'-6" X 2'-6" skylights at approximately 10'-0" off the "back" wall provides a relatively even distribution of horizontal illumination across the classroom section. Daylight through the skylights adds to the vertical surface brightness of the back wall and increases surface luminance within the classroom. This serves to reduce contrast and increase visual comfort. This configuration illuminates 85% of this 30'-0" deep classroom under overcast sky conditions.
17.5(o): Daylight from Top and Side: Classroom
Perimeter + window + skylight (as-built)

The “as-built” configuration combines perimeter glazing a pair of translucent (light diffusing) 3'-6" X 2'-6" skylights, and a small vertical window to wash the teaching wall with daylight. This combination of apertures provides excellent interior surface illuminance and a well-composed distribution of brightness. This serves to reduce contrast and to increase visual comfort, especially viewers to the exterior. Nearly all of the interior of this 30'-0" deep classroom meets ambient illumination goals with daylight under overcast sky conditions.
17.6(o): Daylight from Top and Side: Classroom
Perimeter + skylight engaging back wall

This configuration combines perimeter glazing with a pair of translucent (light diffusing) 3’-6” X 2’-6” skylights in a “slot” lightwell engaging the back wall of the classroom. This combination of apertures provides a continuous wash of daylight on the back wall to balance the brightness of the perimeter glazing. Nearly all of the interior of this 30’-0” deep classroom meets ambient illumination goals with daylight under overcast sky conditions.
17.7(o): Daylight from Top and Side: Classroom
Perimeter + slot skylight

This configuration combines perimeter glazing with four translucent (light diffusing) 3'-6" X 2'-6" skylights in a "slot" light well engaging the back wall of the classroom. This combination of apertures provides a continuous wash of daylight on the back wall to balance the brightness of the perimeter glazing. Nearly all of the interior of this 30'-0" deep classroom meets ambient illumination goals with daylight under overcast sky conditions. Though substantially increasing surface luminance, the horizontal area exceeding 300 lux is nearly unchanged with the doubling of skylight area.
17.8(o): Daylight from Top and Side: Classroom
Perimeter + south clerestory

This configuration combines perimeter glazing with a continuous 2'-0" translucent (light diffusing) south facing clerestory above the back wall of the classroom. Given the directionality of the clerestory, this configuration creates high illumination levels at the center of the classroom, with somewhat less surface brightness on the back wall. Nearly all of the interior of this 30'-0" deep classroom meets ambient illumination goals with daylight under overcast sky conditions.
17.9(o): Daylight from Top and Side: Classroom
Perimeter + north-facing clerestory

This configuration combines perimeter glazing with a continuous 2'-0' transparent (clear glass) north facing clerestory opposite the back wall of the classroom. Given the directionality of the clerestory, this configuration creates high surface brightness on the back wall, balancing the brightness of the perimeter glazing. Nearly all of the interior of this 30'-0' deep classroom meets ambient illumination goals with daylight under overcast sky conditions.
Pattern 5: Interior Furniture Layout

Daylight from One Side

Overview

The selection and design of open office furniture, especially workstation partitions, requires care to ensure the preservation of daylight and views. Even in the most carefully considered daylighting schemes, effective workstation design can be the difference between realizing daylighting goals and unintentionally compromising design intentions. In side lit spaces, office partitions must be kept low (42” or less) and undeveloped parallel to the direction of the daylight distribution and to ensure the maintenance of views to the exterior. Where higher partitions (48” or greater) are required for privacy or to create a sense of enclosure, they should be oriented perpendicular to the perimeter glazing. 60” (or greater) partitions that are perpendicular to the direction of daylight distribution can enable privacy and allow for simple storage without blocking views and creating dark shadows. Additionally it is critical that the partition finishes be light reflective, especially above 42”.

Workstations should be designed so that the primary visual field (the direction that most occupants face while performing visual tasks) is parallel to daylight openings wherever possible. This helps avoid visual discomfort from building users looking into their own shadow, or worse, from the excessive contrast that might occur when a visual task area (commonly a computer screen) is immediately surrounded by the brightness of a view to the exterior.

