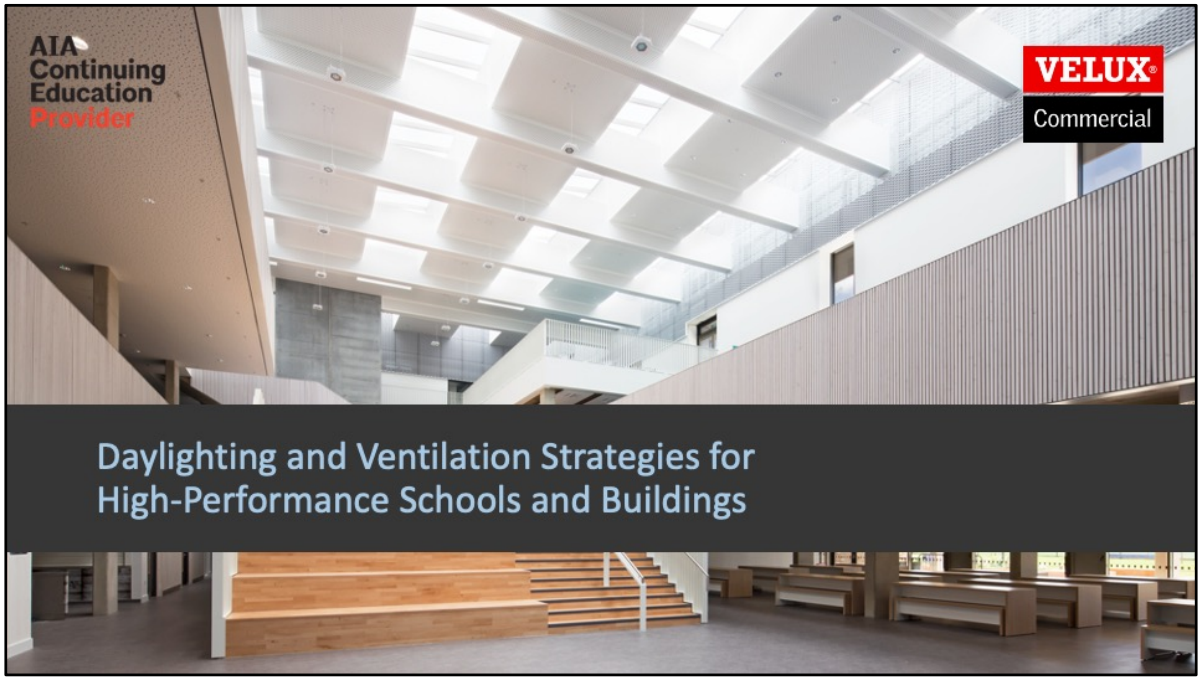
AIA
Continuing
Education
Provider
VELUX
Commercial
Daylighting and Ventilation Strategies for
High-Performance Schools and Buildings

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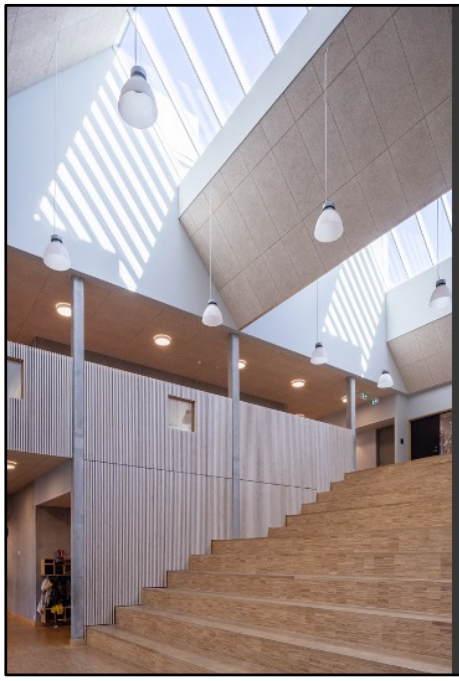
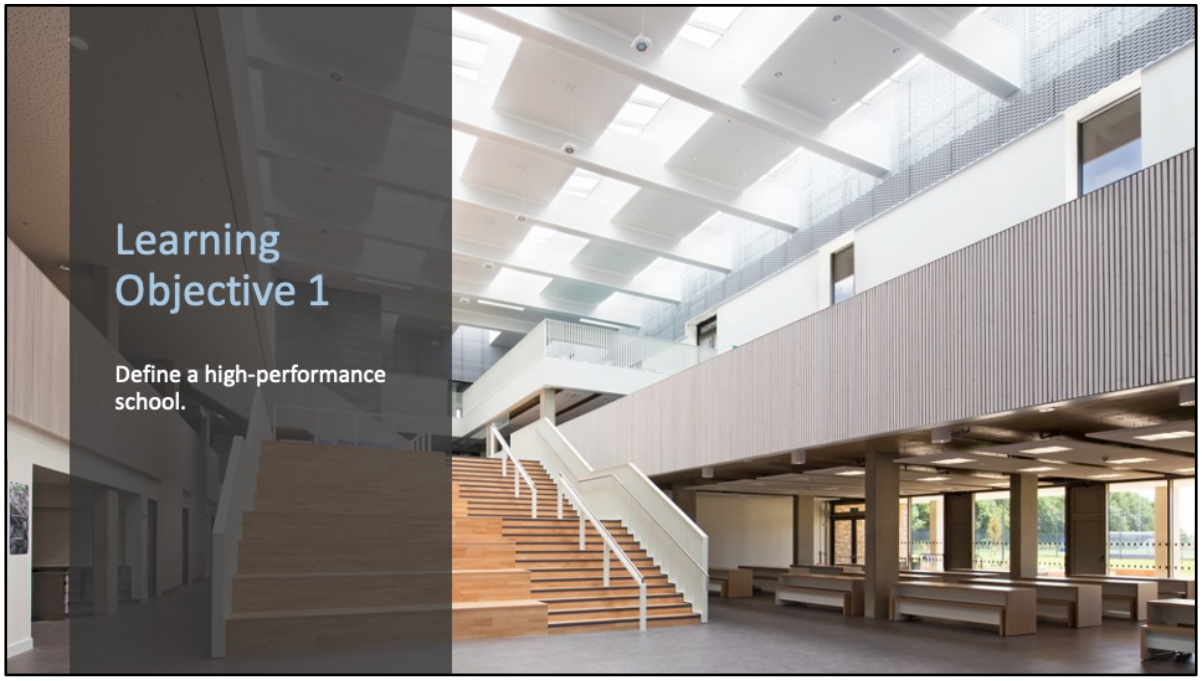
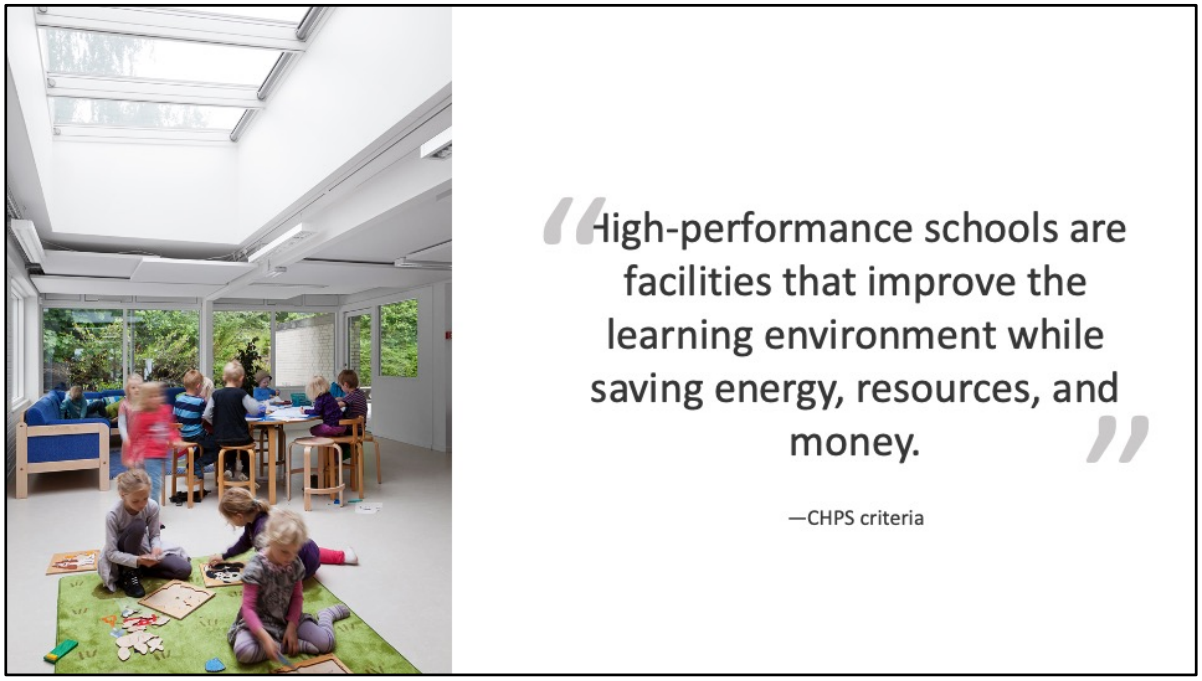


Learning Objectives

1. Define a high-performance school.
2. Review the principles of light, including human physiology, perception, daylight versus electrical light, and impact on health/wellness.
3. Explain indoor air quality and the value of proper ventilation.
4. Understand the need for an integrated whole-building design process.
5. Identify the key design considerations for classrooms.
6. Discuss innovations in high-performance glazing technologies.
7. Describe the value of daylighting and passive air ventilation contributing to a net-zero school.


Learning
Objective 1
Define a high-performance
school.

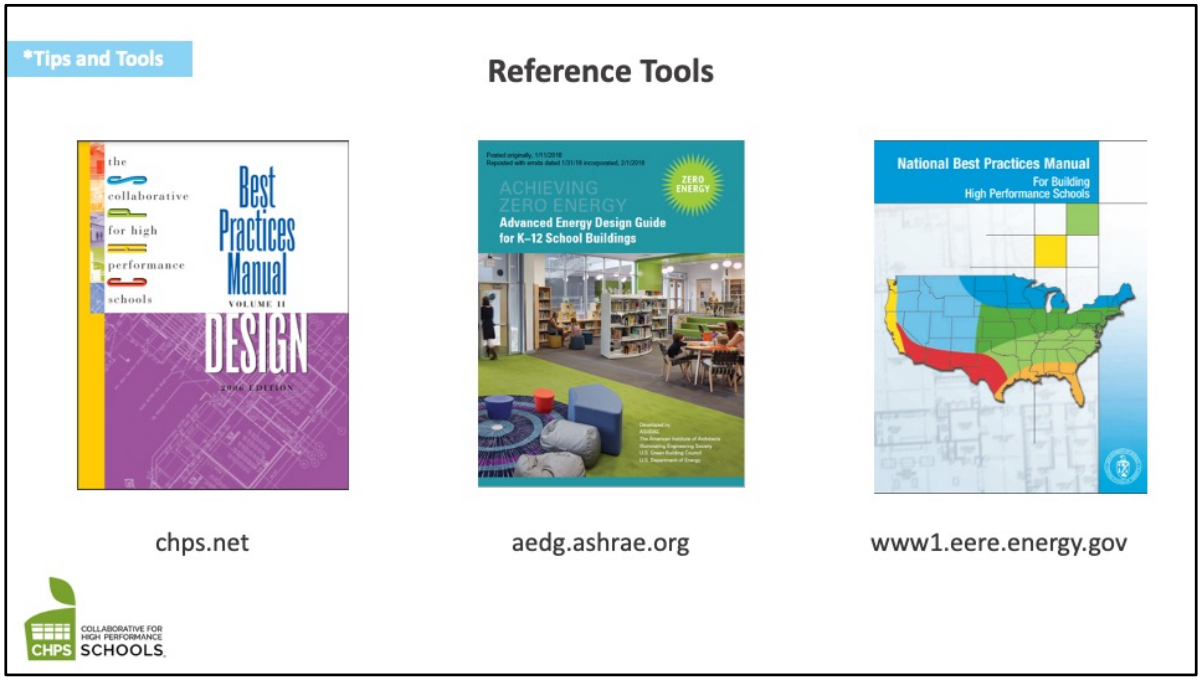


According to the CHPS criteria, “High-performance schools are facilities that improve the learning environment while saving energy, resources, and money.” The key is understanding the lifetime value of high-performance schools and effectively managing priorities, time, and budget during the design and construction process. ”High-performance school" refers to the physical facility—the school building and its grounds. A well-designed facility can truly enhance performance and make education a more enjoyable and rewarding experience. Creating a high-performance school is not difficult, but it requires an integrated, whole-building approach to the design process. Key systems and technologies must be considered together, from the beginning of the design process, and optimized based on their combined impact on the comfort and productivity of students and teachers.” (https://chps.net/knowledge-library)

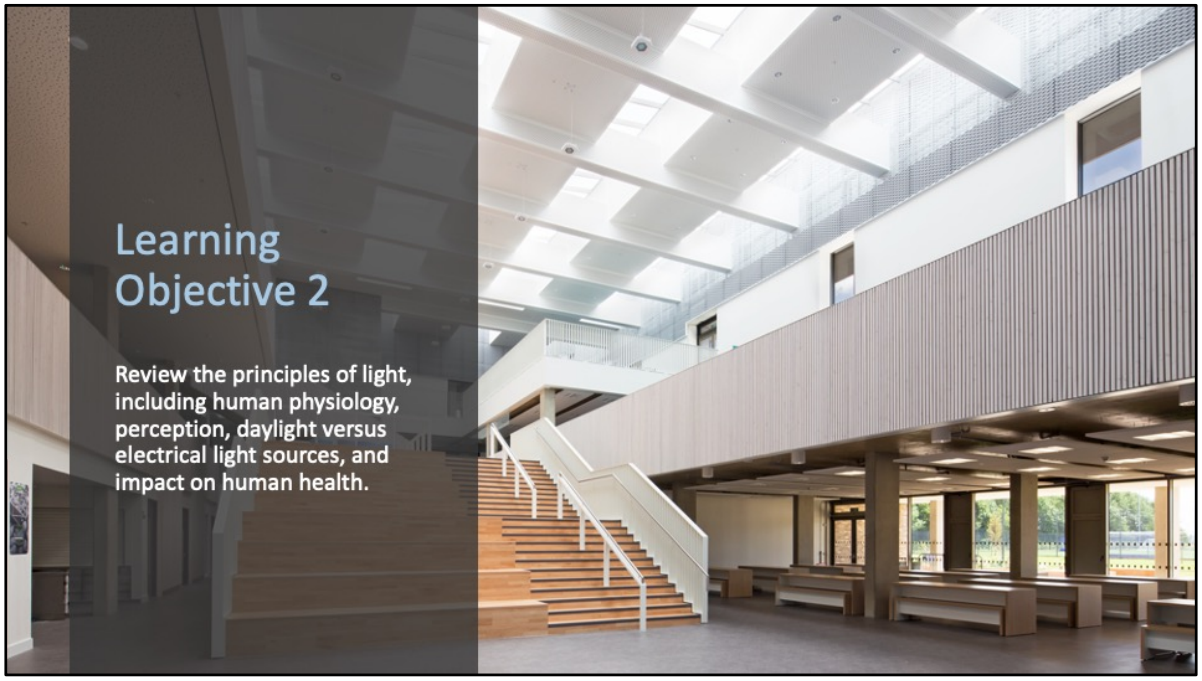
•Healthy
•Comfortable
•Energy efficient
•Material efficient
•Easy to maintain and operate
•Commissioned
•Environmentally responsive
•Teaching sites
•Safe and secure
•Community resources
•Architecturally stimulating
•Adaptable to changing needs

A high-performance school is healthy and thermally, visually, and acoustically comfortable. It is also energy, material, and water efficient. A high-performance school must be safe and secure, easy to maintain and operate, commissioned, and an environmentally responsive site. (CHPS.net)

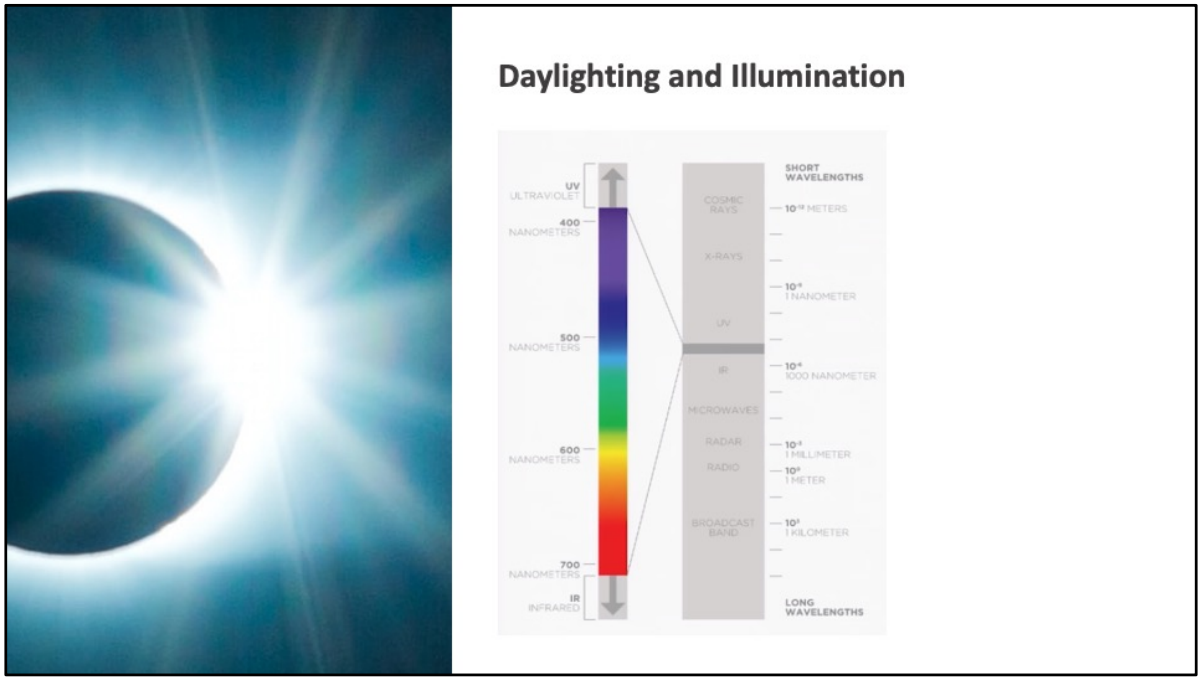
"Most of all a high-performance school is one that teaches and is a community resource. It should also be stimulating as well as adaptable to changing needs." —Frank Cunha III (https://ilovemyarchitect.com/)



Throughout the presentation, resources and tools to support the design community for creating such valued and sustainable learning environments are referenced. In addition, many states have created and adopted their own design standards, reflecting and incorporating many similar requirements.



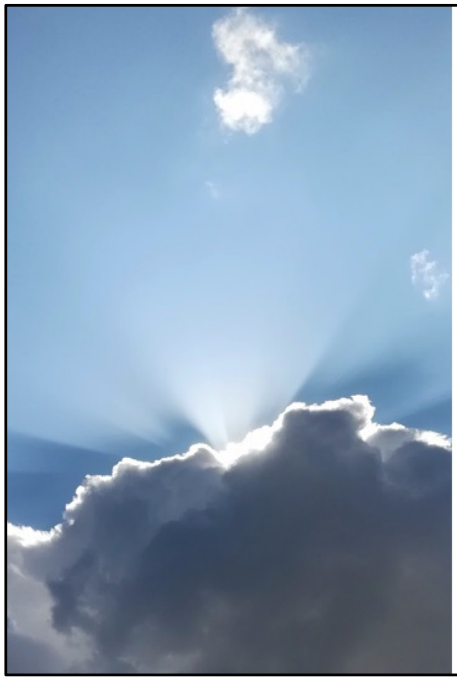
The design of schools, offices, and commercial spaces have evolved, reflecting the integration of changing design trends, construction methods, and new technologies—and the value of sustainable design for energy efficiency and healthy environments. The design of schools have especially reflected the application of such theories, influenced by additional theories of educators. Lisa Heschong provides a well-documented overview of this in *Visual Delight in Architecture (2021).* In the United States, the earliest school design standard (of 1910) referenced specific window sizes and configurations for both primary light sources and operable windows for ventilation. Yet in the next century, school design would become more engineered and economized with advancements in electric lighting and HVAC systems. By the 1960s, many learning environment became 'windowless' in concern for both heat gain from glass and the potential of perceived visual glare. The Illumination Engineers Society (IES) set guidelines for lighting classrooms from 3 footcandles (1920) to 30, then jumped to 70 footcandles in 1959. (By 1980, it was reduced to 50 footcandles.) As energy costs rose (as they historically do and will), the idea of maximizing natural light and shutting off electric lights, when possible, came forward to save energy. Fortunately, the reintroduction of natural light greatly improved the learning environments for students and working environment for teachers. There are significant differences between daylight and electric light—and its important to understand the science and human physiology to understand why. Without the background science, daylight or views can be perceived as a 'nice to have' or 'feel good' proposal.



The difference with daylight starts more than 92 million miles away to reach our planet. Light, as we know it, is the frequency range of the electromagnetic spectrum to which our human visual system is sensitive. (Review of the visual light spectrum: 400 to 700 nm and sunlight reaching earth.)

Daylighting and Illumination

Understanding how natural light changes through the day is important to understand in an overall light strategy. With the advancing of LED technologies and tunable lighting, understanding the changing color temperature will support the successful integration of electric lighting in hours not supported by natural light. One key difference between daylight and electric light is daylight's changing intensity, color, and direction through the day and night and across the seasons—all of which have an impact on the variation of perception within a space.

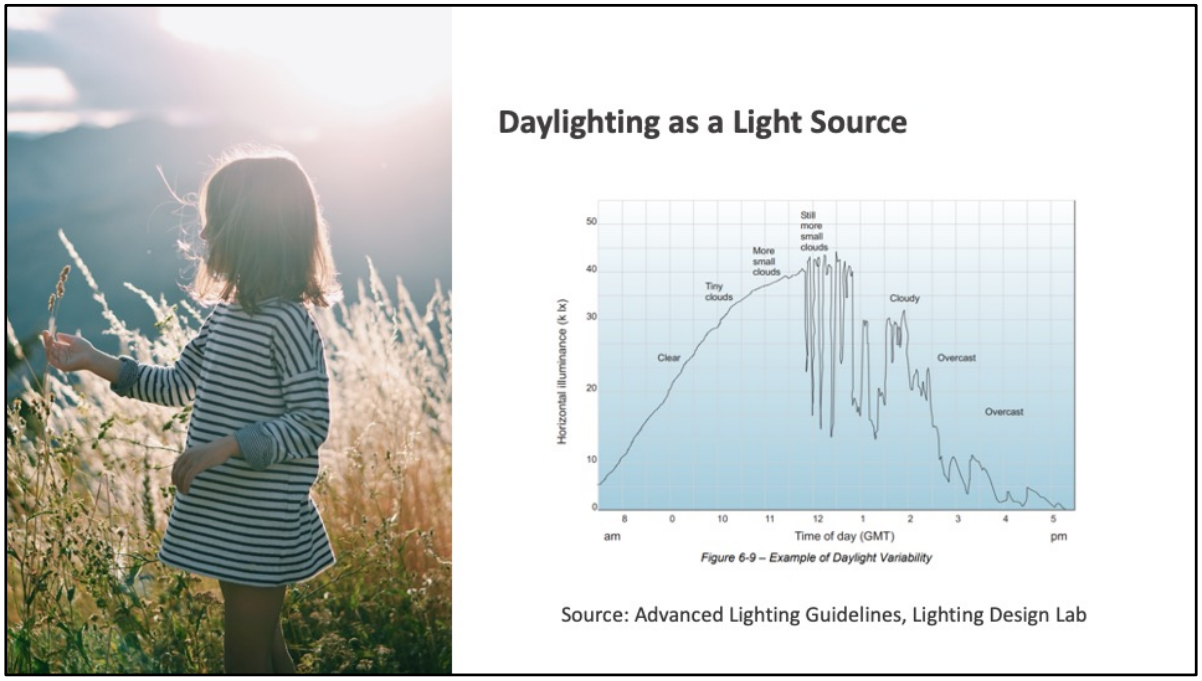


Daylighting as a Light Source

In general, we want to maximize diffuse natural illumination in buildings while rejecting direct sun penetration.

- Direct sun
- Clear blue sky
- Partly cloudy sky
- Overcast sky

Successful daylighting is maximizing opportunity for illumination with limiting the potential for glare. The energy use for lighting in a school facility accounts for 20 percent of the budget (upgraded lighting systems). Allowing the controlled admission of natural light, direct sunlight, and diffused-skylight into a building significantly reduces the electric lighting and results in up to a 30 percent saving energy. Most important, it also creates a visually stimulating and more productive working environment for both students and building occupants.



The ever-changing dynamic nature the sky provides keeps us visually and psychologically engaged.

In addition, there has been an alarming rise (globally in the industrialized world) in the number of children experiencing myopia, or nearsightedness. “The risk of myopia is lowered by exposure to daylight and increased by activities performed at short visual distances (close-up work). A person with little exposure to daylight has a fivefold risk of developing myopia, which can rise as high as a 16-fold risk if that person also performs closeup work. ” (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5615392)

Daylighting as a Light Source

Bill Lam identified eight important needs for biological information:

Location – with regard to water, heat, food sunlight, escape routes, destination, etc.

Time – and environmental conditions that relate to our innate biological clock.

Weather – as it relates to the need for clothing and heating or cooling, the need for shelter, opportunities to bask in the beneficial rays of the sun, etc.

Enclosure – the safety of the structure, the location, and nature of environmental controls, protection from cold, heat, rain, etc.

Source: Advanced Lighting Guidelines, Lighting Design Lab

Lam distinguished between two main groups of criteria: the "activity needs," which are the needs resulting from performing activities within a visual environment, and the "biological needs," which sum up the psychological demands placed on a visual environment and are applicable in every context.

(William M.C. Lam was a visionary in the world of lighting and a consultant to the architectural community, teaching at Harvard and MIT, in addition to an AIA Achievement award. Source: Sunlight as a formgiver for Architecture, www.wmclam.com)

Daylighting as a Light Source

Bill Lam identified eight important needs for biological information:

Other living things – the presence of plants, animals, and people.

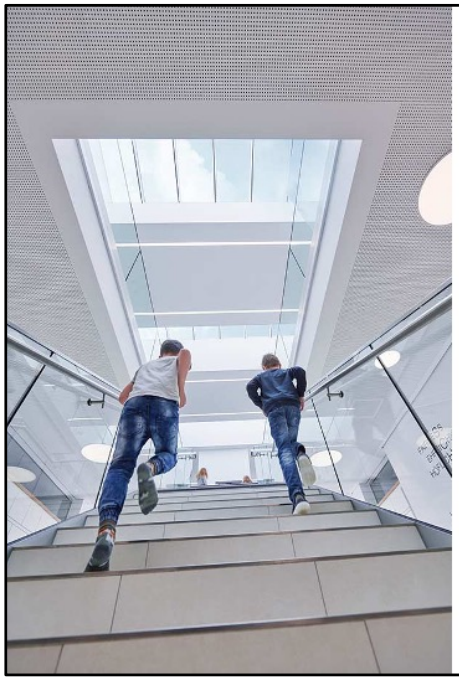
Territory – its boundaries and the means available within a given environment for the personalization of space

Relaxation and stimulation – for the mind, body, and senses.

Place of refuge – shelter in times of perceived danger.

Source: Advanced Lighting Guidelines, Lighting Design Lab

The concept of biological needs mirrors concepts of 'biophilic design,' which aims to recreate that connection to nature by activating the senses with natural elements or mimics natural systems, such as daylight, natural patterns, fresh air, moving water, and plant life.



Daylight, Health, and Well-Being:

"We need dynamic cues and a connection to nature and the passage of time:

…unvarying electric light can lead to low -evel sensory deprivation manifested by 'impairment of organized thinking, oppression and depression, confusion, suggestibility, and general irritability.'"

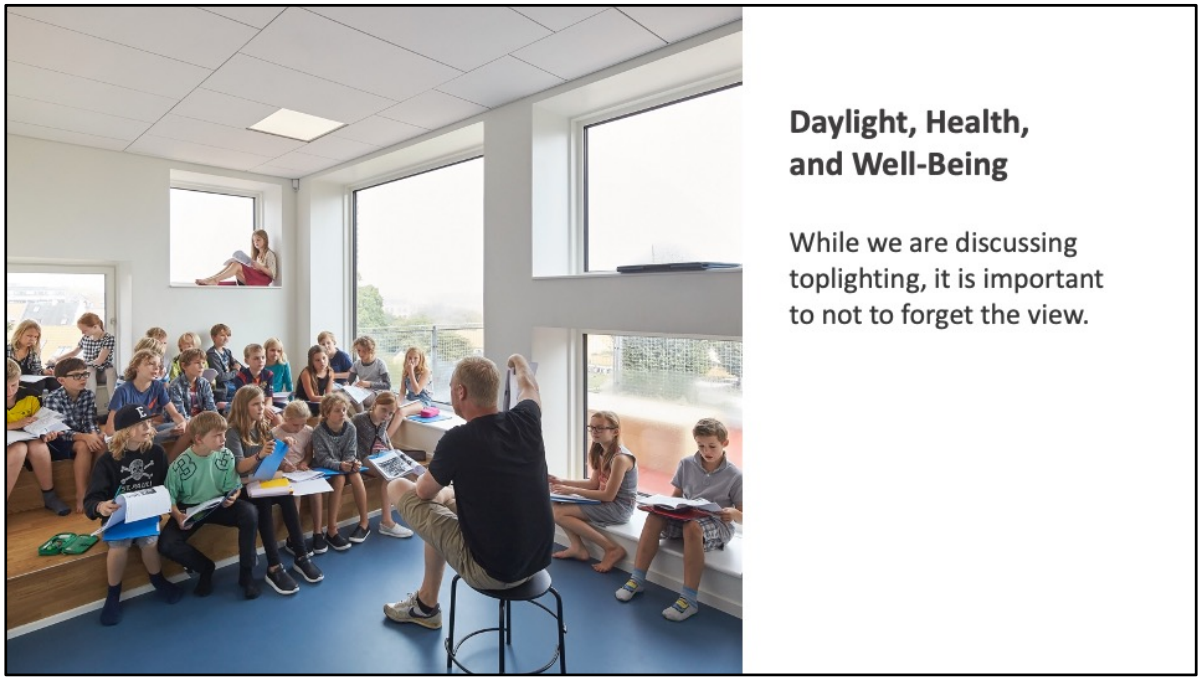
—Aldsworth and Bridgers (1971)

Daylight, Health, and Well-Being:

Adopt the goal of maximizing daylighting opportunities and unobstructed view to the outside work in as many cases as possible.

- Visual fatigue
- Regulation of the chrono-biological system
- Seasonal affective disorder
- Synthesis of vitamin D
- Biophilia

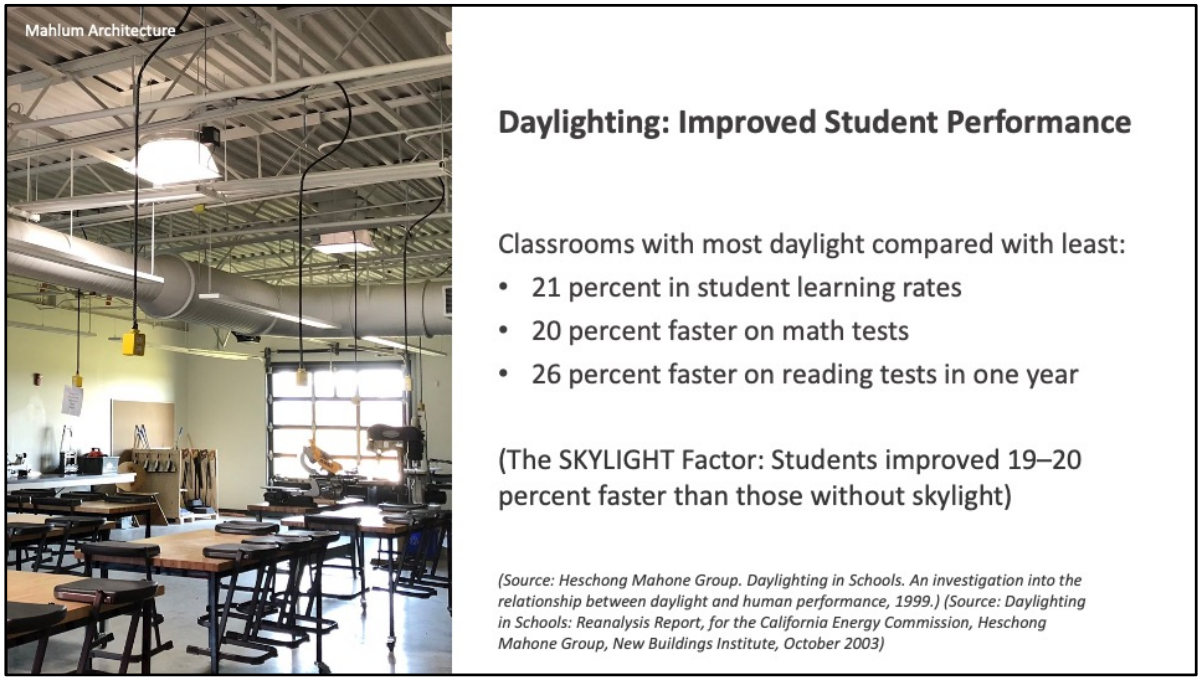
The benefits of maximizing daylight and views go far beyond energy savings.



A study of office workers concluded that a natural view is preferred over a view of man-made infrastructure. More specifically, workers appreciated information about exterior conditions—notably location, time, weather, nature, etc. Skylights and roof windows are especially effective at achieving this.

In education studies from the Heschong Mahone group, working with the Fresno School District, it was determined with "a high degree of certainty that windows in the classrooms were powerfully associated with student performance."

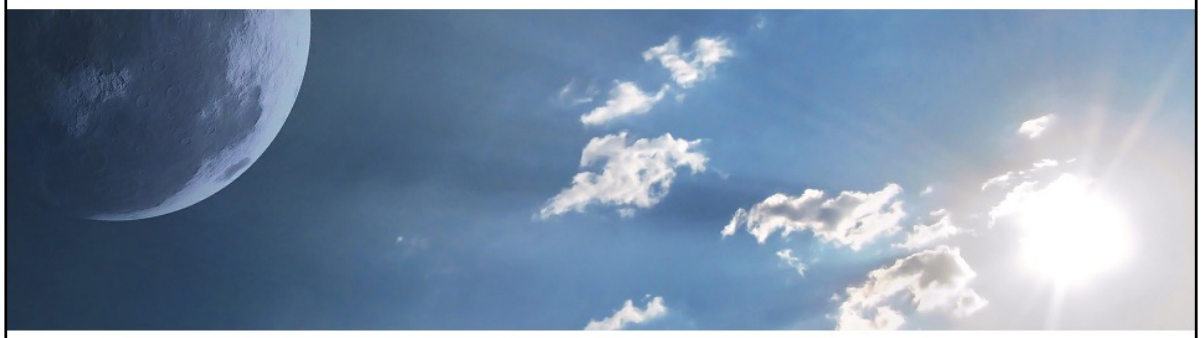
The final report lists: "An ample and pleasant view of a window, that includes vegetation or human activity and objects in the far distance, supports better outcomes and student learning." However, "direct sun penetration—particularly east or south facing—is associated with glare and has a negative impact on student learning. (Heschong, "Windows and Classrooms," 2003)



The Skylight Factor: With properly oriented skylights that allowed for the teacher to control the amount of light, students improved 19–20 percent faster than those without a skylight. In addition, the tubular daylighting devices used in this school shop (with the transition box, typically used in acoustical ceiling applications but adapted as a luminaire) balanced the contrast of the side-lighting shop door and perception of glare.

Health Impacts

All living things need darkness and quality daylight to function properly…



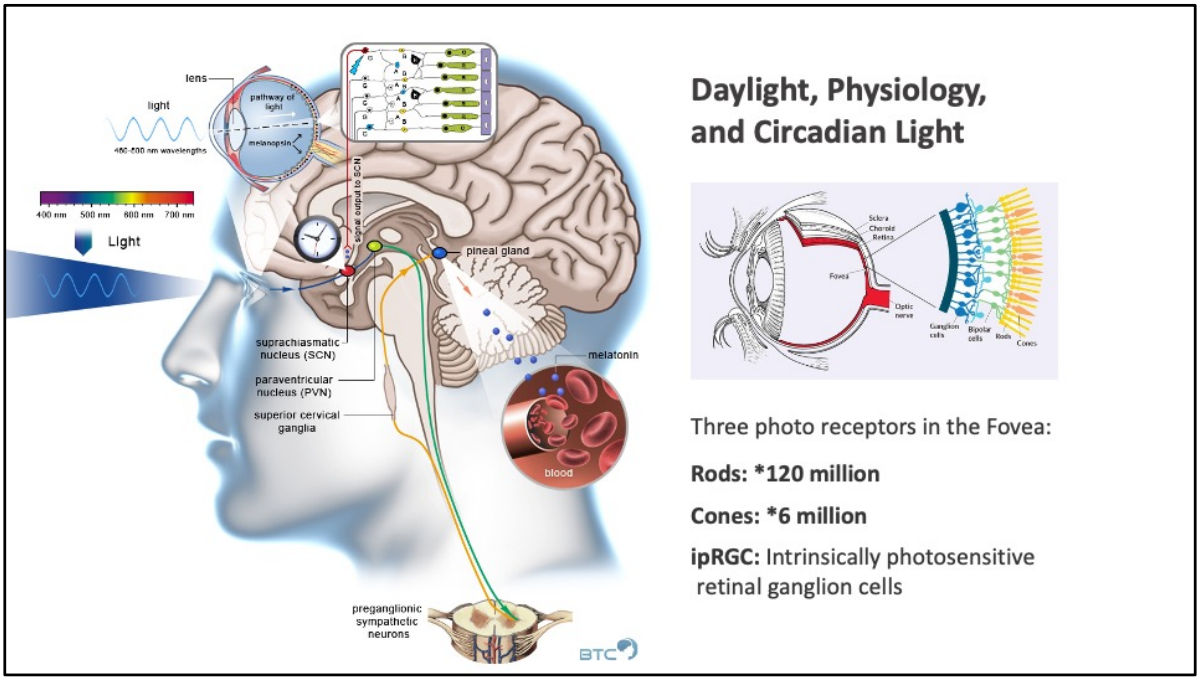
"In people, the daily cycle of light and dark produces a rhythm of hormonal cycles that are essential for proper immune response."

—Joan E. Roberts, Ph.D.. (Therapeutic Effect of Lights on Humans)

The term 'circadian rhythm' comes from the latin word '*Circa diem*' meaning approximately a day.

Circadian rhythm defines the chemical and biological changes that occur daily in people triggered by visible light and darkness, leading to a natural "rhythm" of hormonal changes.

It has become evident that all living things need a certain period of darkness and then quality daylight in order to function properly. Understanding and control of circadian rhythm is a very powerful tool in understanding and improving human health.



As much as 80 percent of our environmental perception is visual. The human body and mind are regulated by circadian rhythms. To maintain overall good health, we need appropriate light signals during the day, as well as darkness at night. For example, light in the morning helps to synchronize our biological clock and increase our alertness, paving the way for increased performance during the day. In supporting circadian health, light is considered a strong 'zeitgeber' or time keeper. (German Zeit – 'time' + Geber – 'giver').

Our vision receptors are described as tri-chromatic (unless one diagnosed with color blindness, when the color of red is not perceived) . Consequently, we can three base colors–red, green, and blue, allowing us to discern up to about a million–although the communication of color can be subjective.

Daylight, Physiology, and Circadian Light

The discovery of the ipRGC photoreceptor began in 1923 by a geneticist Clyde E. Keeler who observed that the pupils in the eyes of blind mice still responded to light.

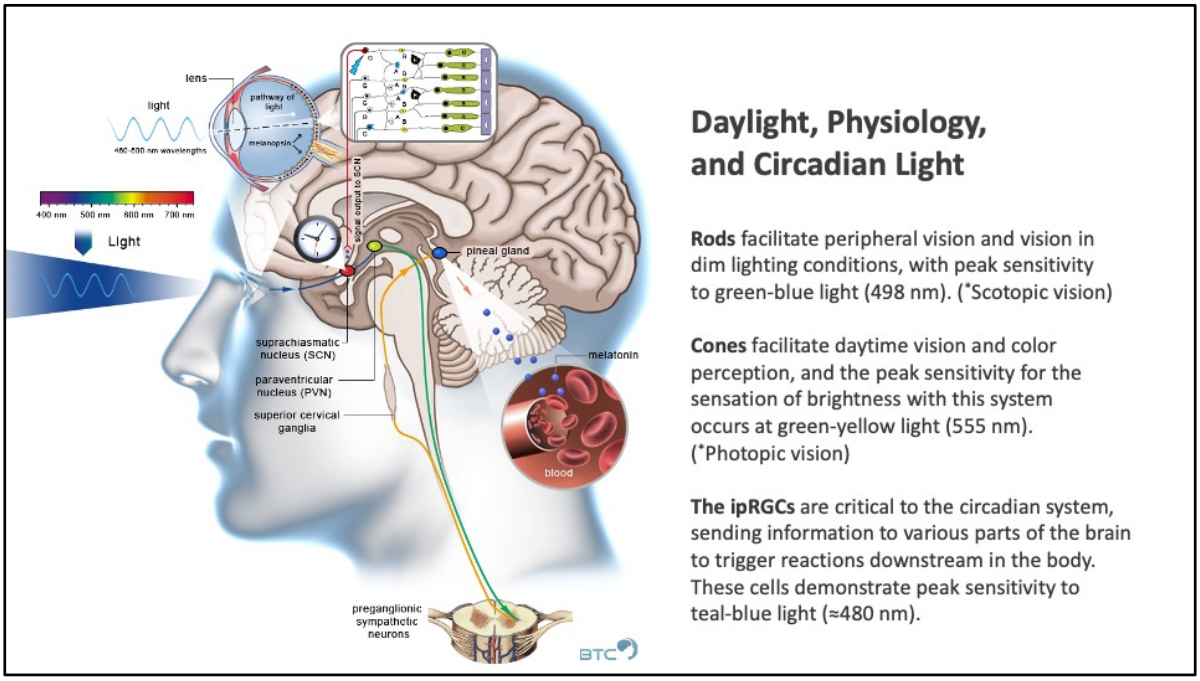
In the 1980s, again rod- and cone-deficient mice exhibited photoentrainment.

In 2002, the photoreceptors were identified by Samer Hatter and colleagues to be melanopsin expressing ganglion cells, responsive to light but non-visionary.

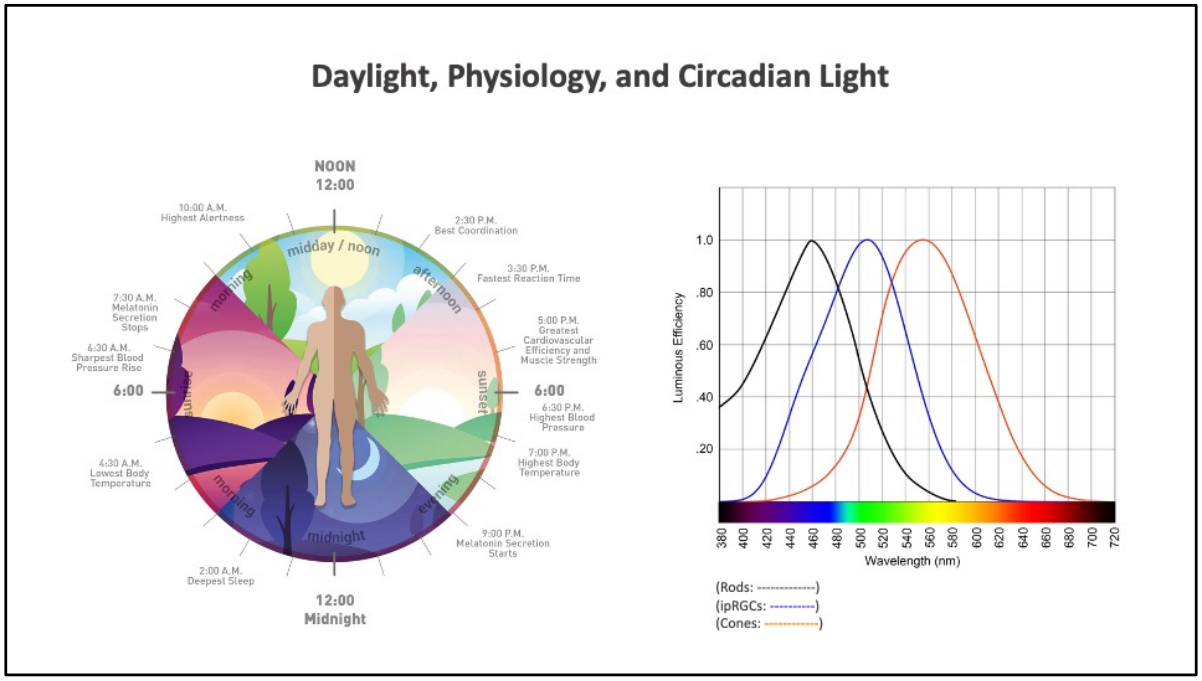
In 2003, another group of scientists further identified the vitro spectral sensitivity range most associated with melanopic response: 480 nm.

The discovery of the *intrinsically photosensitive retinal ganglion cell (ipRGC) has changed our understand of light and daylight on our lives. In 2007, the studies involved humans who had degenerative visionary loss. (https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0017860)

*Provencio and Foster, 1995; Provencio et al., 1998; Brainard et al., 2001; Thapan et al., 2001; Berson et al., 2002; Panda et al., 2002; Dacy et al., 2005; Guler et al., 2008; Hughes et al., 2016 (The studies continue, as there is still much to learn.)

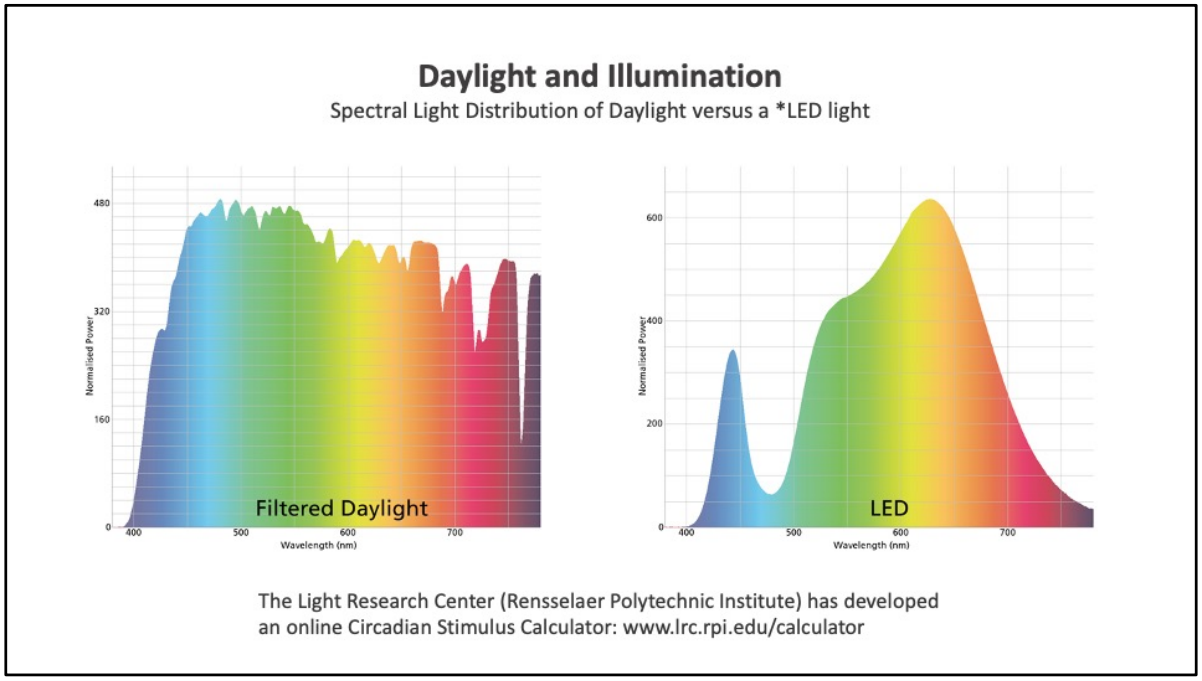


The amazing process of light entrainment, begins in the back of the fovea, where the ipRGC's respond to light (particularly in the blue 460–480 nm range), signaling the suprachiasmatic nucleus (SCN) through the optic nerve. The superchiasmatic nucleus is located near the base of the of the brain in the hypothalamus, connecting your nervous system to your endocrine system. It signals the pineal gland in response to daylight, to turn off melanopsin. In the presence of light, it also signals the body to raise temperature, heart rate and blood pressure. (In the presence of darkness, the process is reversed.)



Early in the morning, there is the greatest rise in blood pressure, our memory, concentration rise– and mid morning, is the period of greatest alertness. Coordination peaks in the early afternoon and early evening, we experience the warmest temperatures. Once the daylight transitions to night, melatonin secretion is no longer suppressed.

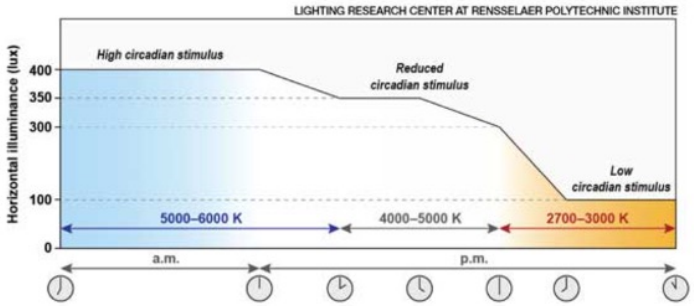
The graph illustrates the light spectrum and peak vision of rods, ipRGCs, and cones.



Review of the spectral distribution and critical portions of the light spectrum. With the emerging technologies of tunable LED lights, it remains important to understand not just the color of light but also the actual spectral radiance. Note the LED, while exhibiting all colors within the visual spectrum, greatly drops within the blue (480 nm range).

Source: Circadian Stimulus Calculator

Daylight and Illumination

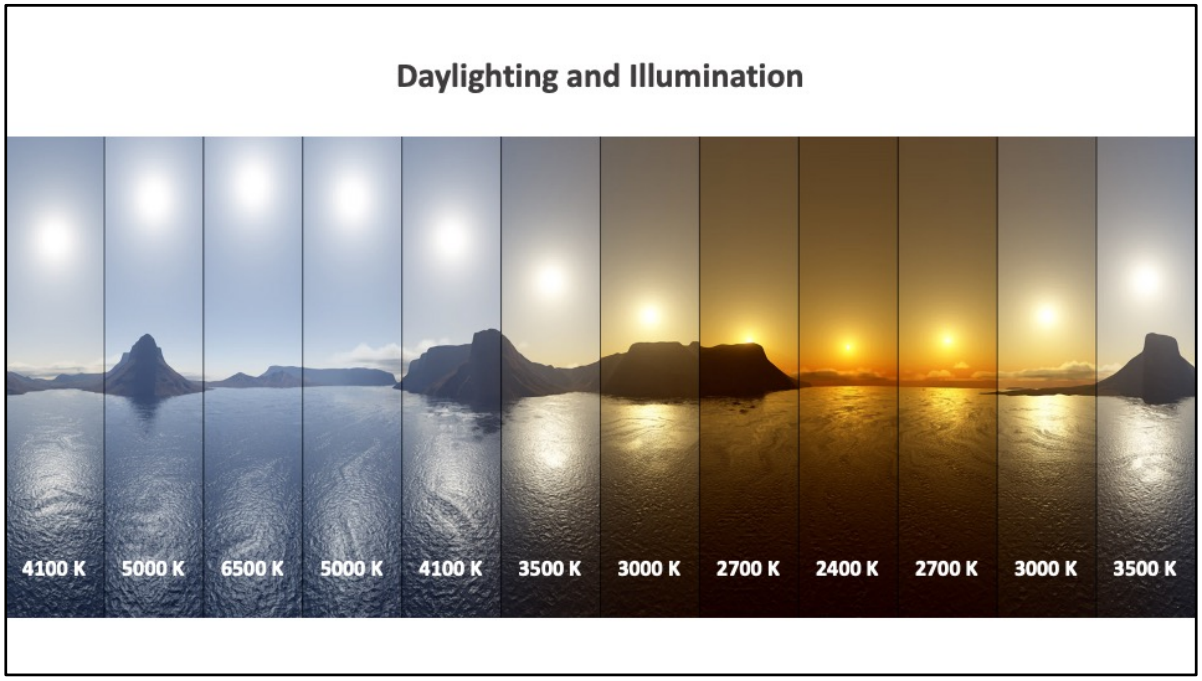


Source: LDL, Seattle

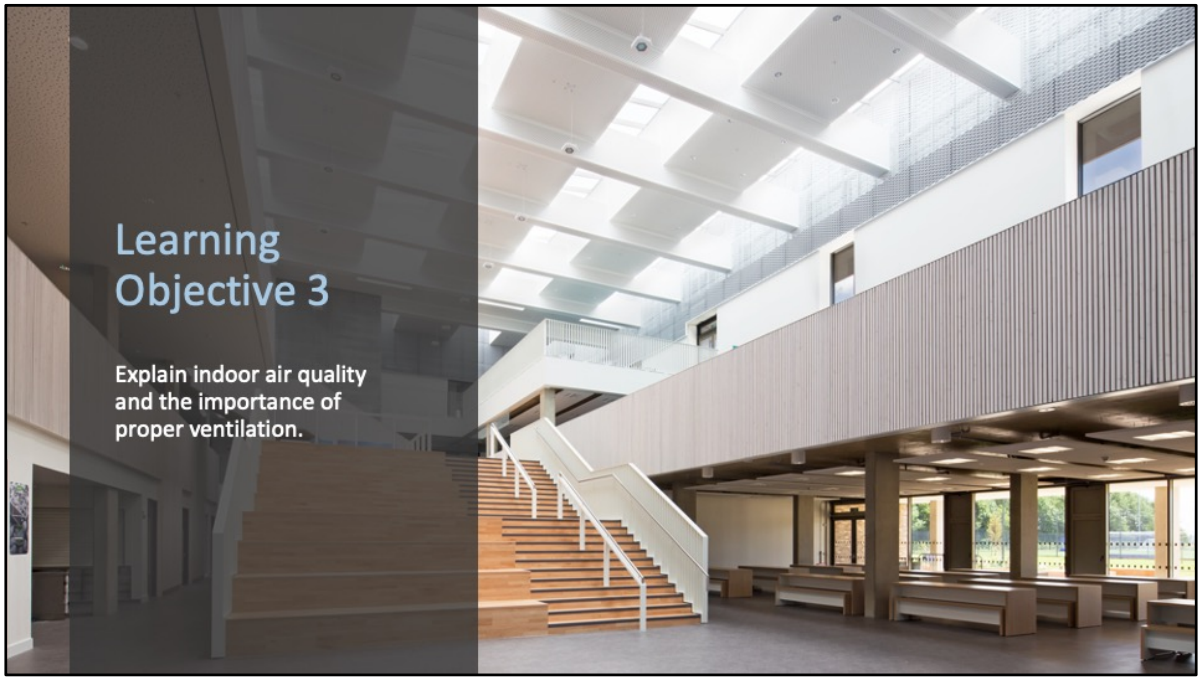
- Spectral distribution
- CCT (Kelvin Temperature)
- Dimming
- Stimulus intensity
- Stimulus duration
- Stimulus timing
- Lighting controls

Color and spectral distribution are an important consideration when addressing lighting controls.