Often daylighting design decisions are made in early schematic design, prior to the specification of workstation layout and configurations. However, it is crucial to ensure that daylight distribution patterns are not compromised by selecting panel sizes, orientations, and reflectances that substantially hinder daylight performance. An interior office workstation layout that is carefully integrated with the daylighting design intent is critical to realizing the highest quality interior environment and delivering maximum lighting power savings from daylight.

Our case study patterns are based on the Banner Bank Building in Boise, ID. It includes a 40% window to opaque exterior wall ratio with a window head height at 9'-6", a sill height at 3'-0" and a ceiling height at 10'-0". Interior reflectances are roughly 80-50-20 for ceiling, walls, and floors, respectively.
A horizontal band of windows at 40 percent of the opaque wall area provides daylight illumination that meets or exceeds commonly accepted minimum daylight illumination criteria at approximately 75 percent of the adjacent 26'-0" deep open office area.
Pattern 5.2: Interior Furniture Layout

Desks Only

The inclusion of “open” desk workstations has limited impact on the daylight distribution across the horizontal workplane. Daylight levels exceed commonly accepted ambient illumination criteria at all areas except at the circulation aisle (at left).
Pattern 5.3: Interior Furniture Layout

Low Panels

The inclusion of modesty panels below the 30" desk height has virtually no impact on the daylight distribution across the horizontal workplane. Daylight levels exceed commonly accepted ambient illumination criteria at all areas except the circulation aisle (at left).
Pattern 5.4: Interior Furniture Layout

42° Panels

The inclusion of 42° panels begin to create some shadowing at the horizontal workplane. However, ceiling brightness begins to diminish as the reflectance off of the floor and desk surfaces is reduced by the panels. Daylight levels continue to exceed commonly accepted ambient illumination criteria at nearly all workstations.
Pattern 5.5: Interior Furniture Layout
42” Panels with Glass Partition (As-Built)

The addition of a glass partition between the aisle and the workstation area increases acoustic privacy while maintaining brightness at the “back” wall (at left). Horizontal daylight levels continue to exceed commonly accepted ambient illumination criteria at nearly all of the workstation areas.
Pattern 5.6: Interior Furniture Layout
42" Panels with 60" Panels Perpendicular to Glazing

The addition of a 60" panel perpendicular to the window wall, increases both visual and acoustic privacy. Though diffuse daylight levels are reduced, views to the exterior remain largely unobstructed. Horizontal daylight levels continue to exceed commonly accepted ambient illumination criteria at 50 percent workstations.
Pattern 5.7: Interior Furniture Layout

60° Panels

The addition of 60° panels surrounding all workstations substantially reduce daylight levels at the back wall and beyond the workstations directly at the perimeter. Views to the exterior are constrained dramatically at all workstations. Horizontal daylight levels exceed commonly accepted ambient illumination criteria only directly adjacent to the perimeter glazing.
Pattern 5.8: Interior Furniture Layout

72" Panels

72" panels surrounding all workstations reduce daylight levels even further, especially at the back wall. Even the perimeter workstations are marginally daylit. Views to the exterior are constrained dramatically at all workstations. Horizontal daylight levels exceed commonly accepted ambient illumination criteria only at aisle ways directly adjacent to the perimeter glazing.
Pattern 5.9: Interior Furniture Layout
72° Panels with Glass Partitions

Changing the materiality of the workstation panels parallel to the glazing to be transparent allows daylight distribution and views despite the 72° panel height. However, horizontal daylight levels exceed commonly accepted ambient illumination criteria only directly adjacent to the perimeter glazing.
DAYLIGHTING RESOURCES
IES WEBCASTS

IES DAYLIGHTING PODCASTS
5-Part Series

Sample slides
IES SEM-6-12
Daylighting
IES RP-5-13
Recommended Practice for Daylighting Buildings

Sample figure
IES LM-83-12
Approved Method: IES Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE)
IES LEM-7-13
Approved Method: Lighting Controls for Energy Management
Thank you!  Questions?

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And now – a few words from LDL
### Upcoming LDL Online Events

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<td>June 2</td>
<td>11:00 - Noon</td>
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<td>Light Sources &amp; Luminaires</td>
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