(What does CCT mean? Correlated color temperature. Color temperature defines the color appearance of a white LED. CCT is defined in degrees Kelvin; a warm light is around 2700K, moving to neutral white at around 4000K, and to cool white, at 5000K or more.



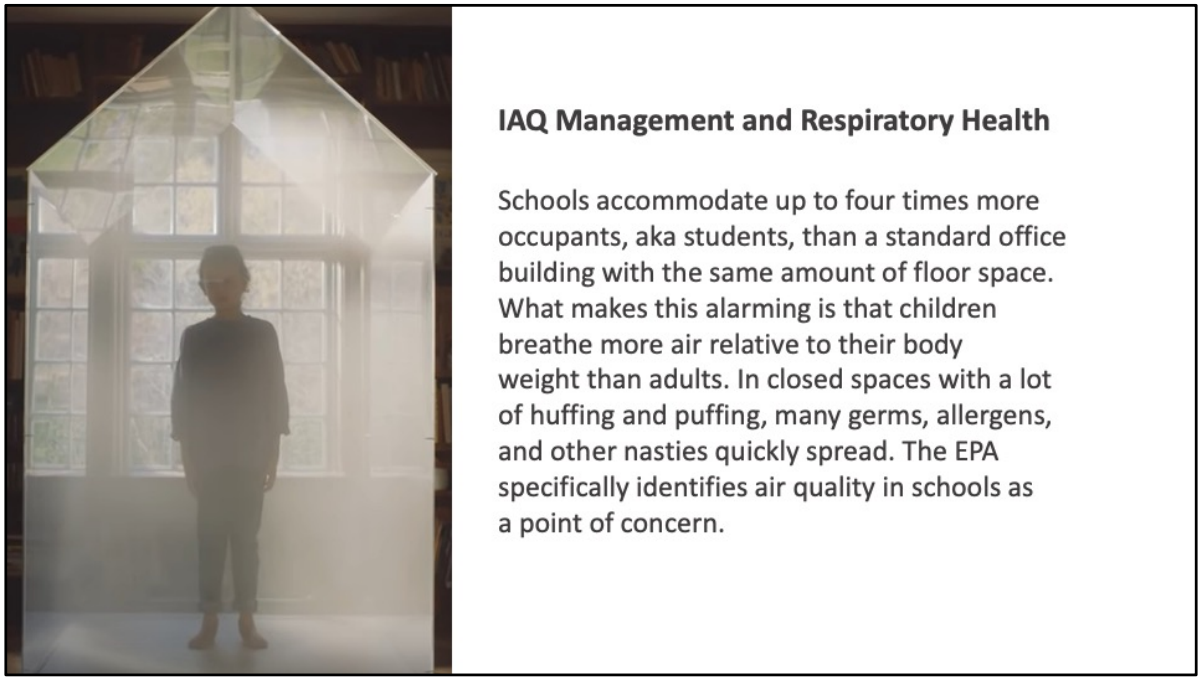
So why is this information relevant to a school and integrated lighting? The dynamic nature of daylight changing throughout daylight hours? Successful daylighting involves the harmony of electrical light with lighting controls.


Learning
Objective 3
Explain indoor air quality
and the importance of
proper ventilation.

Indoor Air Quality: Ventilation

A survey done by the EPA suggests that more than 40,000 schools across the United States—nearly half of which are public schools—have poor indoor air quality (IAQ). They further found that as of 2016, one in every 13 children suffered from asthma, which is the leading cause of school absenteeism.

There are several key concerns when it comes to indoor air quality and health in schools, but most important is the direct relationship between carbon dioxide (CO_2) levels and human cognition and brain function. A study completed by Joseph G. Allen, et al. from Harvard showed that occupants in ventilated spaces with low CO_2 and low volatile organic compounds had improved scores in crisis response, information usage and strategy ranging from 100 to 300 percent (Allen et al., 2016).

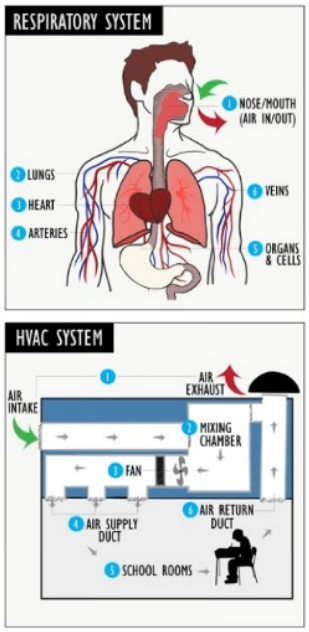


In contrast, excess CO_2 can slow student cognitive function so they are less attentive with memory and concentration levels going down significantly (Bakó-Biró, et al., 2007). (Additionally, studies have shown that students in poorly ventilated spaces have 50 to 70 percent more respiratory illnesses.)

Chronic exposure to indoor air pollution, mold and pesticides can converge to become a major factor in developing asthma, coughing, eye irritation, headaches and severe allergic reactions.

(CO_2 sensors in classrooms can allow teachers to adjust the level of ventilation accordingly.)

Resource: https://www.epa.gov/iaq-schools



IAQ Management and Respiratory Health

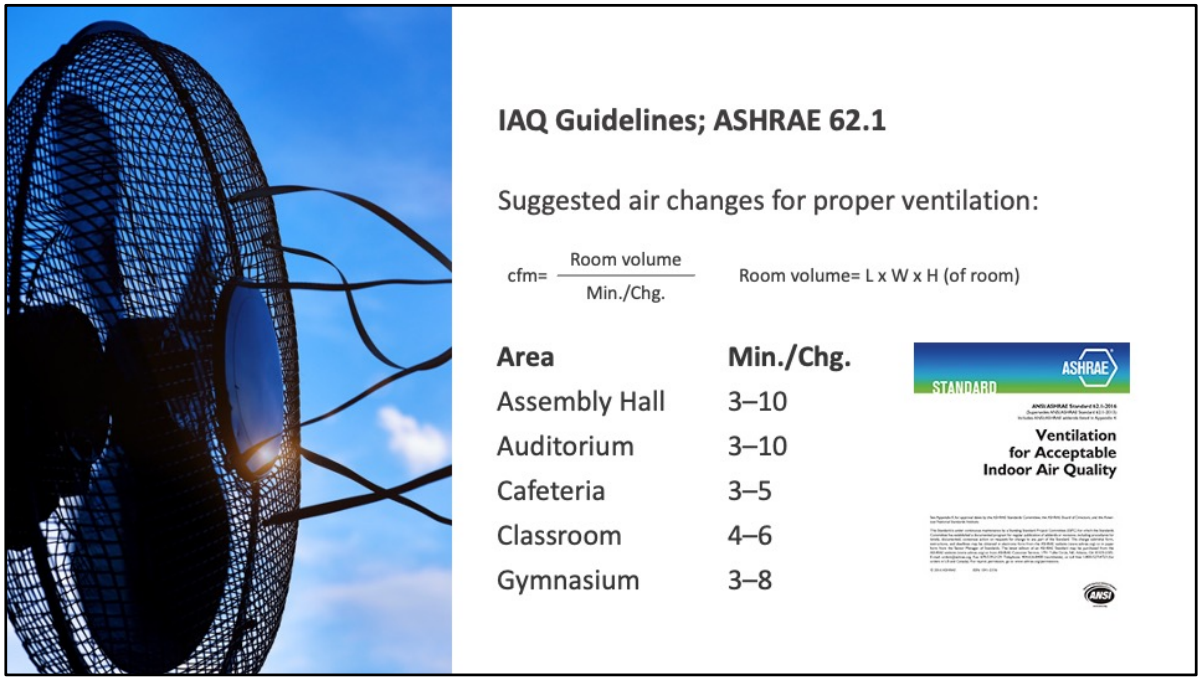
IAQ Management includes:

- Control of indoor air pollutants
- Ventilation and filtration
- Maintenance of acceptable temperature and relative humidity

Ventilation brings in outside air and exhausts building air, which dilutes the concentration of indoor pollutants. IAQ management practices also can help reduce the spread of viruses and other infectious diseases.

ASHRAE, a global professional society that sets standards for building performance, specifies a minimum ventilation rate for classrooms of 15 cubic feet per minute per person. In California, the 2016 Building Energy Efficiency Standards, also known as Title 24, have the same ventilation requirement for classrooms.

There is evidence that occupants of buildings with higher ventilation rates, particularly occupants of schools with higher ventilation rates, have lower rates of absence.



Air changes per hr (ACH / ACPH) simply describes how many times the quantity of air in a room (or structure) is completely replaced per hour.

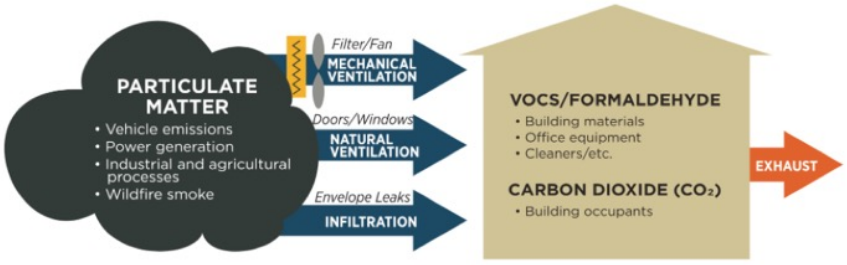
If you have a 10-foot x 10-foot x 10-foot room, the room contains 1,000 cubic feet of air. If the supply and return to the room is supplying a balanced 100 cubic feet per minute (cfm) of air to the room, you would have 100 cfm x 60 minutes = 6,000 cubic feet per hour (cfh), which would equal six air changes per hour (6,000/1,000 = 6).

Different spaces have different ventilation requirements based on occupancy level (how many people are in the room) and use type. This is a fairly simple thing to calculate based on the cubic feet of air in a room, **this is NOT the heat gain /loss of the space,** it is only the ventilation rate of the space. Generally, ACH is used as a guideline or reference for design and not as a basis for the design, a sort of solid rule of thumb used to check a ventilation design against the real world.

This ventilation rate also shouldn't be confused with the outdoor air requirements which is a different, but related consideration and is based on ASHRAE 62.1.

IAQ – Monitoring Matrix

ASHRAE, a global professional society that sets standards for building performance, specifies a minimum ventilation rate for classrooms of 15 cubic feet per minute per person.

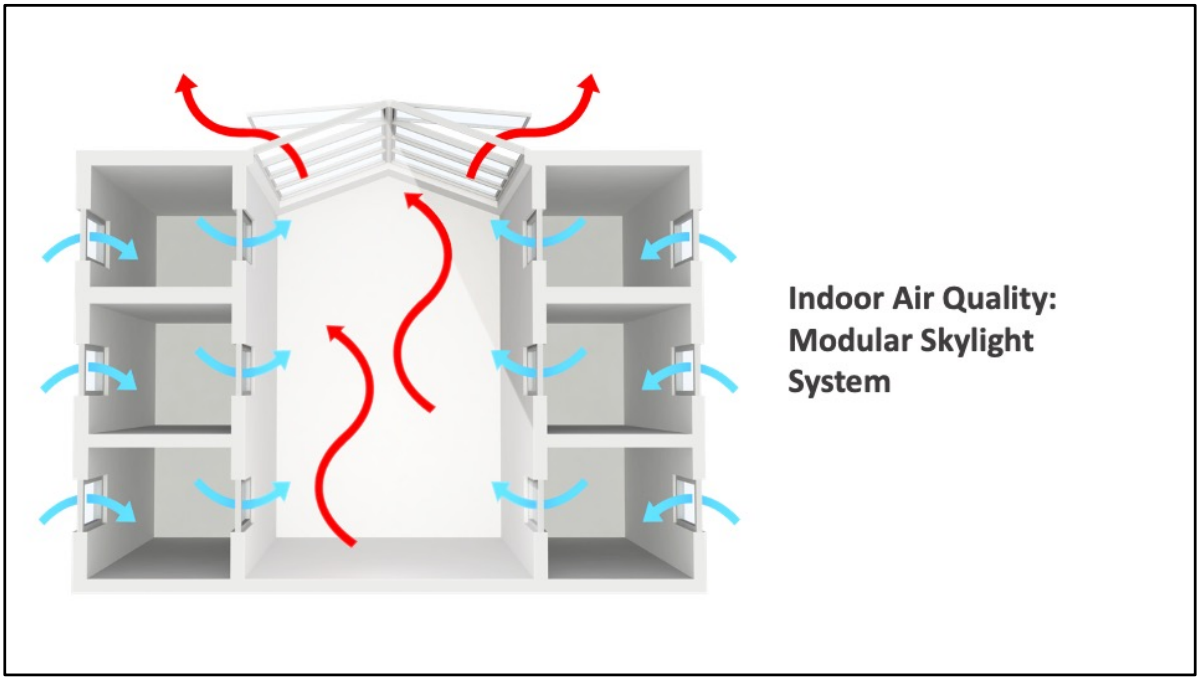


- Carbon dioxide (CO_2) 600 ppm
- Volatile organic compounds
- Particulate matter 2.5
- Radon
- Carbon monoxide
- Thermal/humidity

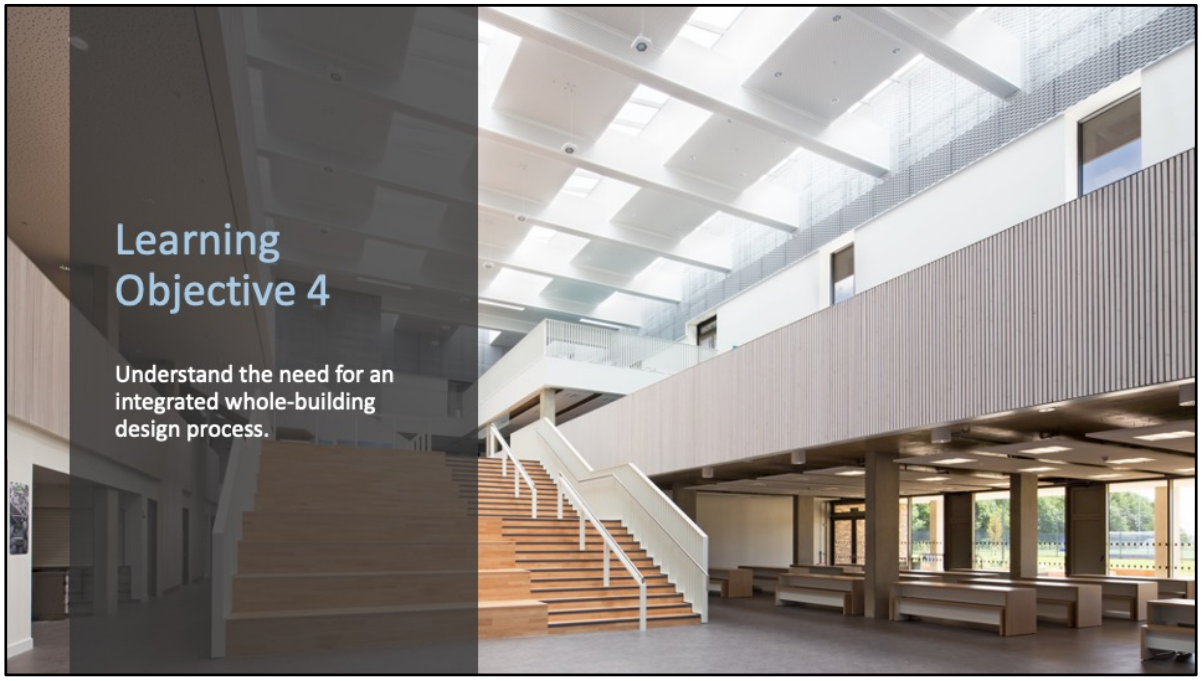
IAQ sensors should be placed in each room, monitoring CO_2, VOCs, ppm 2.5, along with temperature and humidity.

(CO_2 sensors in classrooms can allow teachers to adjust the level of ventilation accordingly.)

Resource: https://www.epa.gov/iaq-schools)



Passive ventilation systems with windows and skylight systems can both improve the air exchange, supporting healthy learning environments.



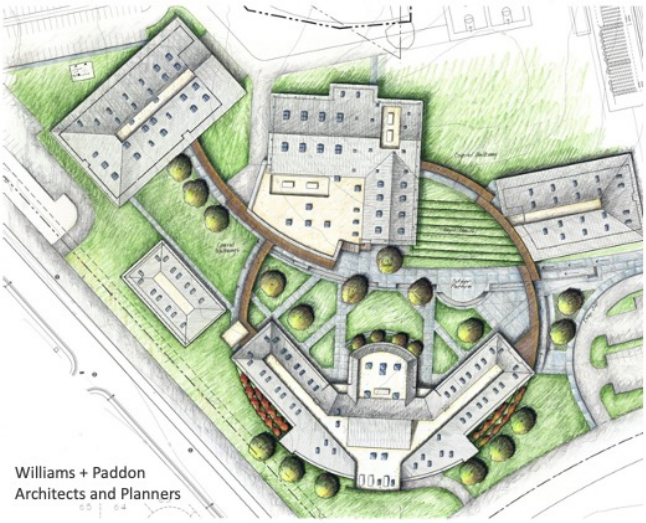
The planning and development of a high-performance school considers regional and site-specific possibilities and challenges for each project. Similar to LEED and sustainability standards, site, water, energy, indoor environmental quality, and commissioning must be considered.

Integrated Design: Site Considerations

A key factor in site design is orientation of the building, which can influence passive heating, natural ventilation, and optimize daylighting.

"A key factor in site design is orientation of the building, which can influence passive heating, natural ventilation, and daylighting. Optimal orientation can reduce year-round heating and cooling costs and optimizes natural lighting. If possible orient buildings so that the majority of windows face either north or south. Strategic placement of vegetation can be used when this orientation cannot be utilized." —Frank Cunha III

Source: https://ilovemyarchitect.com/high-performance-school

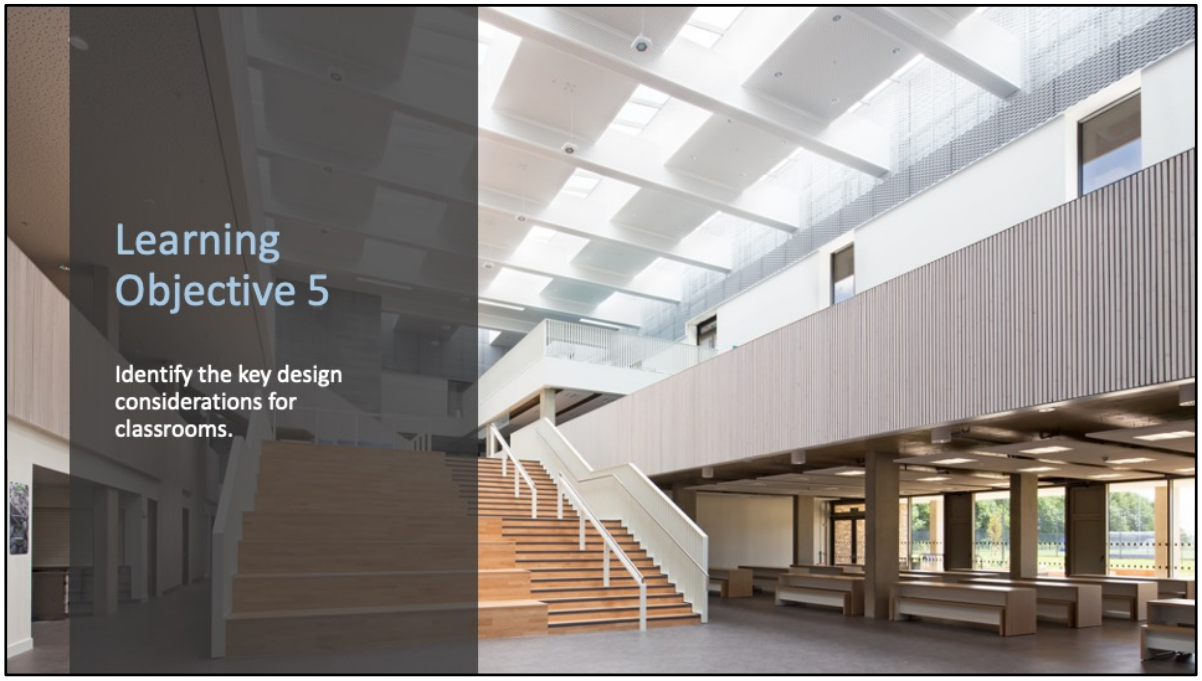


Building Orientation: Elongate East - West

- Organize around north skylight
- Use fixed exterior shading on the south windows
- Use west orientation sparingly
- Avoid east facing when possible
- Maximize diffuse north light
- Minimize solar heat gain
- Minimize glare

Source: LDL, Seattle

The proper siting of buildings contributes to maximizing daylighting potential and controlling acoustics. In addition, understand primary wind directions can support passive air ventilation improving indoor air quality.



Now we will focus in the classroom.

Classroom Study

Their ground-breaking study, the HEAD Project (Holistic Evidence and Design), concluded that differences in the physical characteristics of classrooms explained 16 percent of the variation in learning progress over a year for the 3,766 students included in the study.

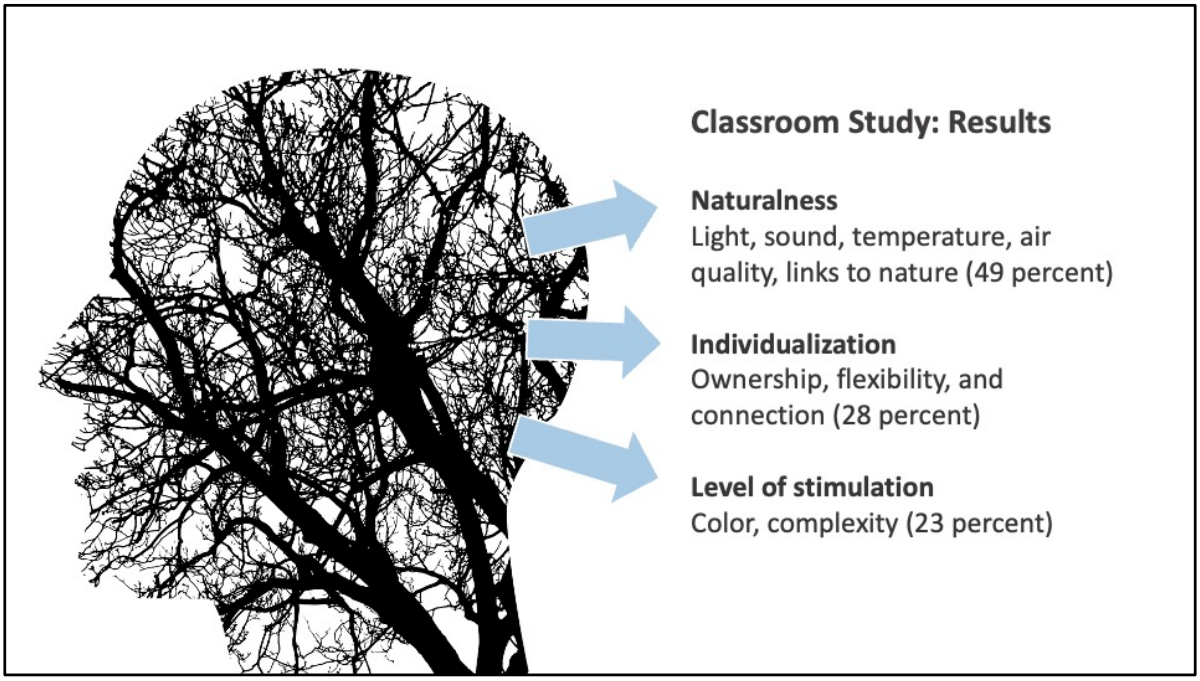
Put simply, the better designed the classroom, the better children do academically.

In 2015, a research study conducted by Professor Peter Barrett and his team of school design experts at the University of Salford, UK, showed clear evidence that well-designed primary schools can substantially boost children's academic performance in reading, writing and mathematics.

For three years, researchers on the HEAD project carried out detailed surveys of 153 classrooms from 27 diverse schools and collected performance statistics for pupils studying in those spaces.

Their ground-breaking study concluded that differences in the physical characteristics of classrooms explained 16 percent of the variation in learning progress over a year for the 3766 students included in the study.

Put simply, the better designed the classroom, the better children do academically.

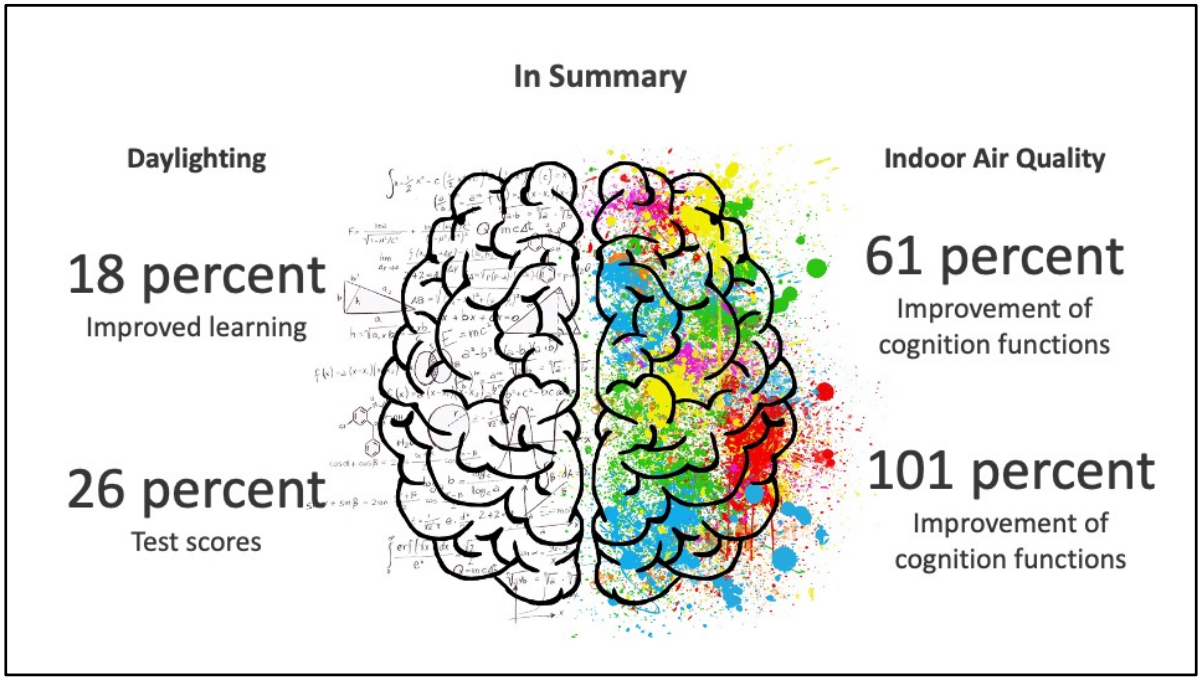


This is the first time that clear evidence of the effect on users of the overall design of the physical learning space has been isolated in real life situations.

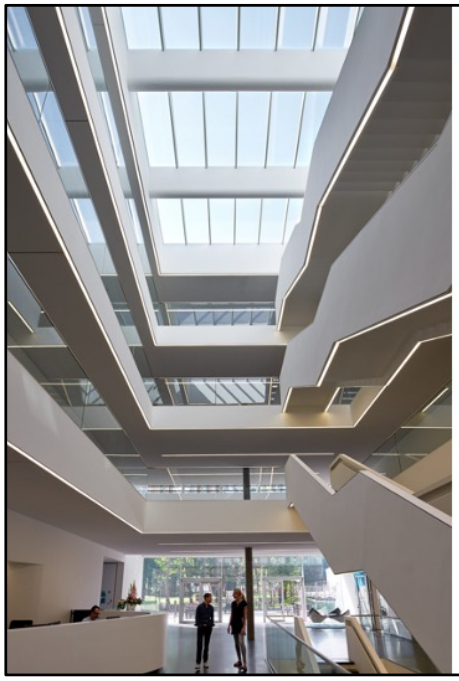
In the past, specific aspects such as air quality or daylighting have been studied, but how it all comes together for real people in real spaces has, until now, been based on gut-feeling and wishful thinking.

Daylighting marked an 18 percent increase in improved learning and air quality showed a 61 percent increase in improvement of cognitive functions.

Natural light is known to regulate sleep/wake cycles.



The evidence of improved student performance with increased ventilation rate up to approximately 15 cfm (7.1 L/s) per person is compelling. Performance improvements with higher ventilation rates ranged from a few percent to more than 15 percent.



Building Characteristics and Challenges

- Single story/multistory
- Campus format
- Varying requirements:
  - Gathering and atrium spaces
  - Classrooms
  - Gymnasiums
  - Auditoriums
  - Cafeteria
  - Libraries
  - Corridors/circulation
- Inspiring design ideals
- Abundant budgets

Accommodating the activities of learning are many and varied. The higher the grade level, typically the more complex the activity and built environment is required.

The Daylighting Pattern Guide is a free, interactive tool that helps design teams incorporate proven daylighting strategies into commercial building projects for substantial reductions in lighting power consumption and overall building energy use, developed in collaboration with the University of Washington, University of Idaho and the College of Built Environments at the University of Oregon.

It is a visual and interactive platform equally useful to both those with and without experience in daylighting and lighting design practices.

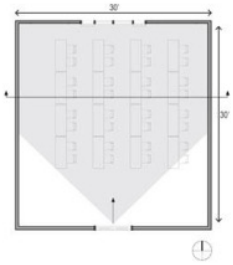
While we are focusing on the school environment, the site also includes offices, libraries, museums, industrial facilities and recreational facilities.

https://newbuildings.org/resource/daylighting-pattern-guide

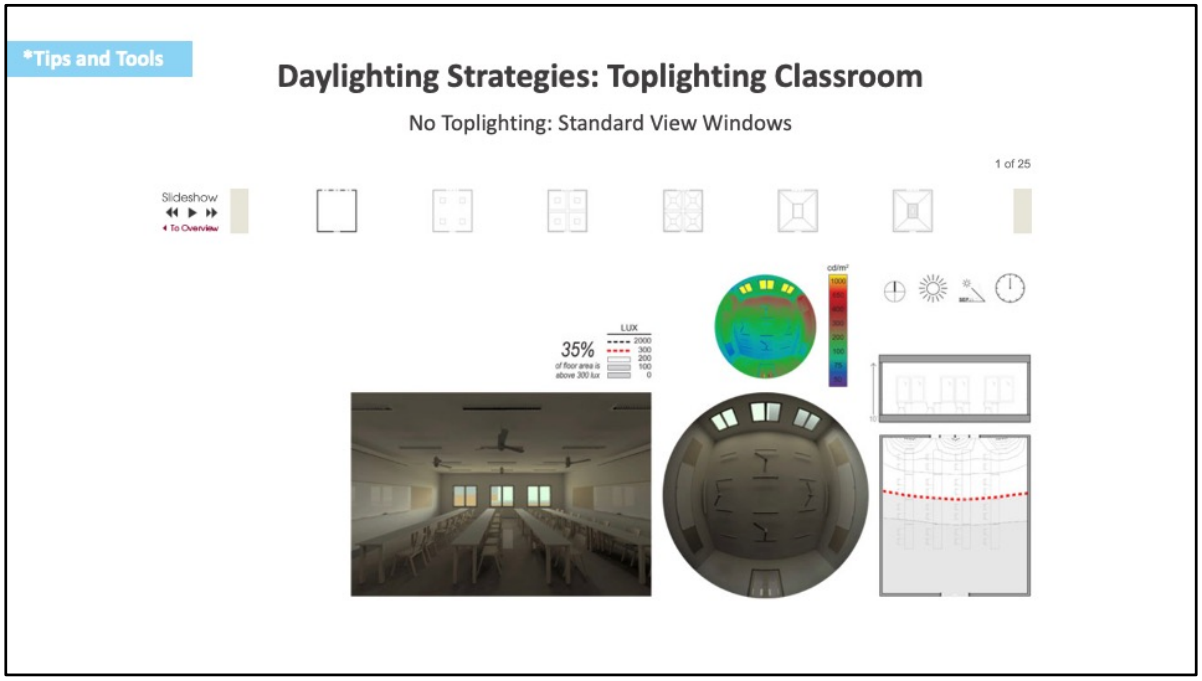
*Tips and Tools

Daylighting Strategies: Toplighting Classroom

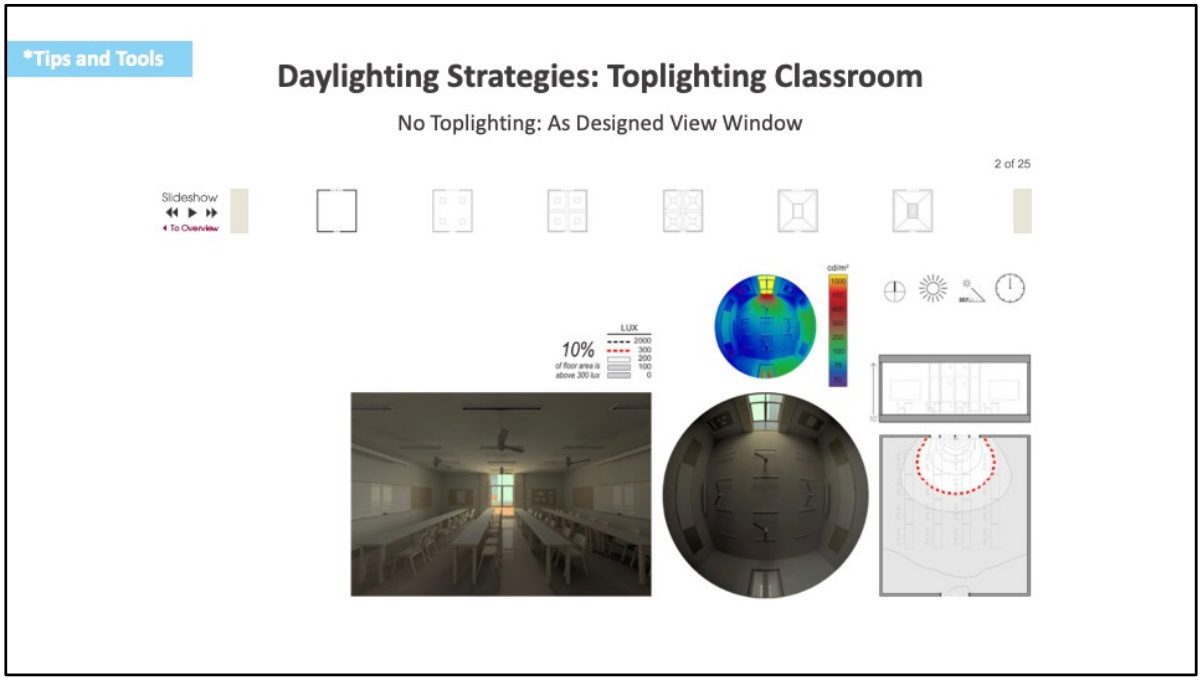
Slideshow
PLAY



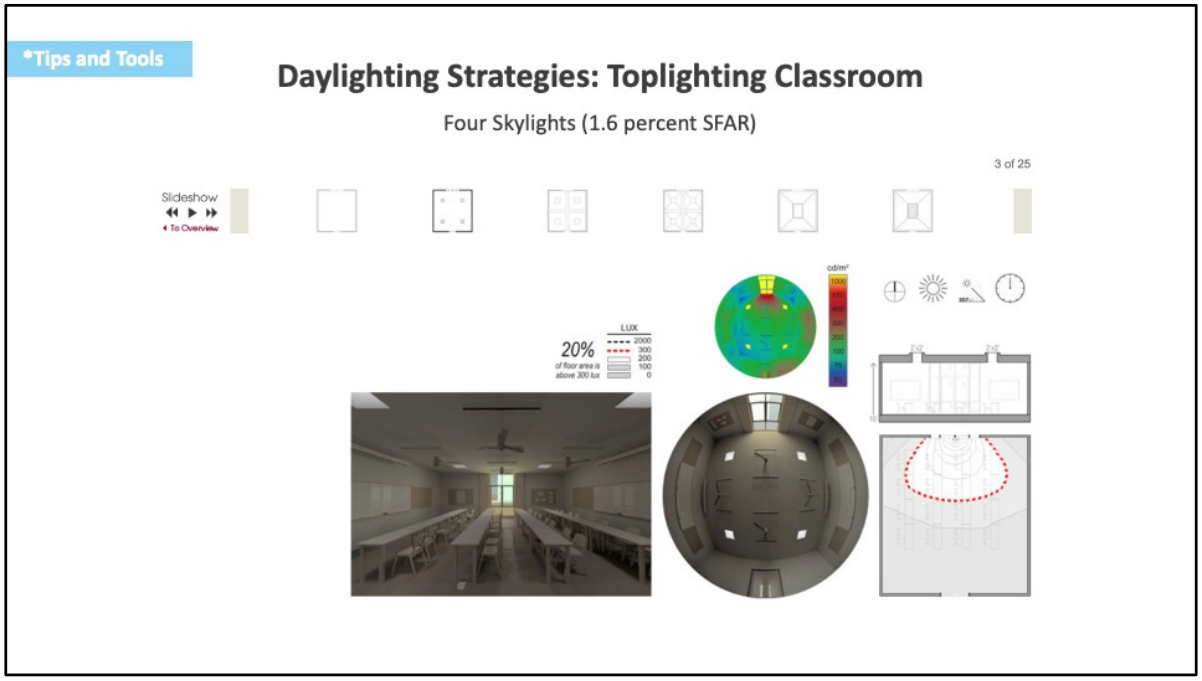
Mount Angel Abbey | St. Benedict, OR | SRG Partnership



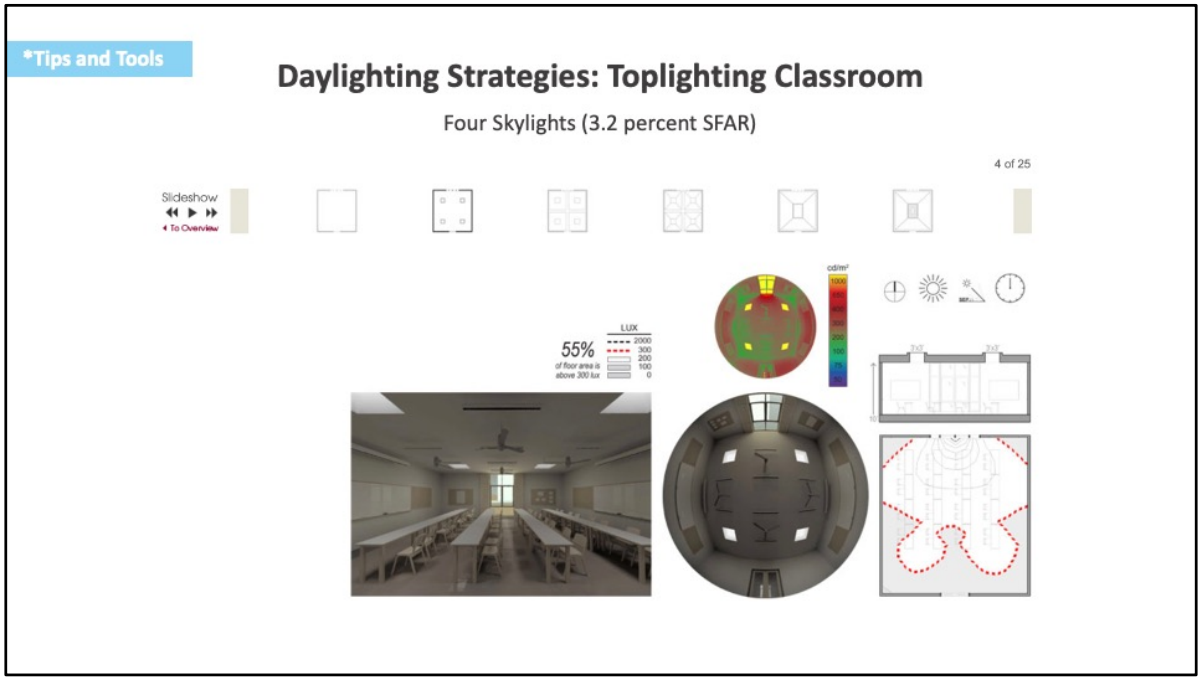
These data represent a common classroom design with three standard view windows along one facade. The floor area above 300 lux is 35 percent.



These data represent the single view window present within the as designed condition without any toplighting. The floor area above 300 lux is 10 percent.



These data represent a single view window with four skylights (2 feet x 2 feet) translucent (light diffusing) skylights with a 50 percent visible light transmission (Tvis) representing 1.6 percent of the floor area. The ceiling is 10 feet tall. The floor area above 300 lux is 20 percent.



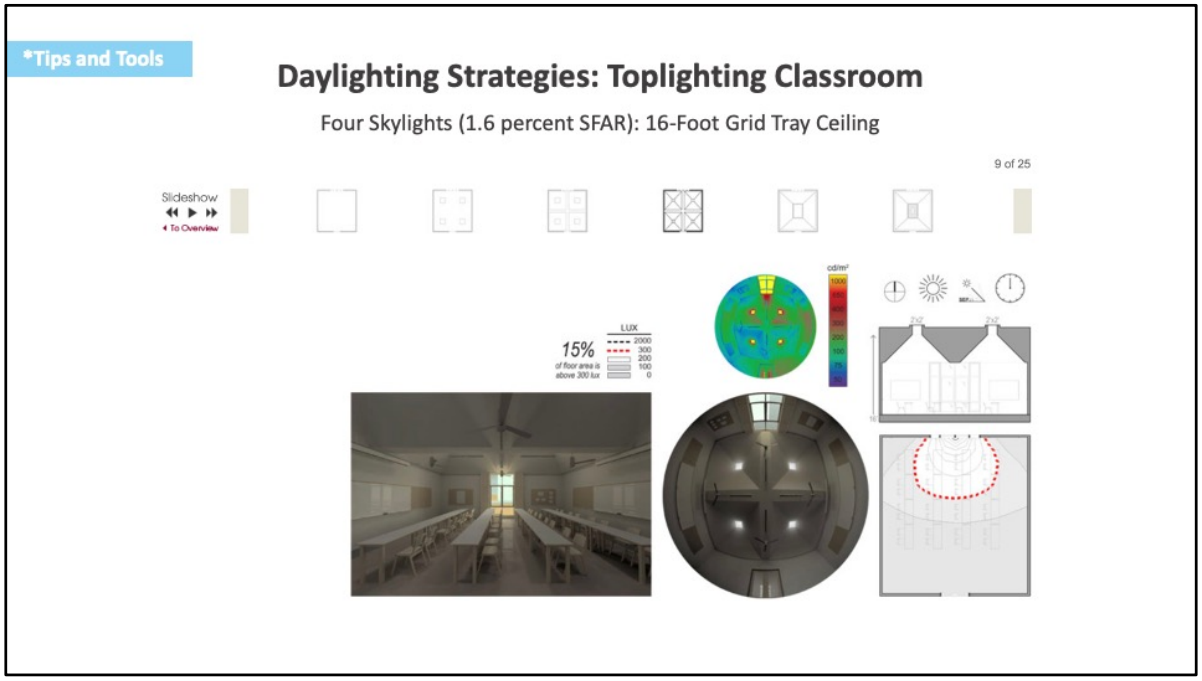
These data represent a single view window with four skylights (3 feet x 3 feet) representing 3.2 percent of the floor area. The ceiling is 10 feet tall. The floor area above 300 lux is 55 percent.

These data represent a single view window with four skylights (4 feet x 4 feet) representing 6.4 percent of the floor area. The ceiling is 10 feet tall. The floor area above 300 lux is 100 percent.

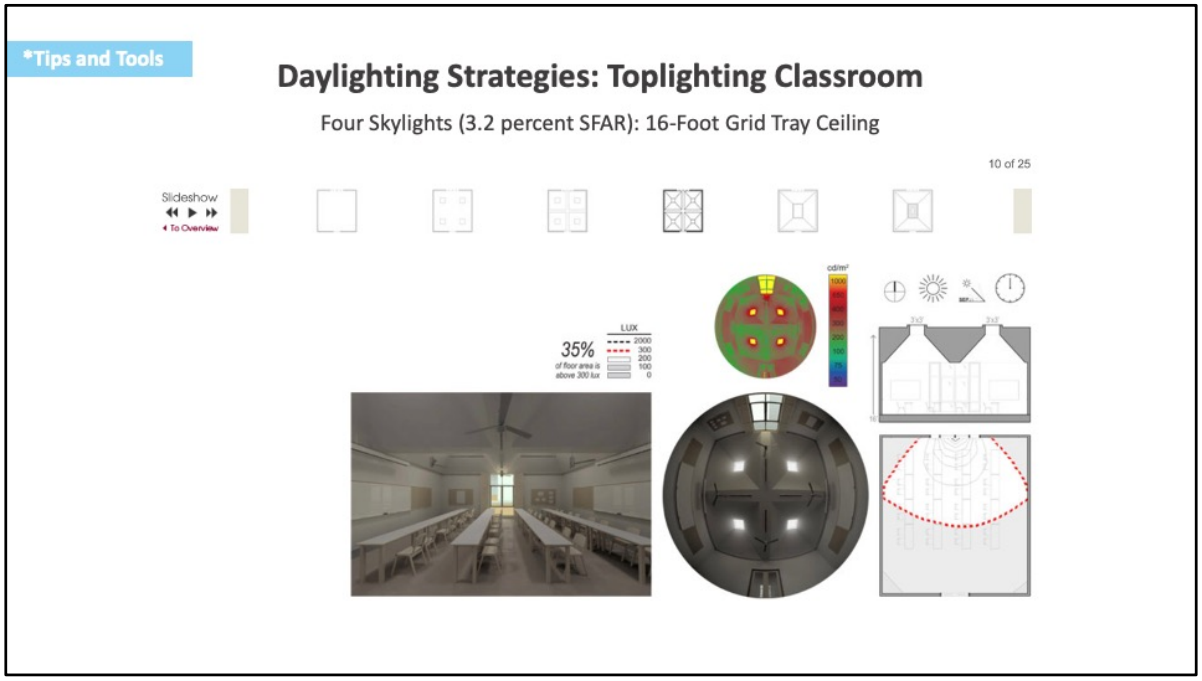
These data represent a single view window with four skylights (2 feet x 2 feet) representing 1.6 percent of the floor area, set within a 16-foot-tall cruciform ceiling grid. The floor area above 300 lux is 15 percent.

These data represent a single view window with four moderately sized skylights (3 feet x 3 feet) representing 3.2 percent of the floor area, set within a 16-foot-tall cruciform ceiling grid. The floor area above 300 lux is 25 percent.

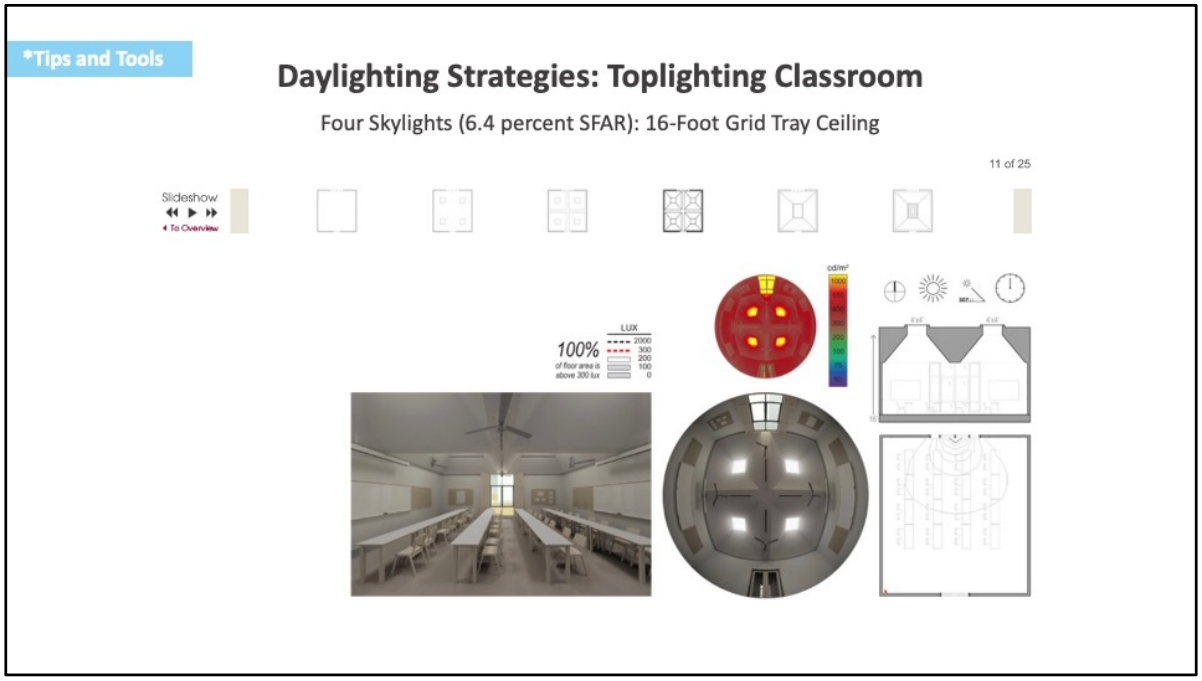
These data represent a single view window with four generously sized skylights (4 feet x 4 feet) representing 6.4 percent of the floor area, set within a 16-foot-tall cruciform ceiling grid. The floor area above 300 lux is 90 percent.



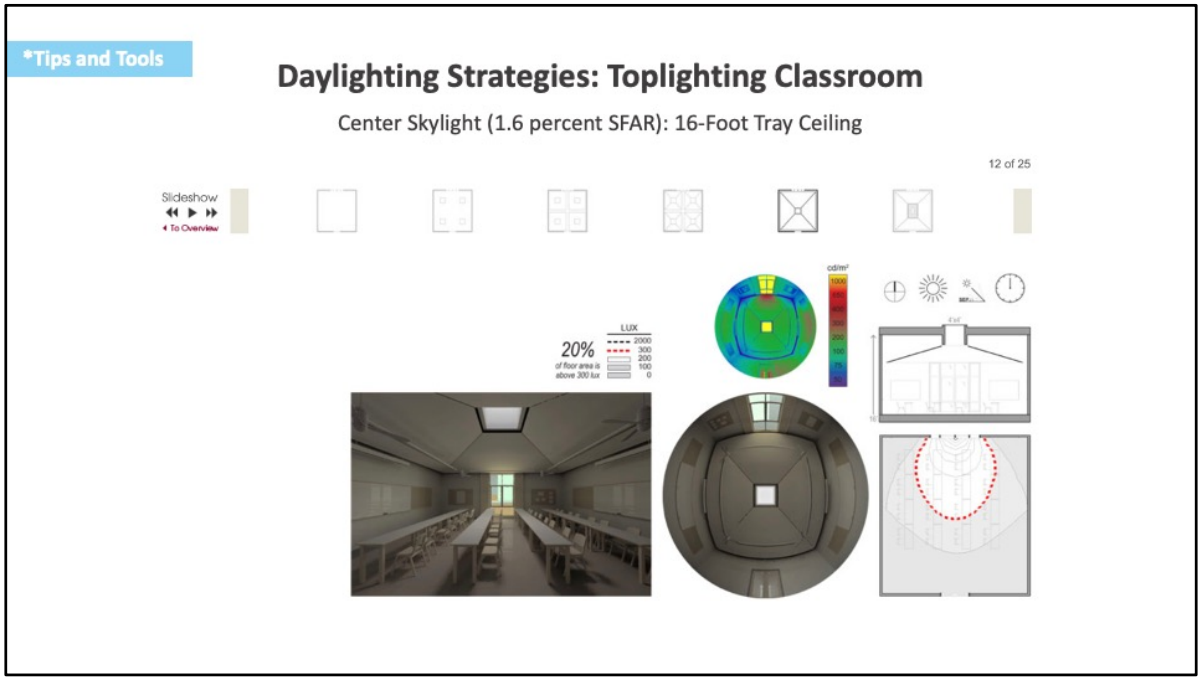
These data represent a single view window with four skylights (2 feet x 2 feet) representing 1.6 percent of the floor area, set within a 16-foot-tall cruciform ceiling grid with sloping T-bar trays. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The floor area above 300 lux is 15 percent.



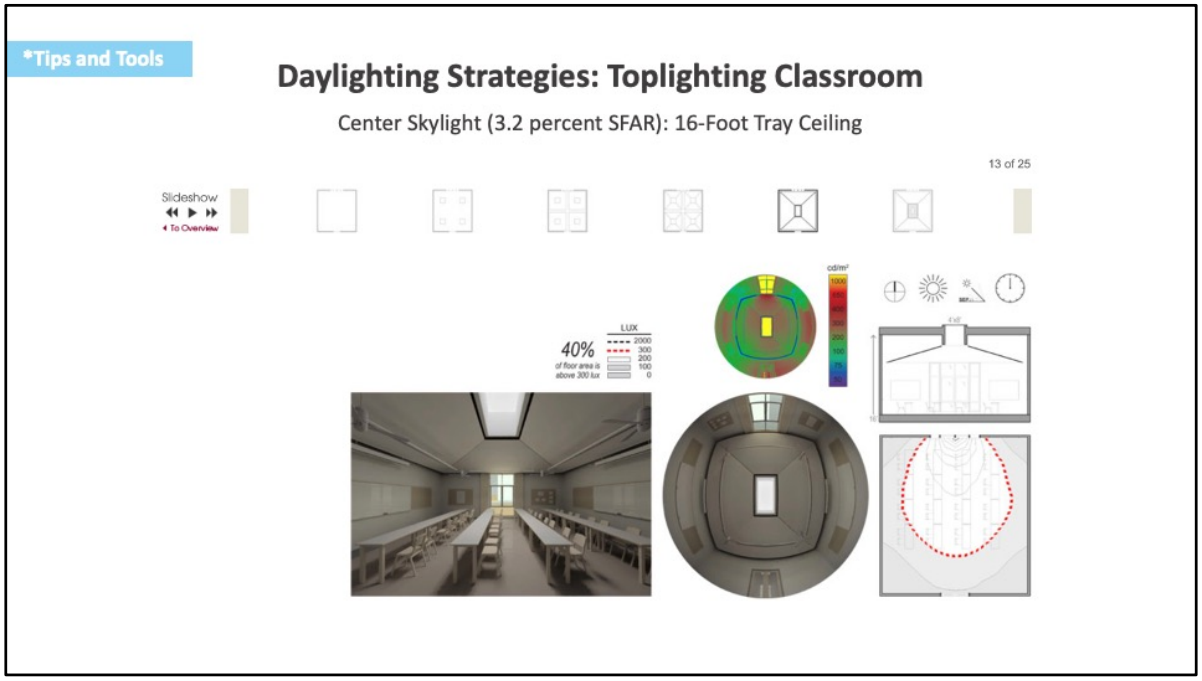
These data represent a single view window with four skylights (3 feet x 3 feet) representing 3.2 percent of the floor area, set within a 16-foot-tall cruciform ceiling grid with sloping T-bar trays. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The floor area above 300 lux is 35 percent.



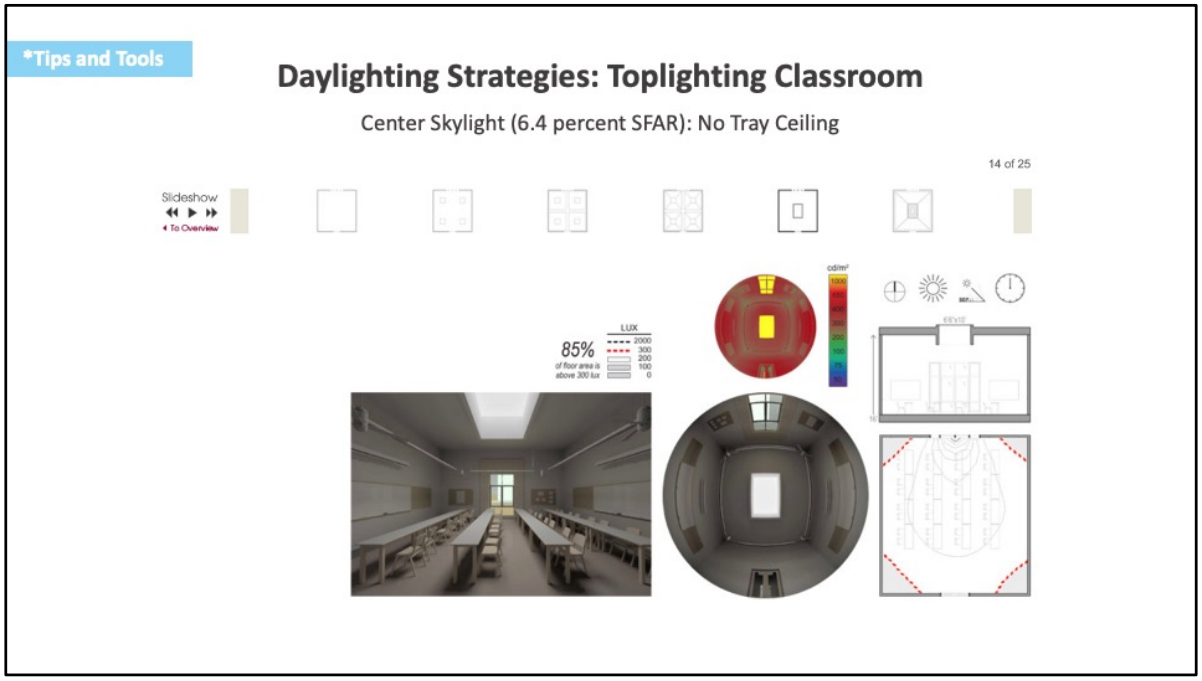
These data represent a single view window with four skylights (4 feet x 4 feet) representing 6.4 percent of the floor area, set within a 16-foot-tall cruciform ceiling grid with sloping T-bar trays. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The floor area above 300 lux is 100 percent.



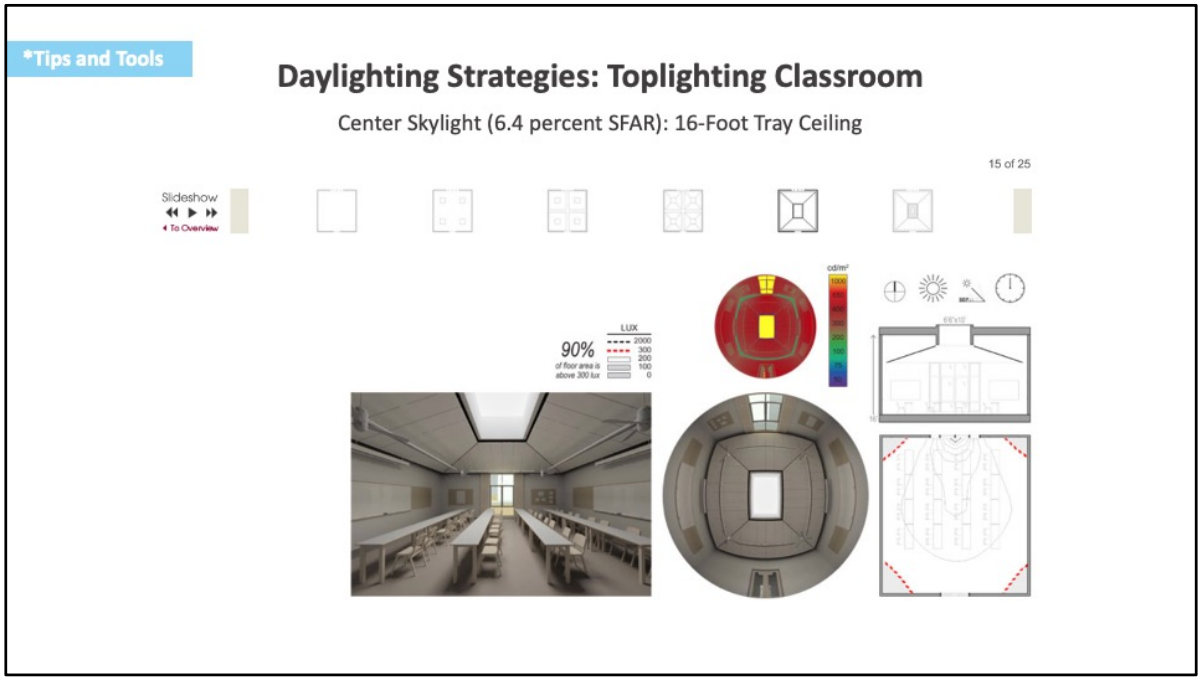
These data represent a single view window with a single skylight (4 feet x 4 feet) representing 1.6 percent of the floor area, set within a 16-foot-tall ceiling with sloping T-bar trays. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The floor area above 300 lux is 20 percent.



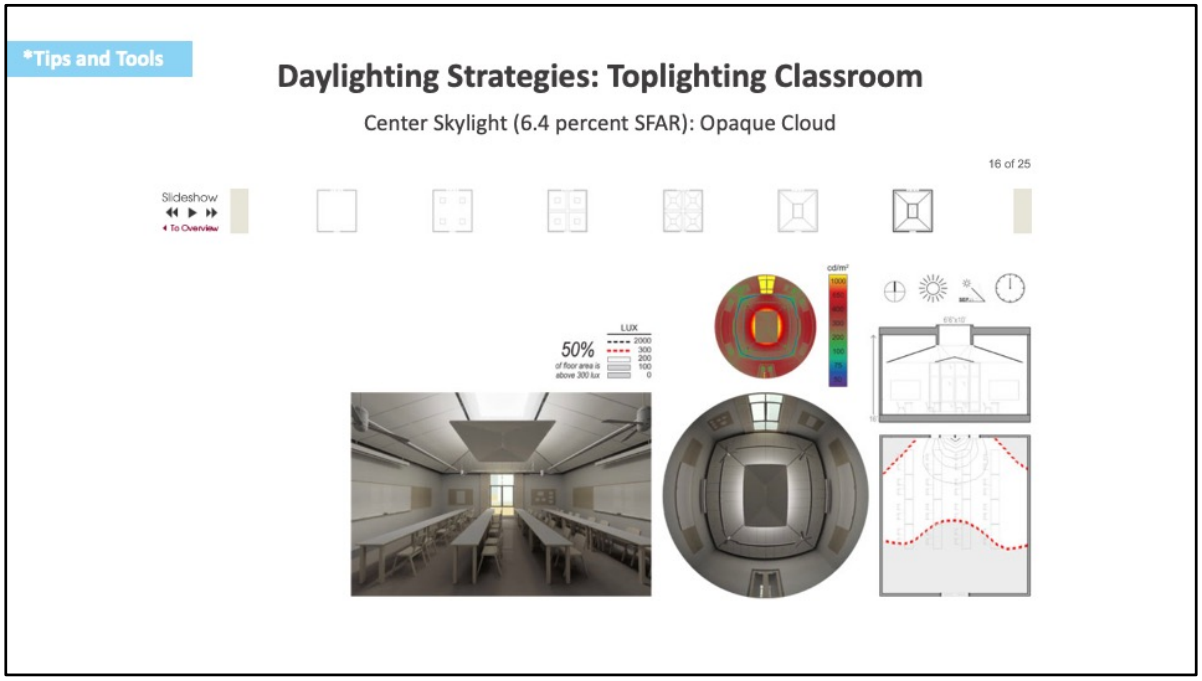
These data represent a single view window with a single skylight (4 feet x 8 feet) representing 3.2 percent of the floor area, set within a 16-foot-tall ceiling with sloping T-bar trays. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The floor area above 300 lux is 40 percent.



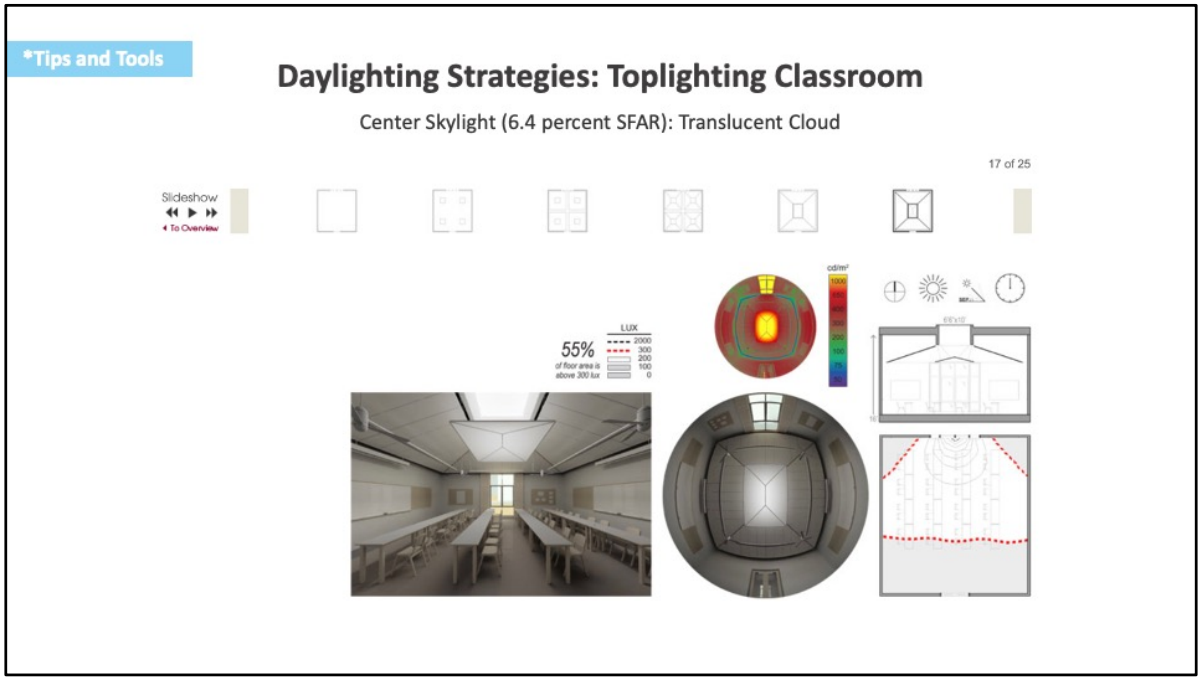
These data represent a single view window with a single skylight (6 feet 6 inches x 10 feet) representing 6.4 percent of the floor area, set within a 16-foot-tall flat ceiling. The floor area above 300 lux is 85 percent.



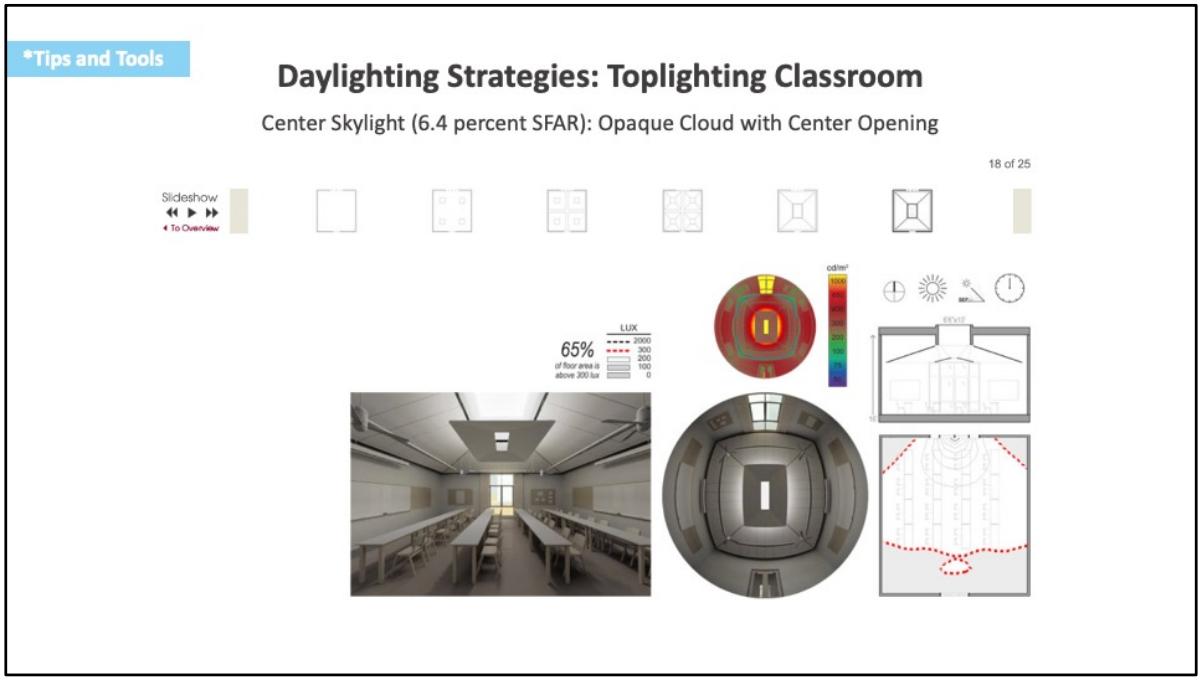
These data represent a single view window with a single skylight (6 feet 6 inches x 10 feet) representing 6.4 percent of the floor area, set within a 16-foot-tall ceiling with sloping T-bar trays. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The floor area above 300 lux is 90 percent.



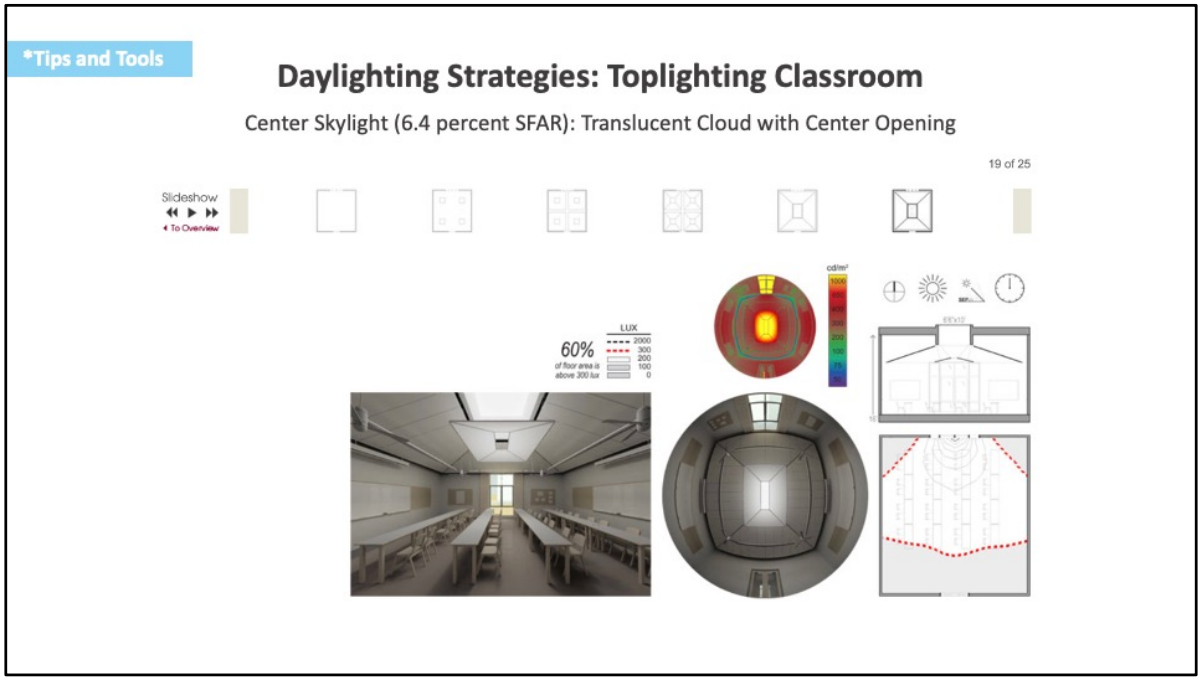
These data represent a single view window with a single skylight (6 feet 6 inches x 10 feet) representing 6.4 percent of the floor area, set within a 16-foot-tall ceiling with sloping T-bar trays, with an opaque reflector hung below the skylight. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The reflector is intended to decrease the illumination directly below the skylight, redirect the brightness onto the sloped ceiling and walls, and minimize the line of sight to the skylight aperture for students seated within the classroom, thus reducing the potential for glare. The floor area above 300 lux is 50 percent.



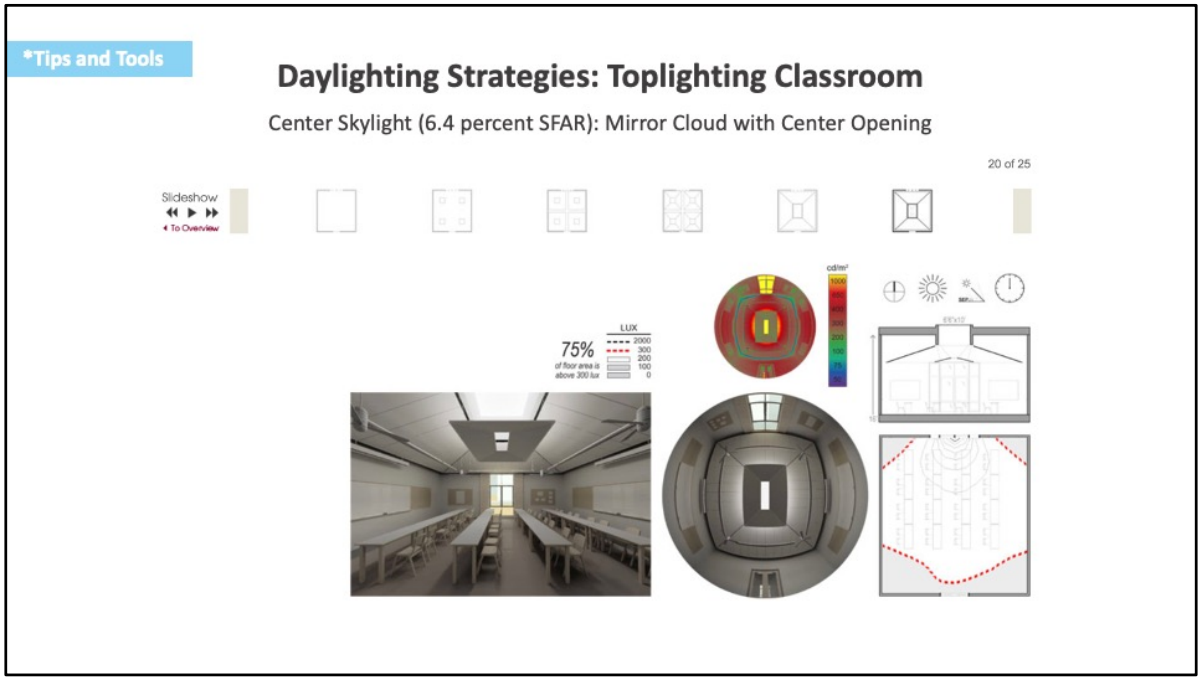
These data represent a single view window with a single skylight (6 feet 6 inches x 10 feet) representing 6.4 percent of the floor area, set within a 16-foot-tall ceiling with sloping T-bar trays, with an translucent reflector hung below the skylight. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The reflector is intended to decrease the illumination directly below the skylight, redirect the brightness onto the sloped ceiling and walls, and minimize the line of sight to the skylight aperture for students seated within the classroom, thus reducing the potential for glare. The floor area above 300 lux is 55 percent.



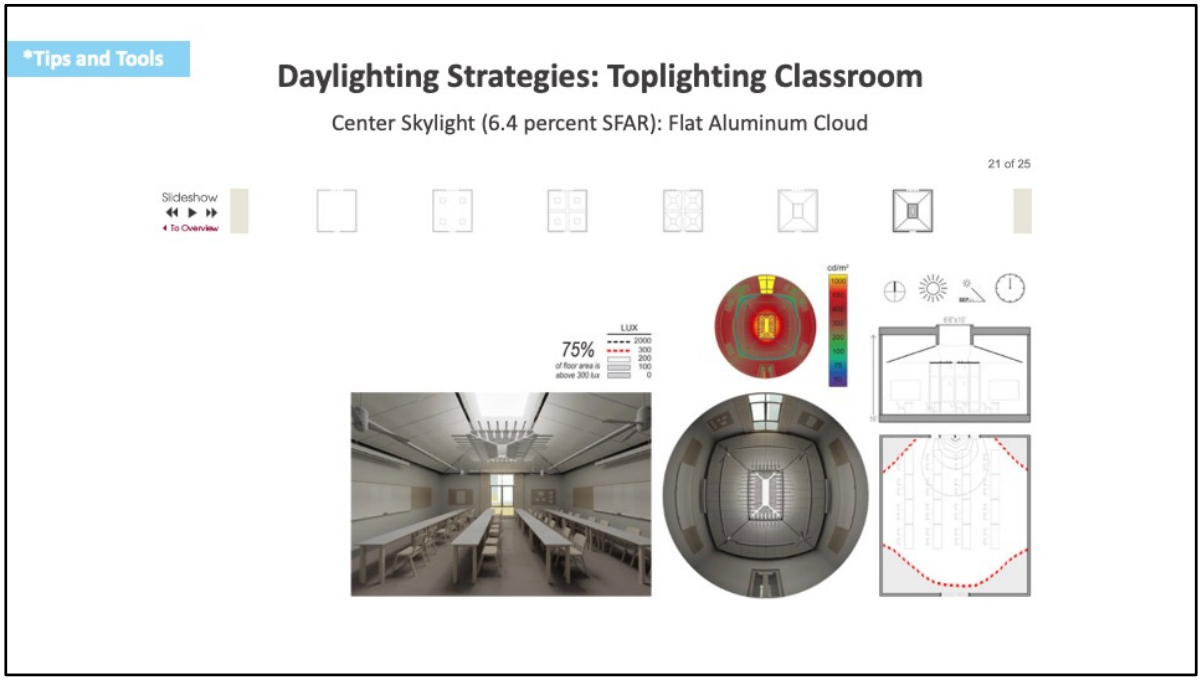
These data represent a single view window with a single skylight (6 feet 6 inches x 10 feet) representing 6.4 percent of the floor area, set within a 16-foot-tall ceiling with sloping T-bar trays, with an opaque reflector hung below the skylight. An opening has been cut in the center of the reflector to allow a selected portion of the daylight to penetrate directly below the skylight. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The reflector is intended to decrease the illumination directly below the skylight, redirect the brightness onto the sloped ceiling and walls, and minimize the line of sight to the skylight aperture for students seated within the classroom, thus reducing the potential for glare. The floor area above 300 lux is 65 percent.



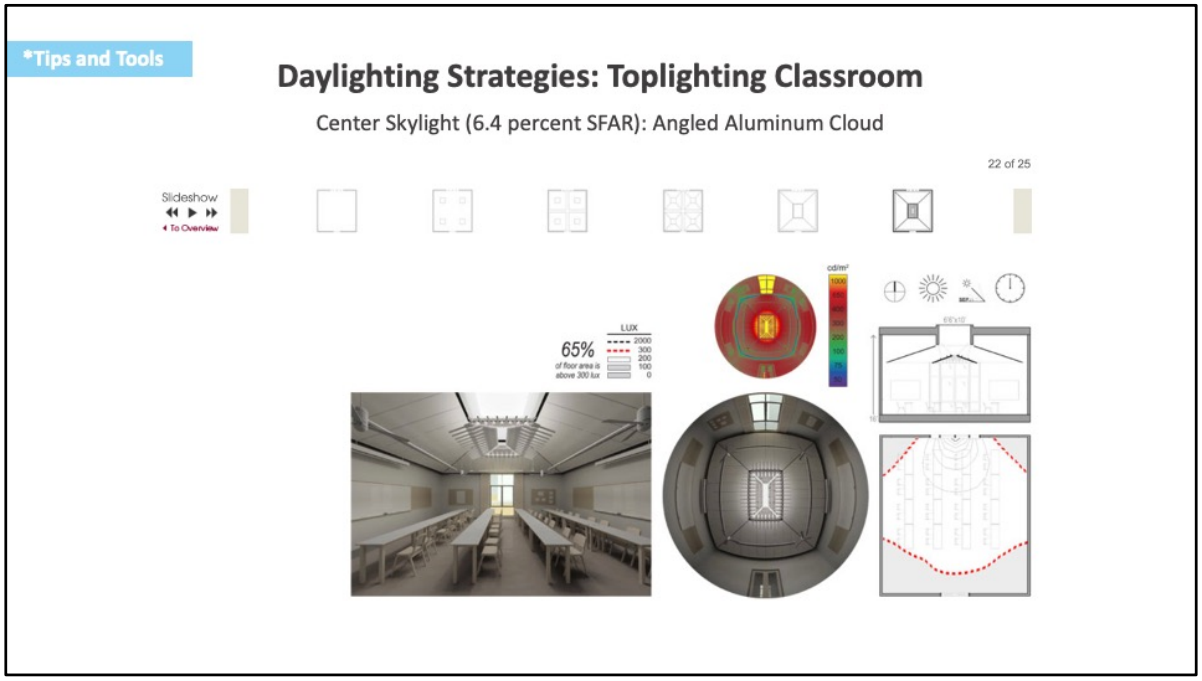
These data represent a single view window with a single skylight (6 feet 6 inches x 10 feet) representing 6.4 percent of the floor area, set within a 16-foot-tall ceiling with sloping T-bar trays, with an translucent reflector hung below the skylight. An opening has been cut in the center of the reflector to allow a selected portion of the daylight to penetrate directly below the skylight. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The reflector is intended to decrease the illumination directly below the skylight, redirect the brightness onto the sloped ceiling and walls, and minimize the line of sight to the skylight aperture for students seated within the classroom, thus reducing the potential for glare. The floor area above 300 lux is 60 percent.



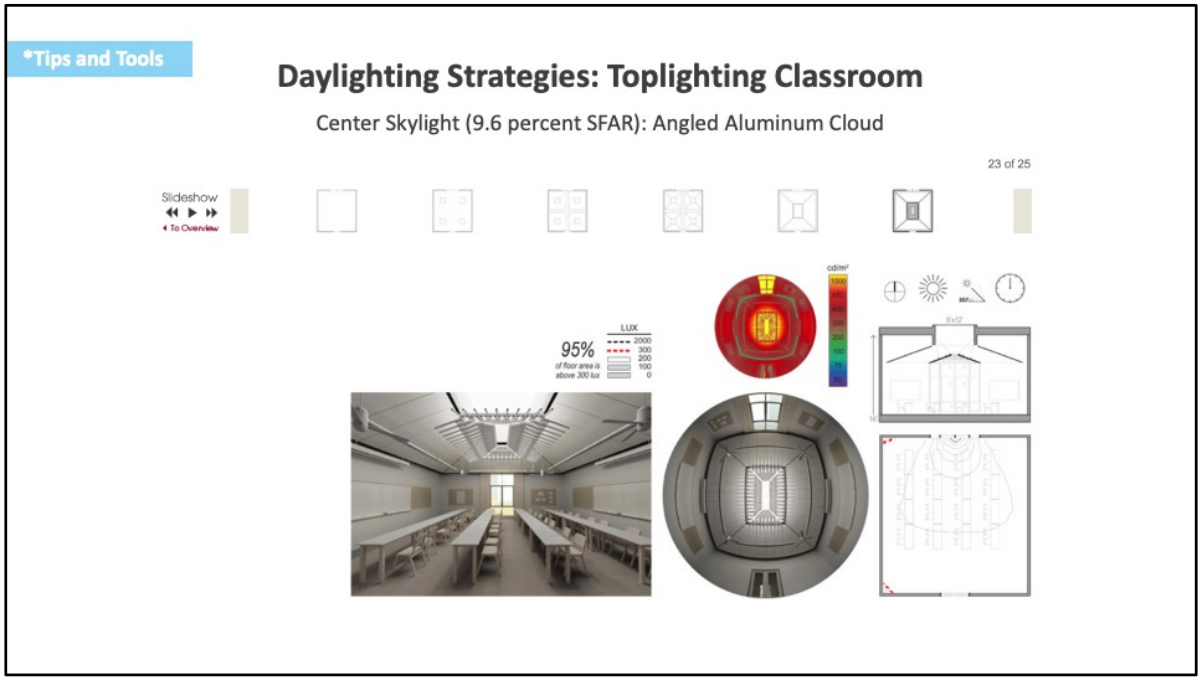
These data represent a single view window with a single skylight (6 feet 6 inches x 10 feet) representing 6.4 percent of the floor area, set within a 16-foot-tall ceiling with sloping T-bar trays, with an opaque, highly polished, reflector hung below the skylight. An opening has been cut in the center of the reflector to allow a selected portion of the daylight to penetrate directly below the skylight. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The reflector is intended to decrease the illumination directly below the skylight, redirect the brightness onto the sloped ceiling and walls, and minimize the line of sight to the skylight aperture for students seated within the classroom, thus reducing the potential for glare. The top surface of the reflector was specified as highly reflective in order to direct an even larger amount of daylight toward the sloped ceilings and walls. The floor area above 300 lux is 75 percent.



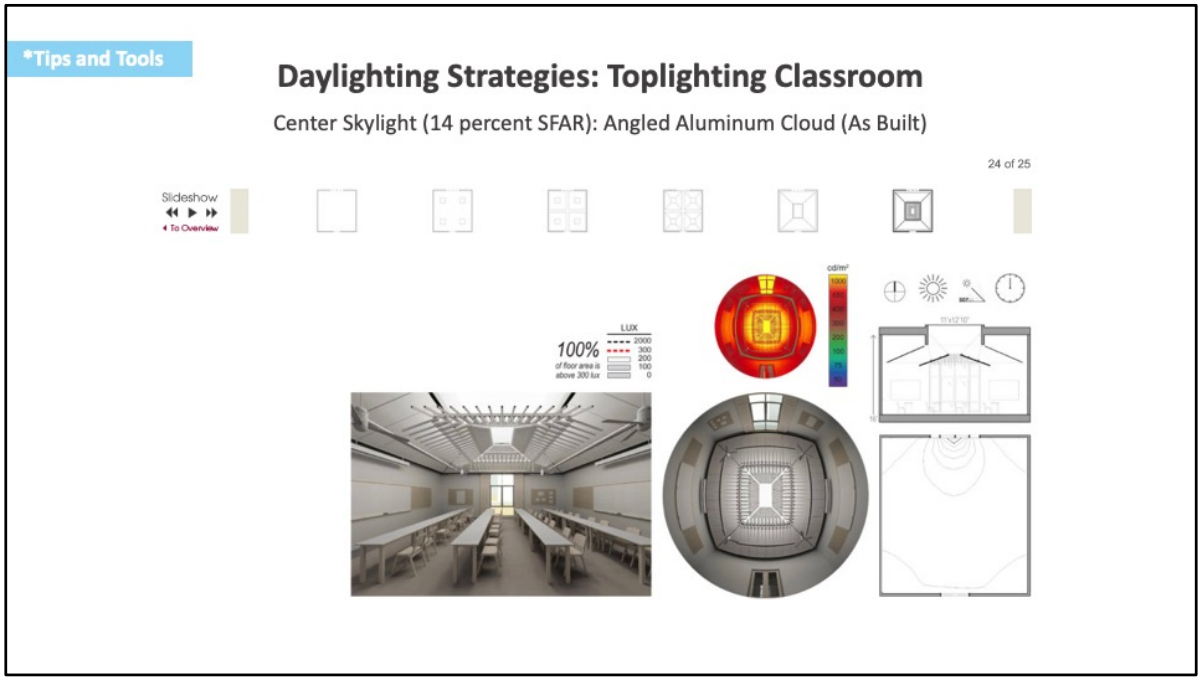
These data represent a single view window with a single skylight (6 feet 6 inches x 10 feet) representing 6.4 percent of the floor area, set within a 16-foot-tall ceiling with sloping T-bar trays, with an flat staggered aluminum reflector hung below the skylight. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The reflector is intended to decrease the illumination directly below the skylight, redirect the brightness onto the sloped ceiling and walls, and minimize the line of sight to the skylight aperture for students seated within the classroom, thus reducing the potential for glare. The floor area above 300 lux is 75 percent.



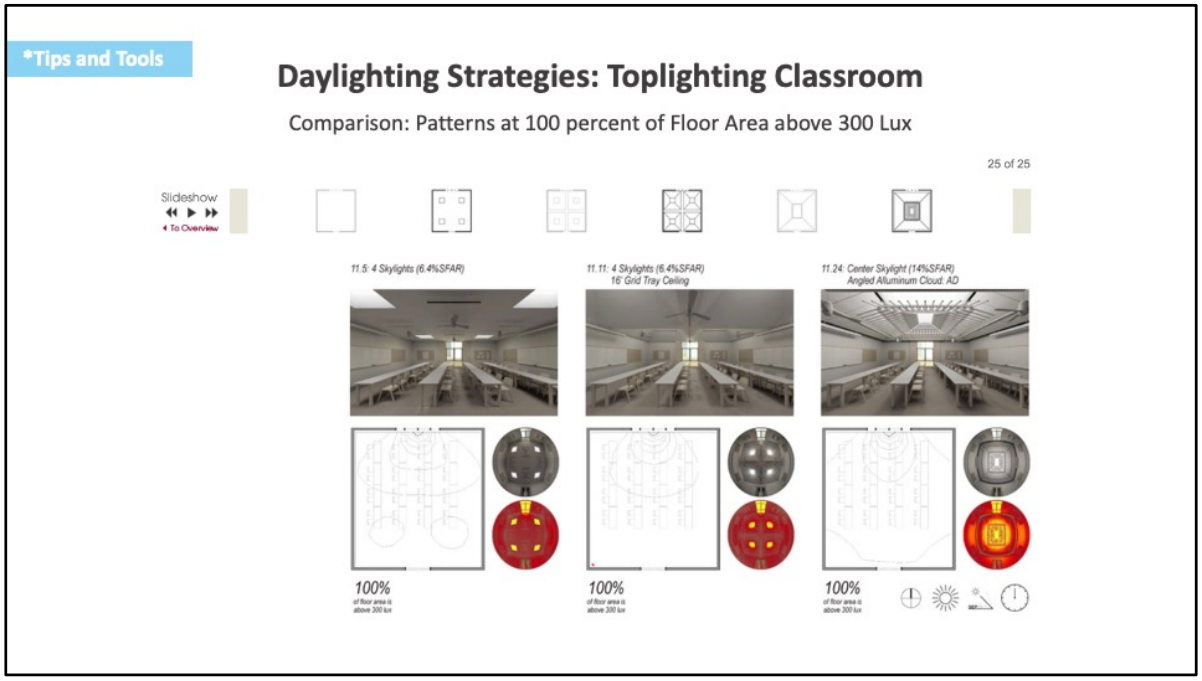
These data represent a single view window with a single skylight (6 feet 6 inches x 10 feet) representing 6.4 percent of the floor area, set within a 16-foot-tall ceiling with sloping T-bar trays, with an angled and staggered aluminum reflector hung below the skylight. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The angled reflector is intended to decrease the illumination directly below the skylight, redirect the brightness onto the sloped ceiling and walls, and minimize the line of sight to the skylight aperture for students seated within the classroom, thus reducing the potential for glare. The floor area above 300 lux is 65 percent.



These data represent a single view window with a single skylight (8 feet x 12 feet) representing 9.6 percent of the floor area, set within a 16-foot-tall ceiling with sloping T-bar trays, with an angled and staggered aluminum reflector hung below the skylight. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The angled reflector is intended to decrease the illumination directly below the skylight, redirect the brightness onto the sloped ceiling and walls, and minimize the line of sight to the skylight aperture for students seated within the classroom, thus reducing the potential for glare. The floor area above 300 lux is 95 percent.



These data represent a single view window with a single skylight (11 feet x 12 feet 10 inches) representing 14 percent of the floor area, set within a 16-foot-tall ceiling with sloping T-bar trays, with an angled and staggered aluminum reflector hung below the skylight. The sloped ceilings improve the distribution of light from the skylights and increase the visual perception of brightness while minimizing shadows. The angled reflector is intended to decrease the illumination directly below the skylight, redirect the brightness onto the sloped ceiling and walls, and minimize the line of sight to the skylight aperture for students seated within the classroom, thus reducing the potential for glare. The floor area above 300 lux is 100 percent.

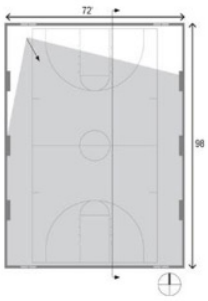


These data represent all three cases that reached 100 percent of the floor area that exceeded the target criteria. The side by side comparison is useful to compare the qualitative differences for alternative design solutions that all achieve the same illumination performance criteria. The solution on the far left has arguably the highest lighting contrast with the shallow skylight wells revealing large bright surfaces within the visual field and a relatively dark ceiling. The middle solution has lower contrast due to the large sloped skylight wells that are washed in daylight. The solution on the far right has the brightest ceiling plane due to the wide sloping ceiling planes that meet at the well of the skylight and due to the intricate daylight reflector and diffuser hanging below the skylight. The diffuser serves to dampen the daylight directly below the skylight well, minimize the direct line of sight to the bright surfaces of the skylight itself, and redirect light toward the walls of the classroom.

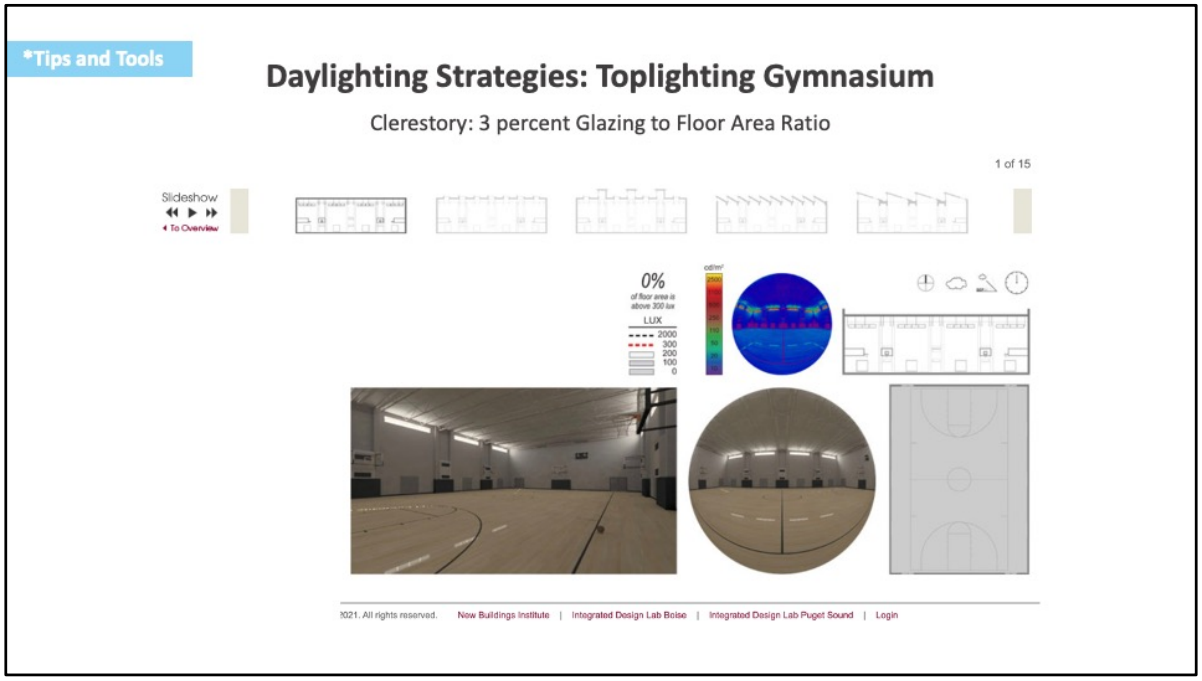
*Tips and Tools

Daylighting Strategies: Toplighting Gymnasium

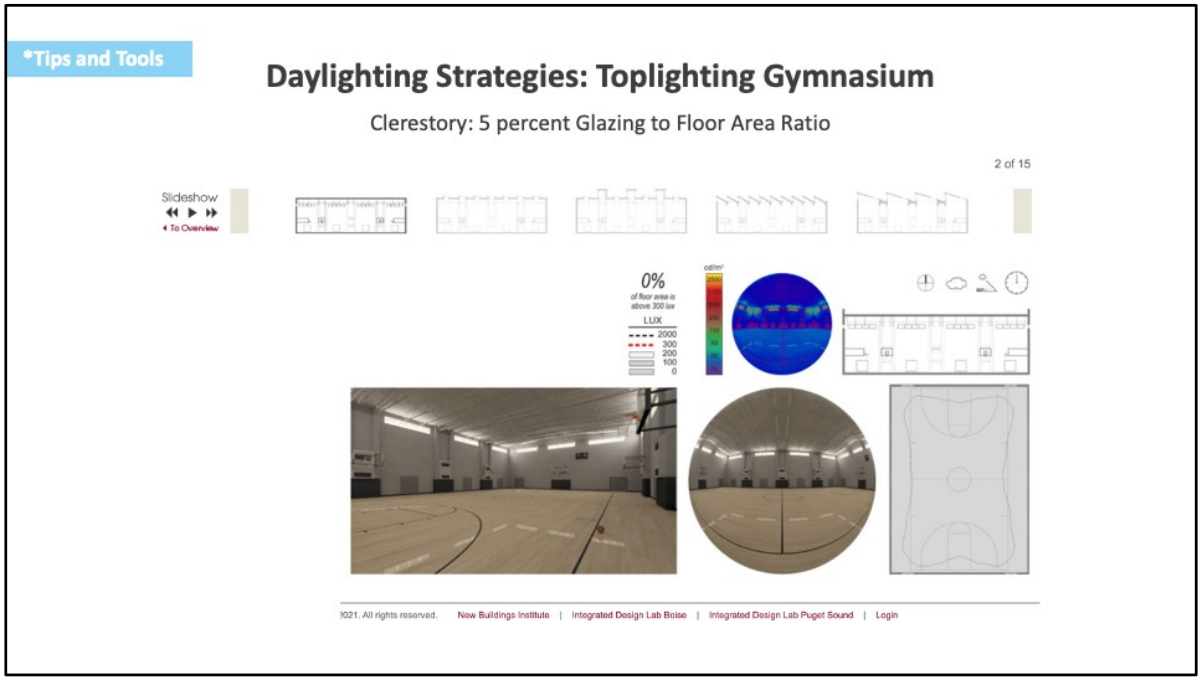
Slideshow
PLAY



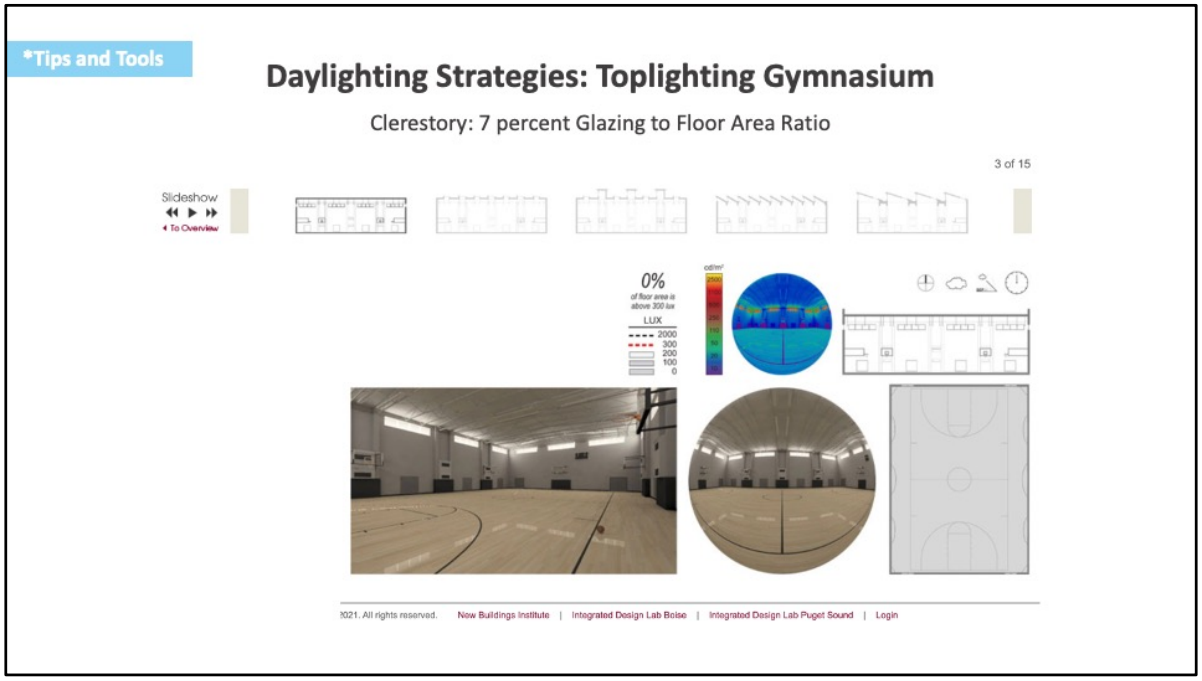
Yesler Community Center Gymnasium | Seattle, WA | Mithun



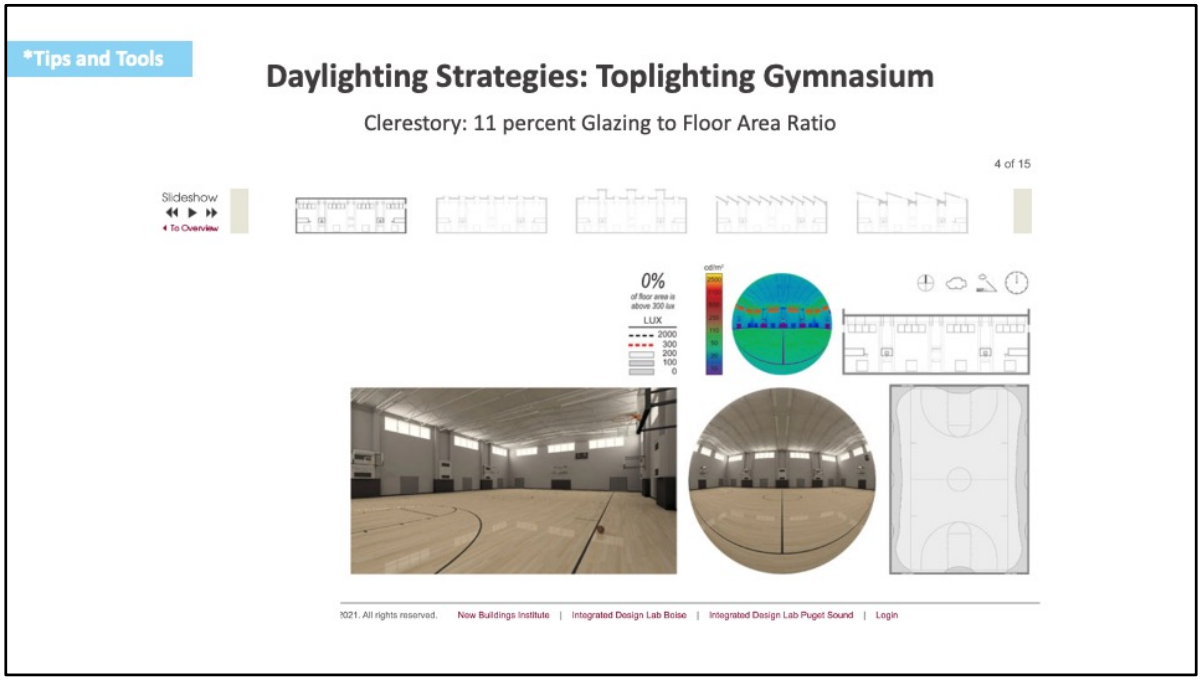
These data represent a common gymnasium design with small ribbon clerestory windows wrapping the two long facades. The glass to floor area ratio (GFAR) is 3 percent, that is 3 percent of the floor area is represented with glass. The floor area above 300 lux is 0 percent.



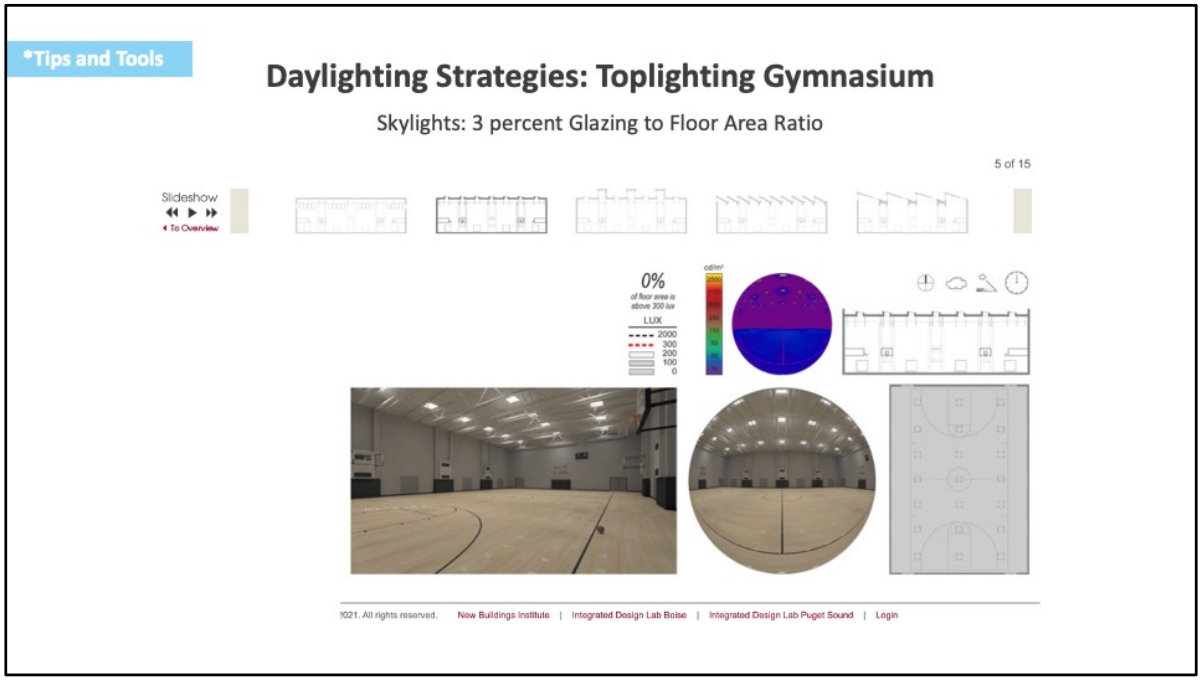
These data represent a common gymnasium design with small ribbon clerestory windows wrapping all facades. The GFAR is 5 percent. The floor area above 300 lux is still 0 percent, however there is a modest improvement in visual perception of brightness.



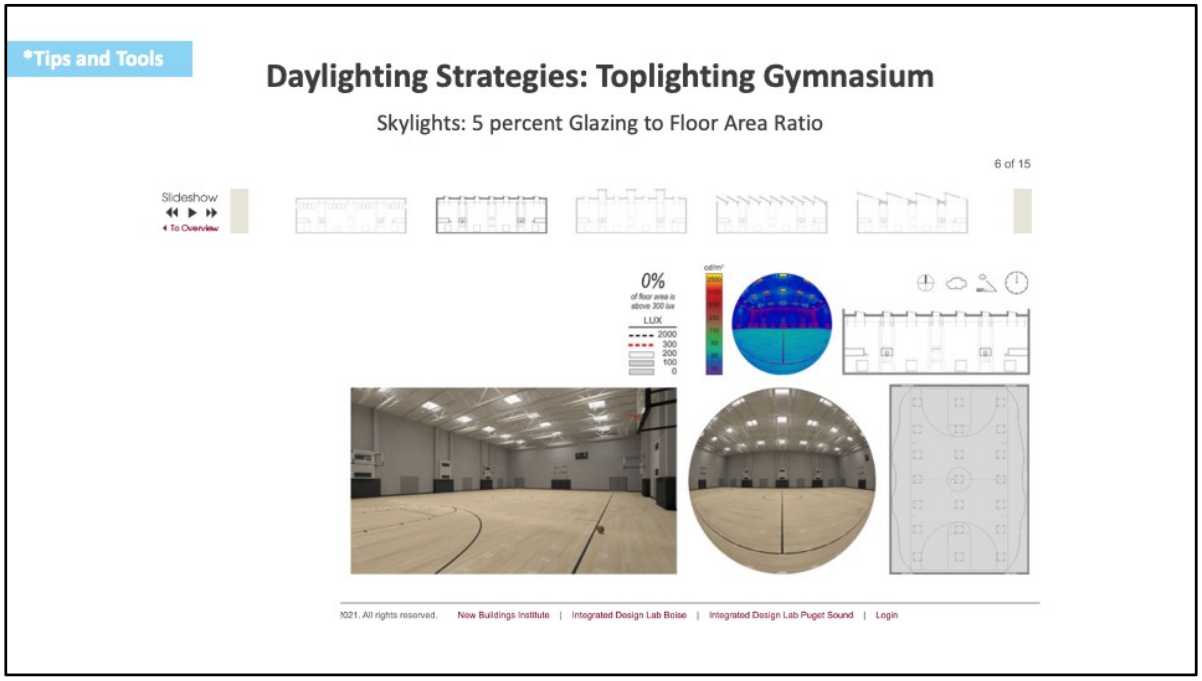
These data represent a gymnasium design with moderately sized ribbon clerestory windows wrapping all facades. The GFAR is 7 percent. The floor area above 300 lux is still 0 percent, however there is a slight improvement in visual perception of brightness.



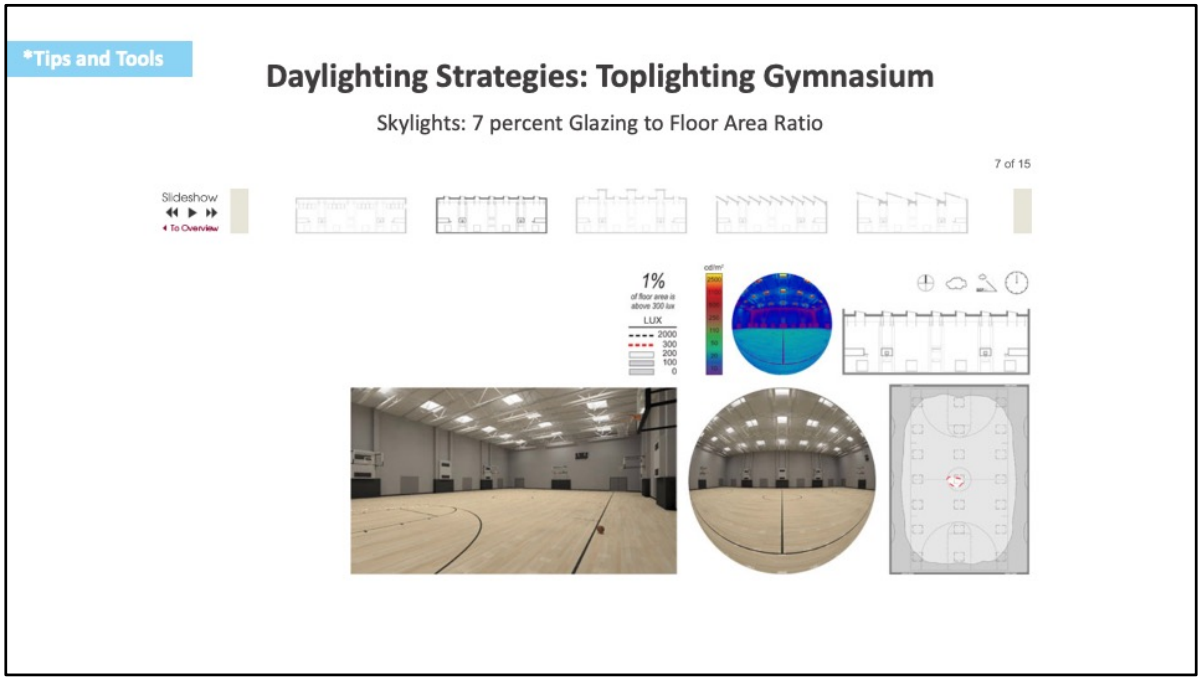
These data represent a gymnasium design with large clerestory windows wrapping all facades. The GFAR is 11 percent. The floor area above 300 lux is still 0 percent, however there is a slight improvement in visual perception of brightness.



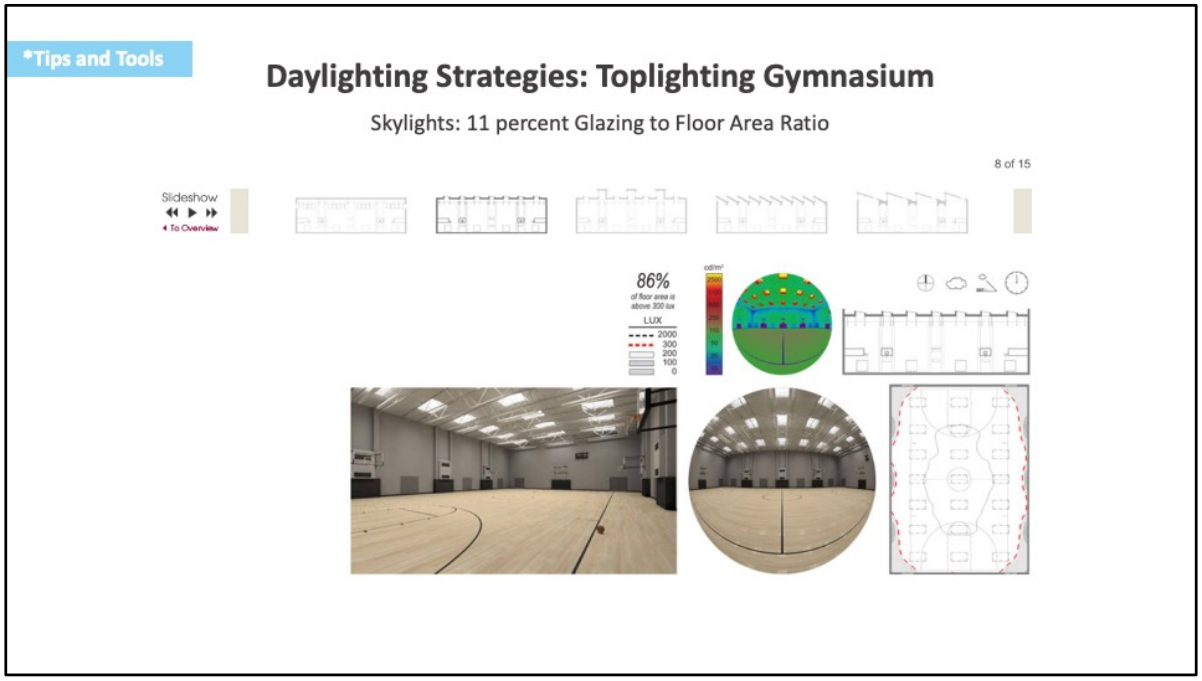
These data represent a gymnasium design with moderately sized ribbon clerestory windows wrapping all facades. The GFAR is 7 percent. The floor area above 300 lux is still 0 percent, however there is a slight improvement in visual perception of brightness.



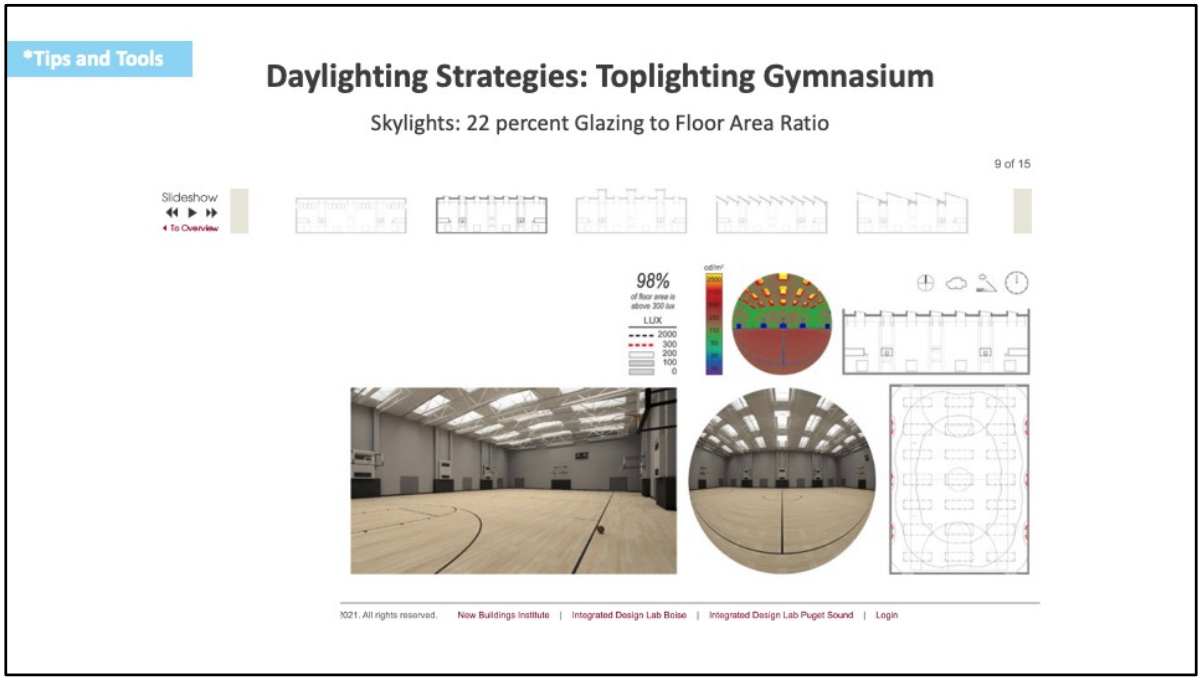
These data represent a common gymnasium design with translucent skylights (50 percent VLT) distributed across the ceiling. The GFAR is 5 percent. The floor area above 300 lux is still 0 percent. These data represent an overcast sky in Seattle on September 21 at noon. The distribution of daylight is improved over the clerestory solutions and the space perceives much brighter as compared to pattern step 9-2 (Clerestory: 5 percent Glazing to Floor Area Ratio) with the same GFAR located in the walls.



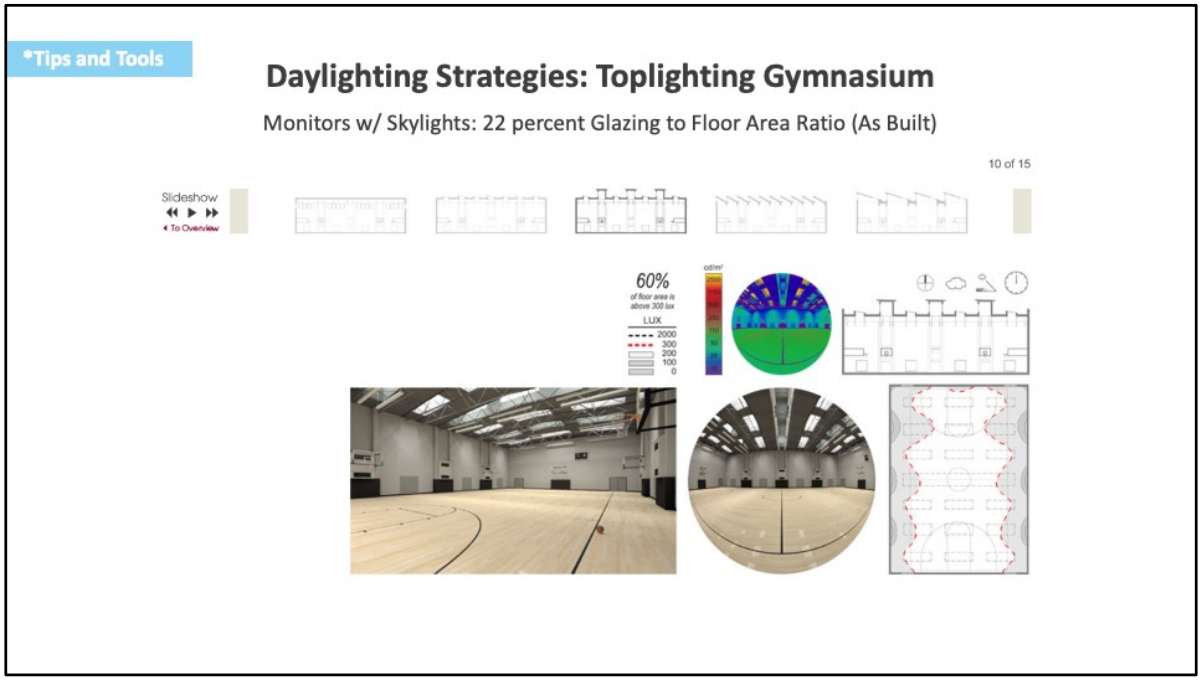
These data represent a gymnasium design with translucent skylights (50 percent VLT) distributed across the ceiling. The GFAR is 7 percent. The floor area above 300 lux is just 1 percent, however the majority of the space is above 200 lux. These data represent an overcast sky in Seattle on September 21st at noon. The distribution of daylight is improved over the clerestory solutions and the space perceives much brighter as compared to pattern step 9-3 (Clerestory: 7 percent Glazing to Floor Area Ratio) with the same GFAR located in the walls.



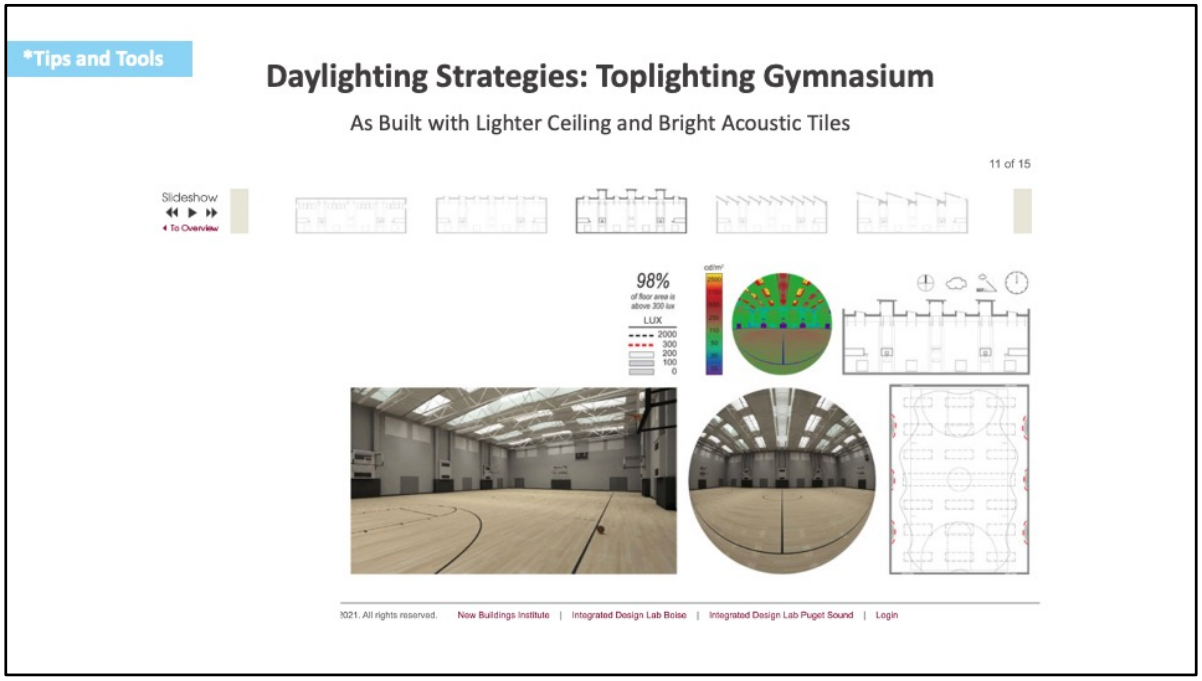
These data represent a gymnasium design with translucent skylights (50 percent VLT) distributed across the ceiling. The GFAR is 11 percent. The floor area above 300 lux jumps dramatically to 86 percent. This dramatic improvement indicates that much of the space approached 300 lux in the previous step but fell just short of the criteria. The distribution of daylight is improved over the clerestory solutions and the space perceives much brighter as compared to pattern step 9-4 (Clerestory: 11 percent Glazing to Floor Area Ratio) with the same GFAR located in the walls.



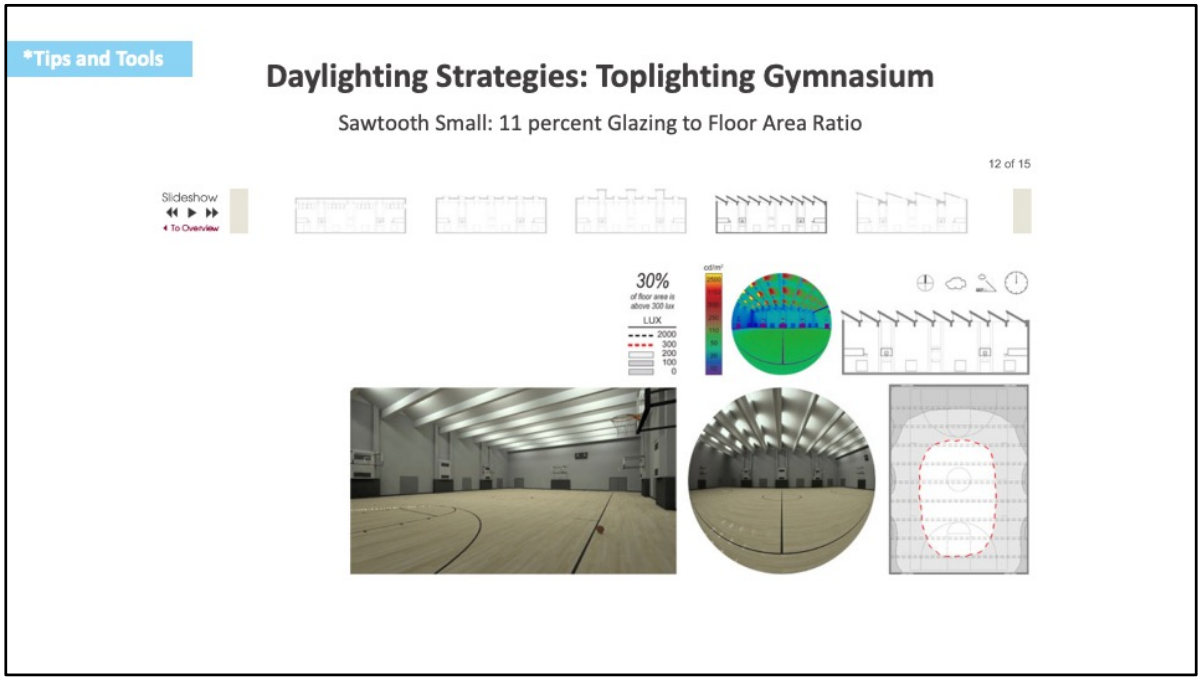
These data represent a gymnasium design with translucent skylights (50 percent VLT) distributed across the ceiling. The GFAR is 22 percent. The floor area above 300 lux jumps to 98 percent. The distribution of daylight is improved over the clerestory solutions and the previous skylight solution. However, in many climates it may be inappropriate to employ this vast amount of toplighting due to overall energy concerns.



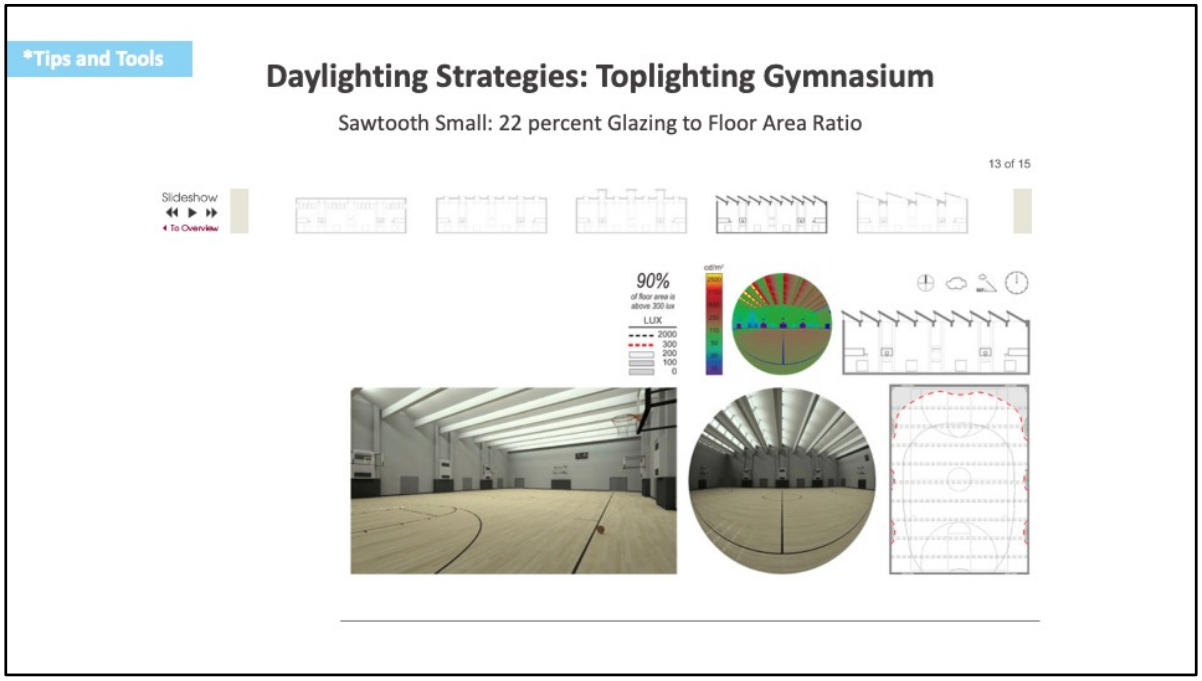
These data represent the gymnasium as designed with translucent skylights (50 percent VLT) alternating with roof monitors with a combination of south-facing (translucent) glass and north-facing (clear) glass. The GFAR remains at 22 percent, however the floor area above 300 lux falls from 98 percent to 60 percent. This decrease is due to the fact that clerestory monitors are not as successful as skylights in their ability to drive daylight to the floor plane. However, this we determined to be the best solution in terms of total energy performance due to the ability to naturally ventilate and cool the space with the clerestory monitors. Finally, the ceiling plane is noticeably darker in this pattern step. Using a darker ceiling for this rendering was a conscious choice and was based upon the actual materials installed, however the rest of the pattern steps use a more reflective ceiling finish.



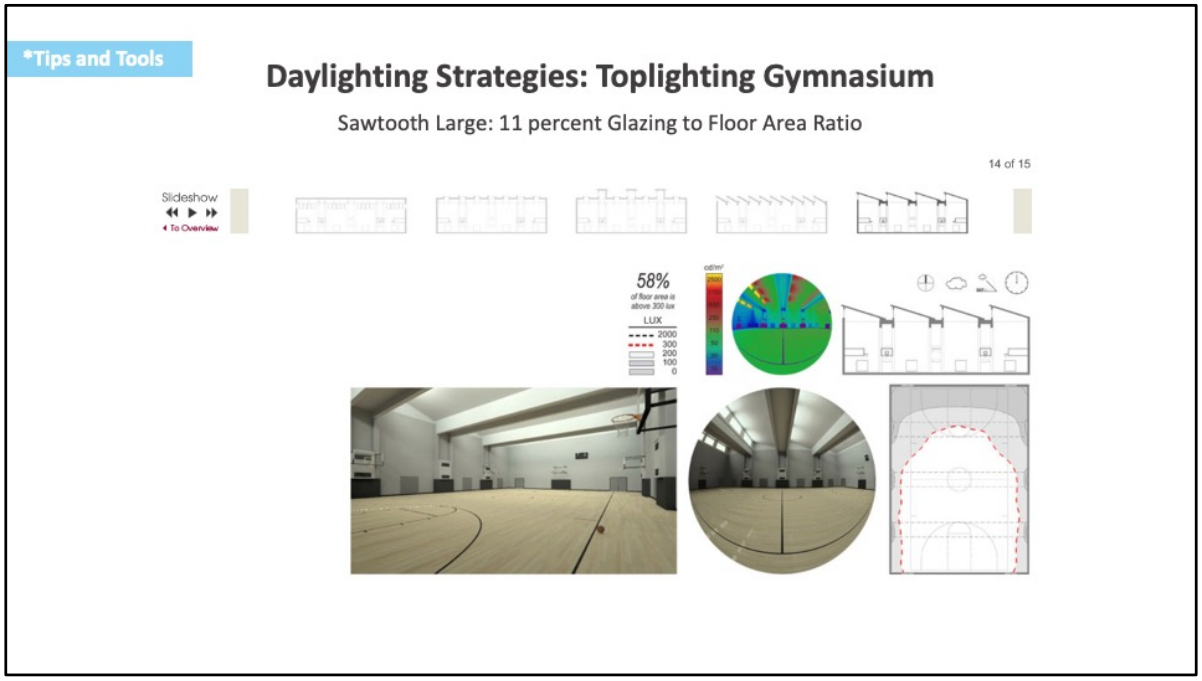
These data represent the as designed condition, however a more reflective ceiling was applied and white acoustical tiles were applied to the top portion of the walls to redirect daylight into the space. The GFAR remains at 22 percent, however the floor area above 300 lux increases dramatically from 60 percent to 98 percent due to these modest surface treatments.



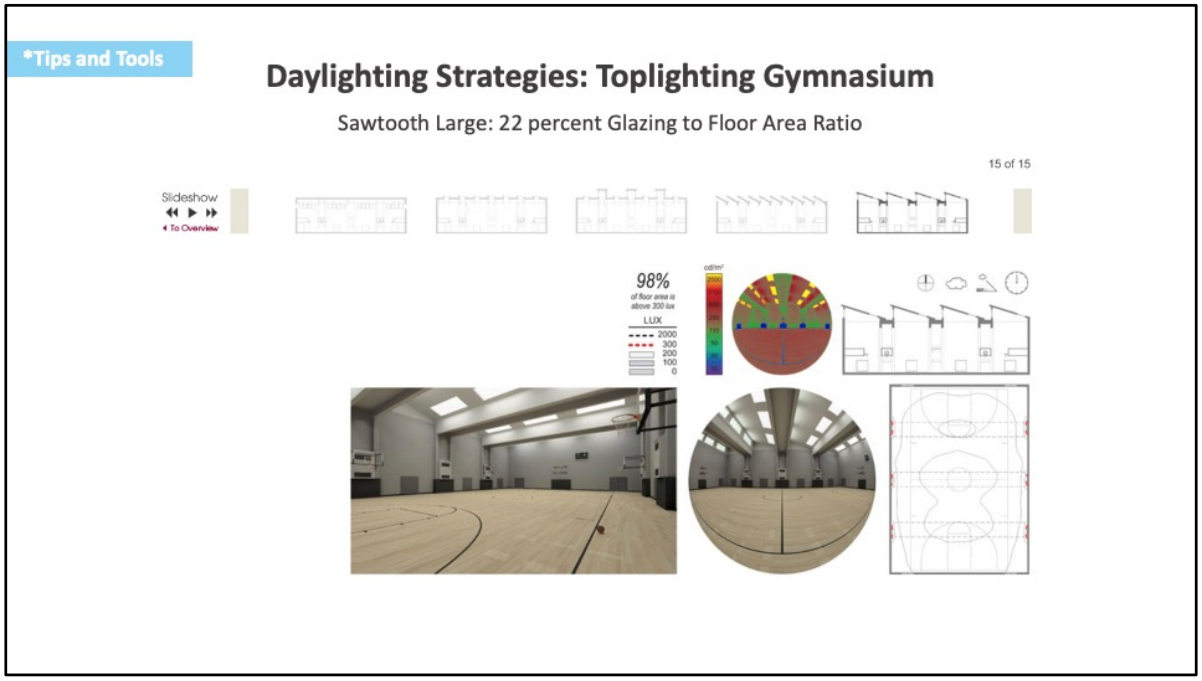
These data represent an aggressive north-facing sawtooth solution. The GFAR is 22 percent. The floor area above 300 lux is 90 percent. Some of the problems discussed in pattern step 9-12 (Sawtooth Small: 11 percent Glazing to Floor Area Ratio) are mitigated by the substantial increase in overall daylight available. Specifically, the contrast in the space is reduced. Notice, however, that there is still a moderate asymmetry in the space due to the directional light emitted by the sawtooth monitors.



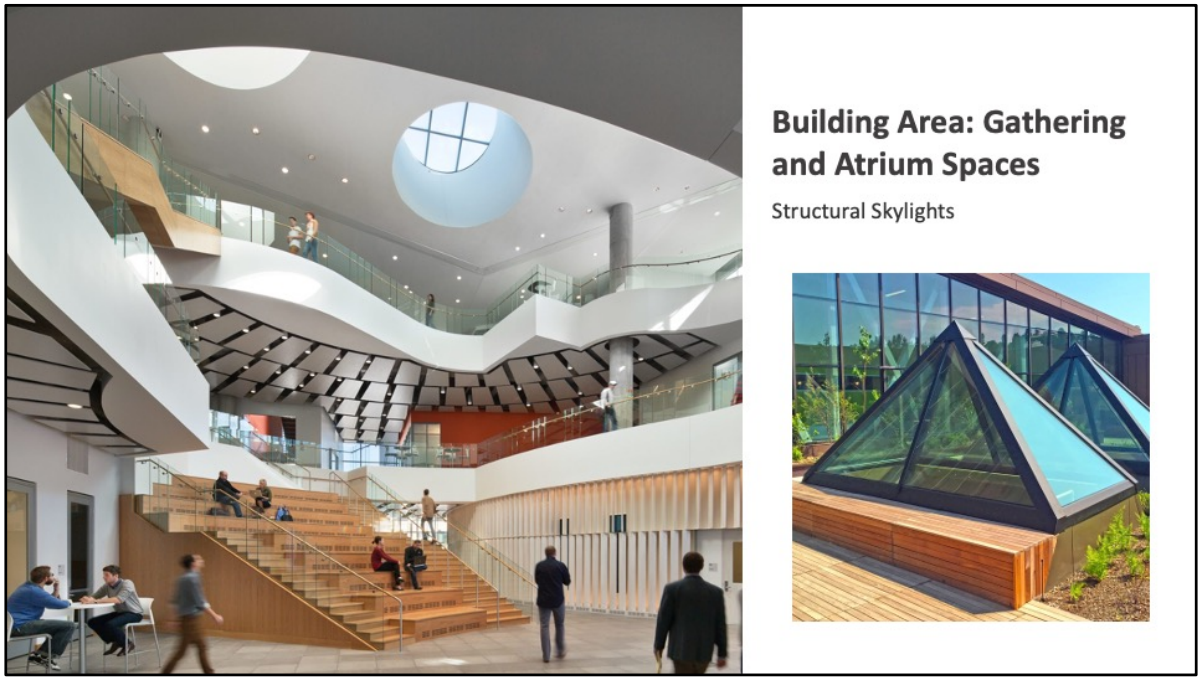
These data represent an aggressive north-facing sawtooth solution. The GFAR is 22 percent. The floor area above 300 lux is 90 percent. Some of the problems discussed in pattern step 9-12 (Sawtooth Small: 11 percent Glazing to Floor Area Ratio) are mitigated by the substantial increase in overall daylight available. Specifically, the contrast in the space is reduced. Notice, however, that there is still a moderate asymmetry in the space due to the directional light emitted by the sawtooth monitors.



These data represent an aggressive north-facing sawtooth solution using large structural members to support a series of broad sloped clerestory monitors. The GFAR is 11 percent. The floor area above 300 lux is 58 percent, which is up from 30 percent using the same GFAR in the small sawtooth approach of pattern step 9-12 (Sawtooth Small: 11 percent Glazing to Floor Area Ratio). Some of the problems discussed in pattern step 9-12 are mitigated by the increase in size of the architectural elements washed in daylight. Specifically, the contrast in the space is reduced. Notice, however, that there is still asymmetry in the space due to the directional light emitted by the sawtooth monitors.

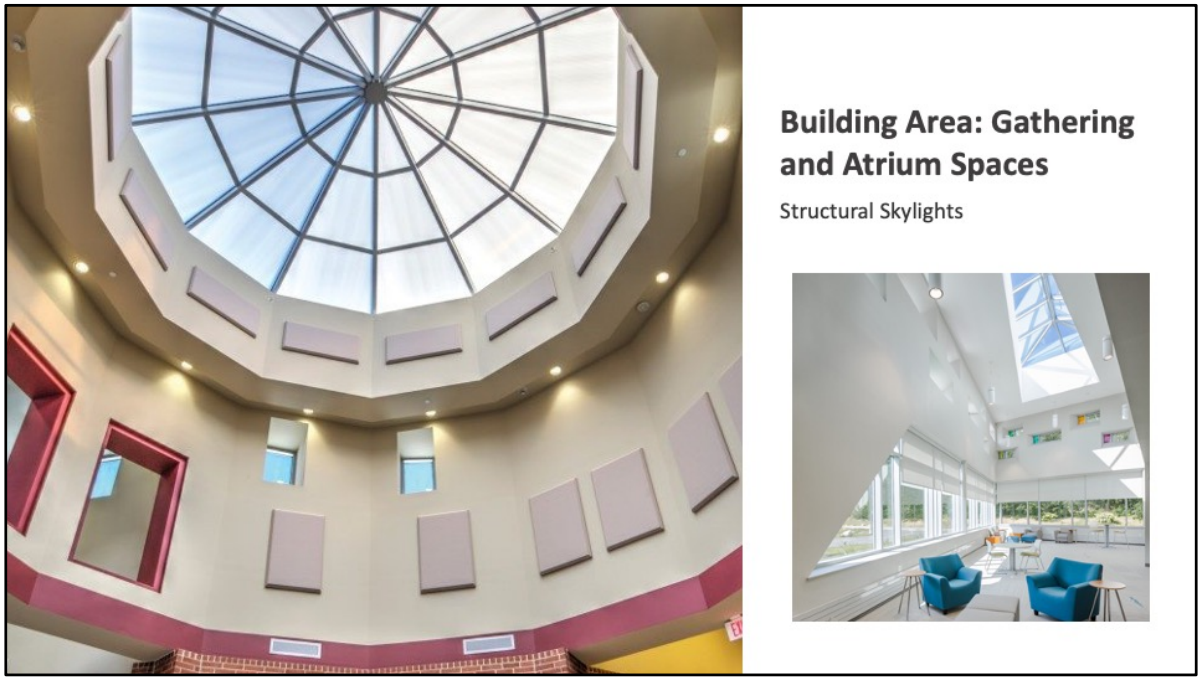


These data represent an aggressive north-facing sawtooth solution using large structural members to support a series of broad sloped clerestory monitors with additional skylights placed on the sloping sides. The GFAR is 22 percent. The floor area above 300 lux is 98 percent, which is up slightly from 90 percent using the same GFAR in the small sawtooth approach of pattern step 9-13 (Sawtooth Small: 22 percent Glazing to Floor Area Ratio). The problems discussed in pattern step 9-12 (Sawtooth Small: 11 percent Glazing to Floor Area Ratio) are mitigated by the increase in size of the architectural elements washed in daylight and the supplemental light of the skylights on the sloped surfaces to provide more uniform daylight distribution.



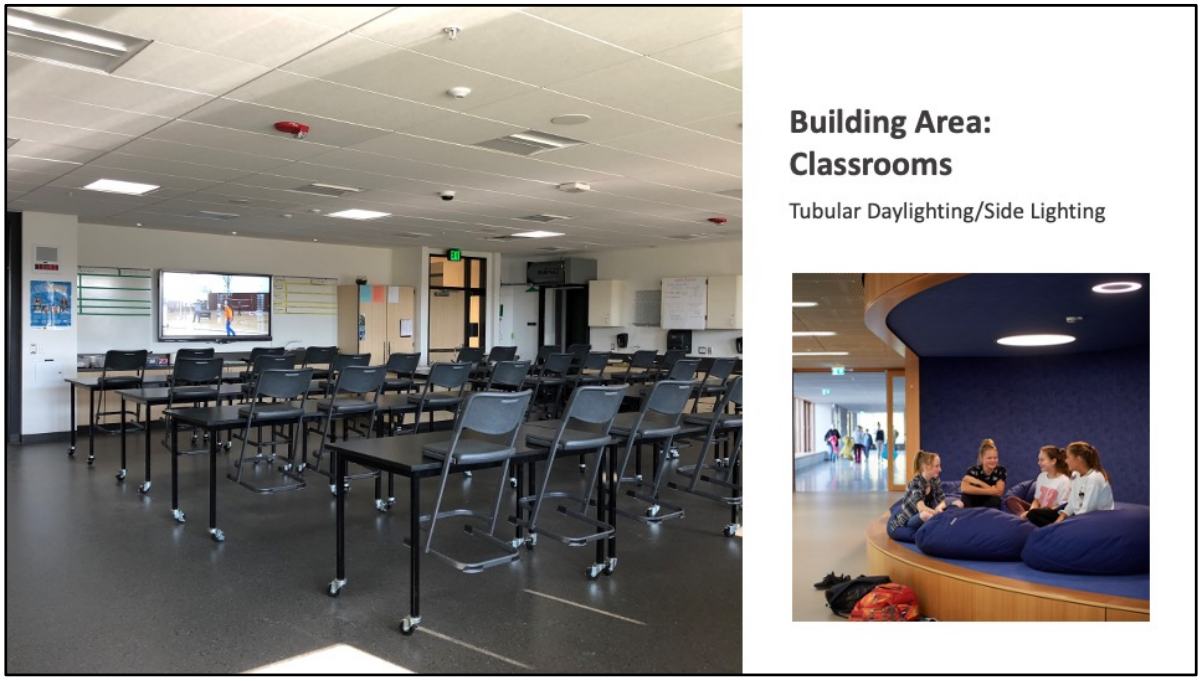
Structural skylight systems allow creative ways to deliver daylight for a striking illuminating array.

Modular skylight systems deliver natural light and the opportunity for both passive ventilation and light controlling blinds.



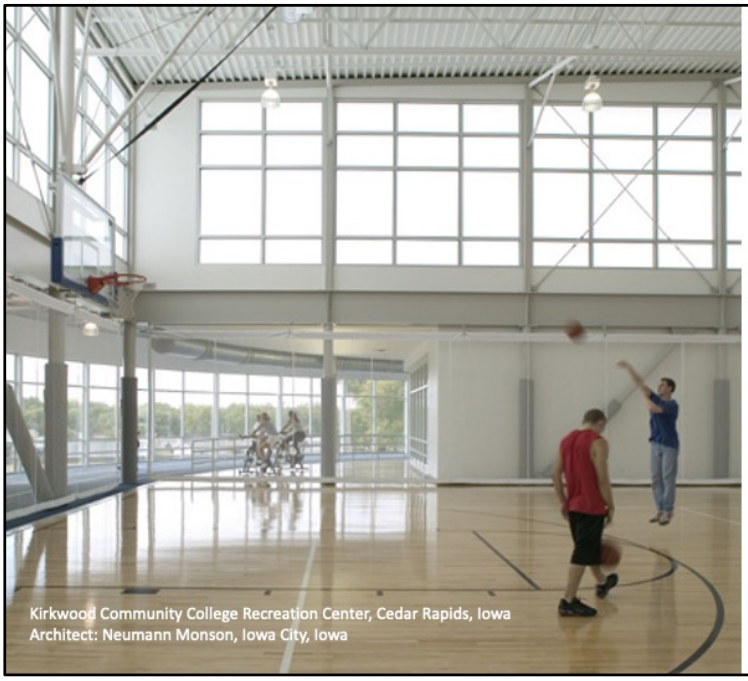
Polycarbonate and glass systems bring the outside in.

Beautiful ambient light with a modular structural ridge skylight system.



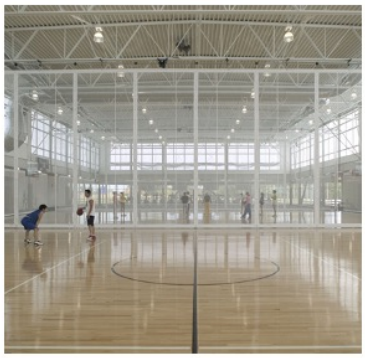
Tubular daylighting with controllers were unitized on the southside of this classroom, while picture windows supported stunning mountain views to the North. (McGranahan Architects, Tacoma, Washington)

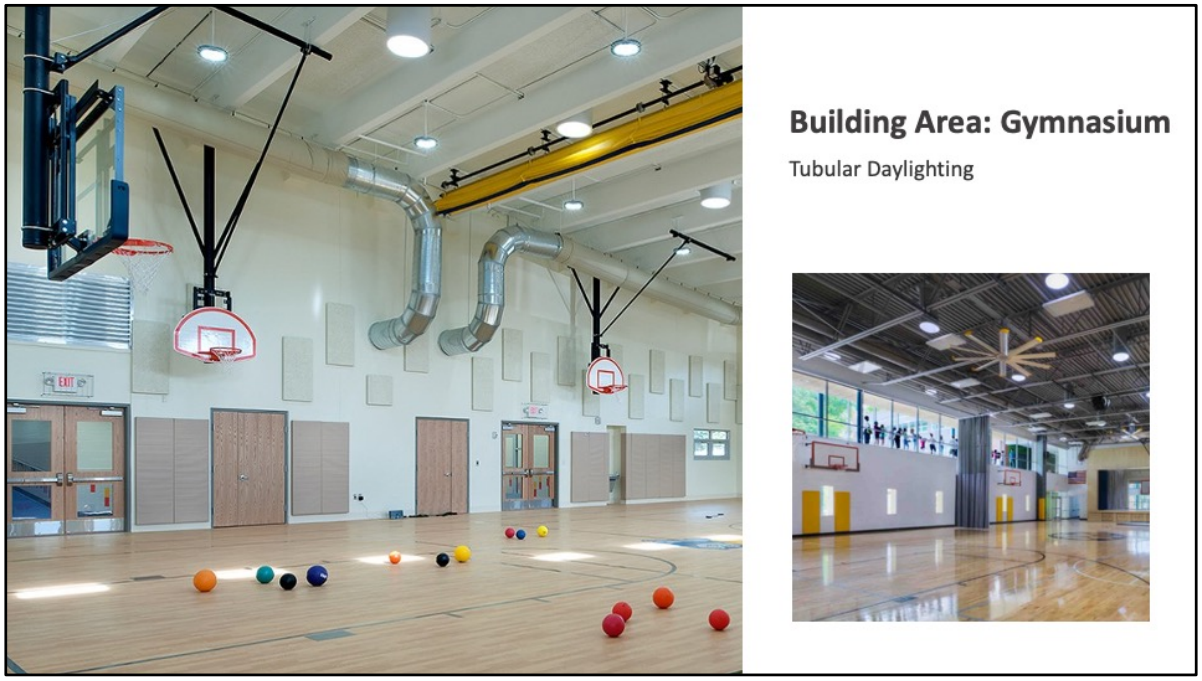
A renovation of fiberglass insulated panel systems with multiwall polycarbonate delivers stunning light to the sports court below.



Building Area: Gymnasium

Structural Skylight





The use of tubular daylighting in gymnasiums with vertical windows systems balance and control light to reduce the chance for glare. In addition, with light controllers, allows the space to become multifunction gathering space.

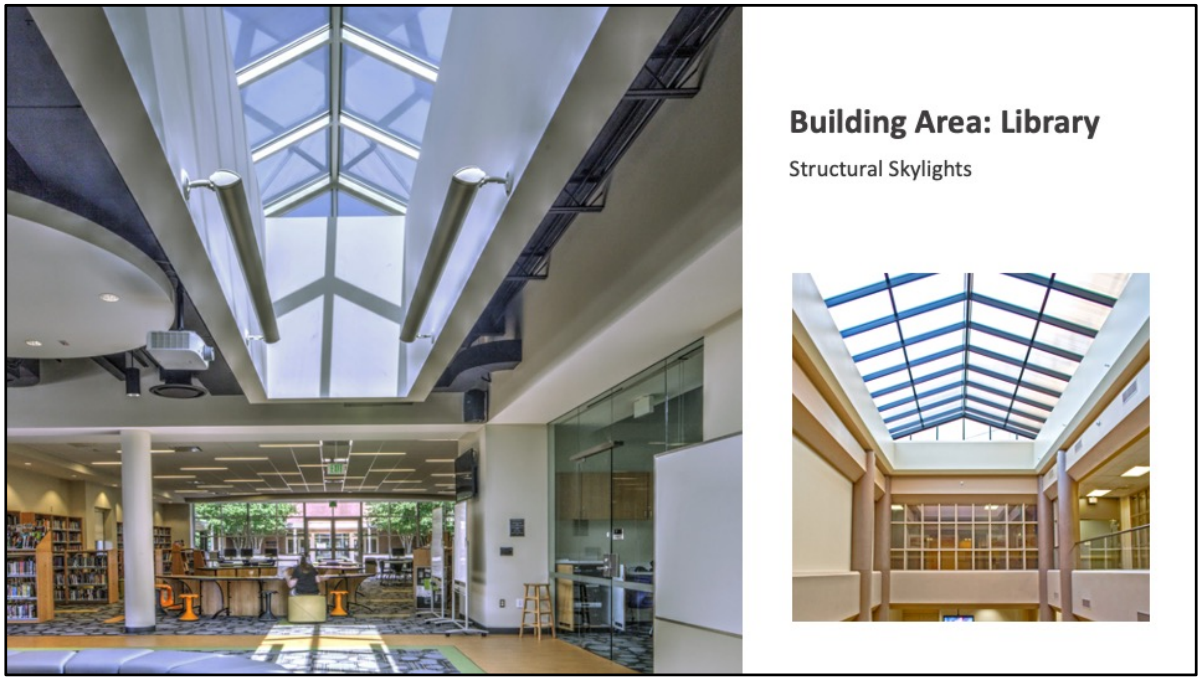
Vertical polycarbonate multiwall delivery illumination without glare for athletic facilities, regarding of sky conditions.

Modular skylights deliver multiple possible for large spaces.

Building Area: Cafeteria

Unit Skylights

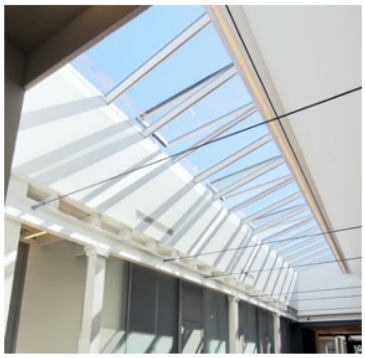
Transom windows illuminate walls, balancing the overhead pyramid units with this cafeteria.

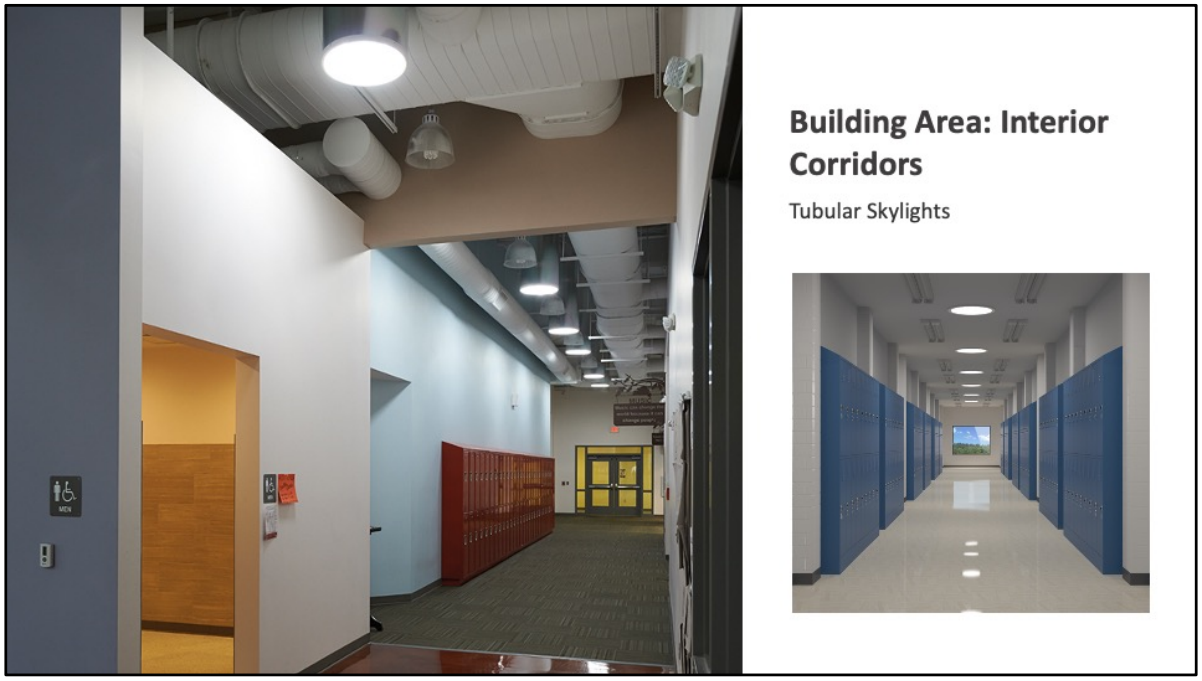


Structural skylight systems provide direction and wayfinding to the library.

Building Area: Library

Modular Skylights –
Daylight/Control/Ventilation

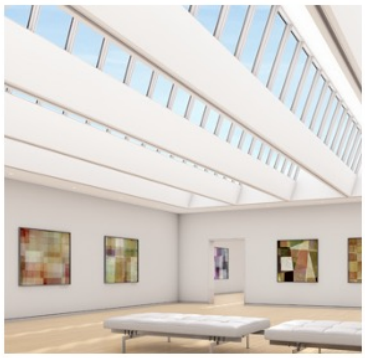




Tubular skylights are a cost-efficient and worthy solution for corridors.

Building Area: Interior Corridors

Modular Skylight: North-facing single-pitch

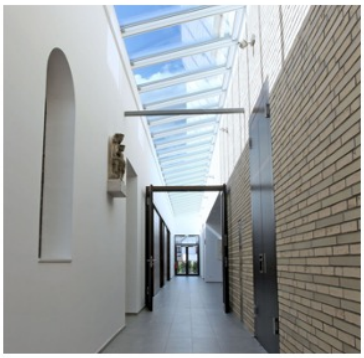


Building Area: Interior Corridors

Modular Skylights: Structural Ridge

Building Area: Interior Corridors

Modular Skylights: Long Structures



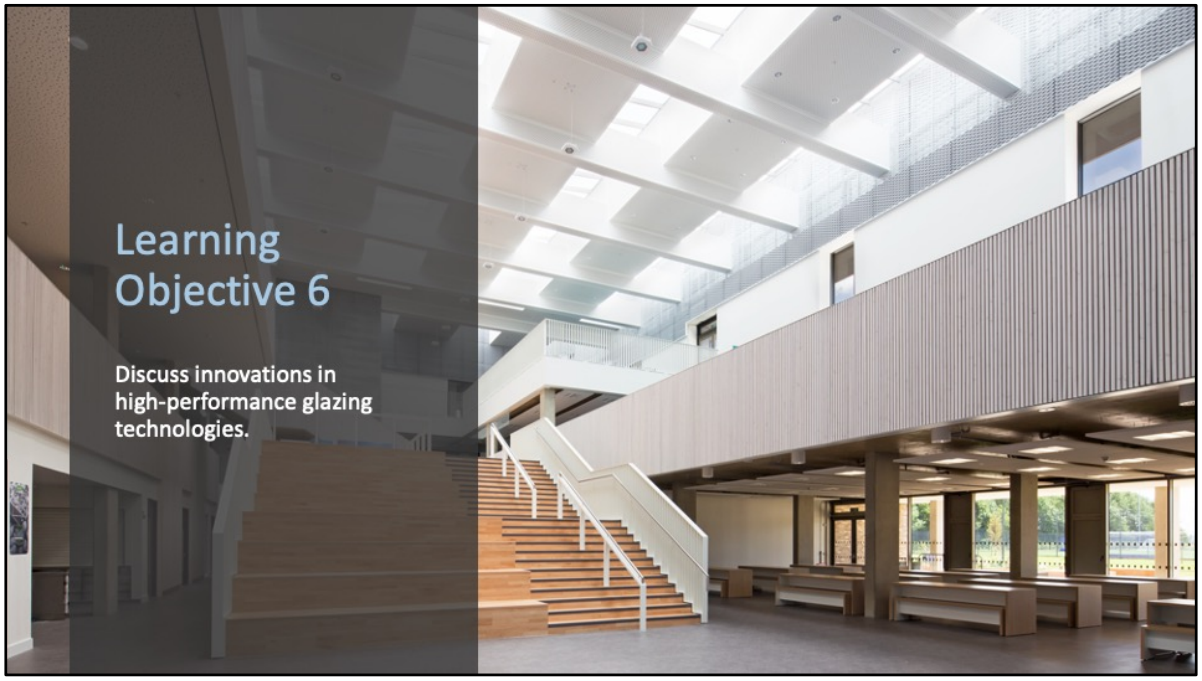
Building Area: Interior Corridors

Unit Skylights
Structural Skylights

Entry and transition spaces require protection from the elements for both students and faculty.

Building Area Exterior Corridors

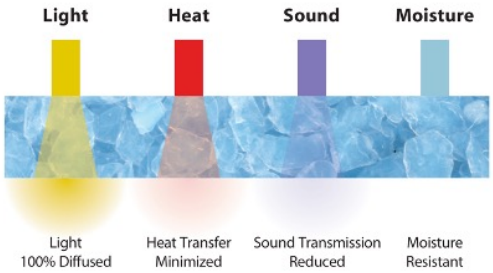
Glass Canopy Systems


Learning
Objective 6
Discuss innovations in
high-performance glazing
technologies.

Glazing Technologies: Aerogel Insulation

Superior Thermal Performance

(six times the thermal value of comparable skylights)

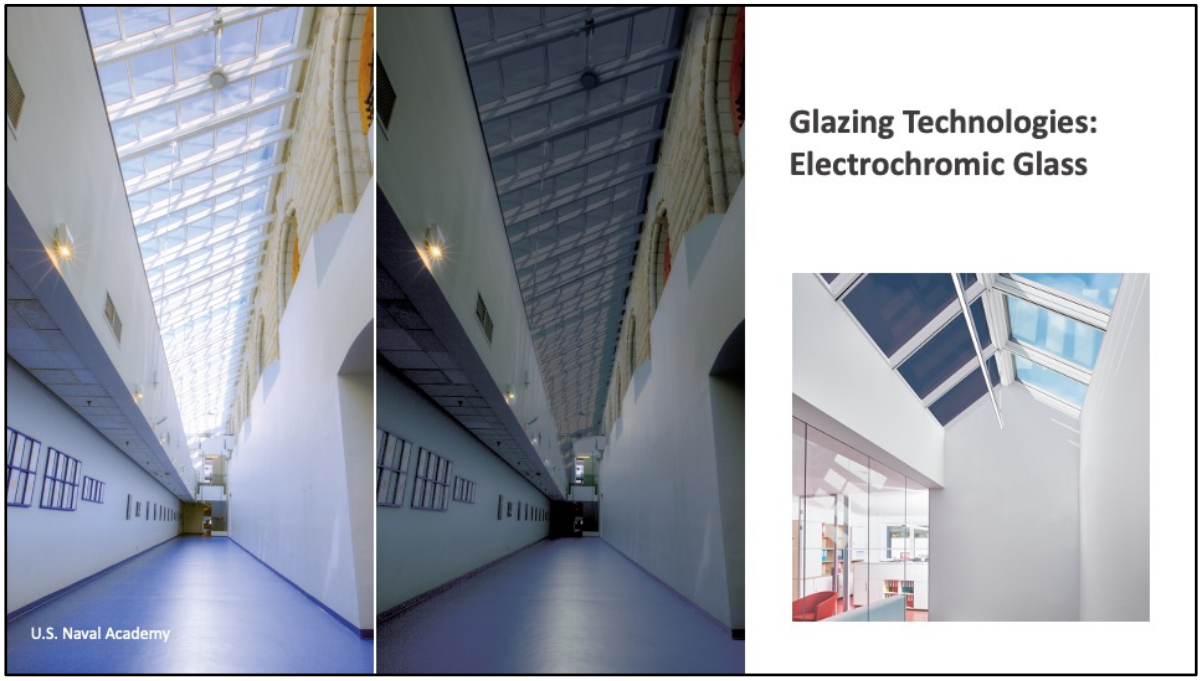


Aerogel filled multiwall polycarbonate panels

The lightest and lowest density solid on the planet, aerogel is made by removing liquid from silica gel, which is made of 10 percent air and 90 percent air. It is inert, made from sand, and has the highest insulative properties known.

When added to skylight systems, it provides superior thermal performance, increasing efficiency six times the thermal value of comparable skylights. Its translucent properties provide diffused, glare-free illumination and it is moisture resistant.

It reduces sound transmission and qualifies as a safer, more sustainable product with a Cradle to Cradle certification.



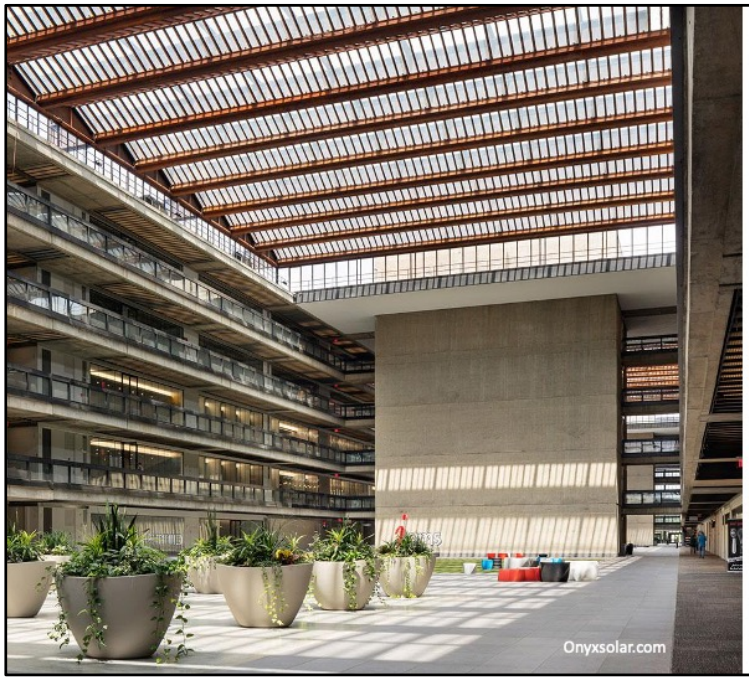
Electrochromic glass provides the glass tinting on demand, allowing unobstructed views with enhanced occupant comfort and reduced heat gain.

Glazing Technologies: Photovoltaic Glass

Modular Skylights with integrated photovoltaic glass.

Both structural and modular skylight systems can incorporate the use of photovoltaics and take advantage of federal and tax energy incentives. Depending on the sky conditions, the crystalline glass is most efficient with direct light; efficiency can reach 16 percent.

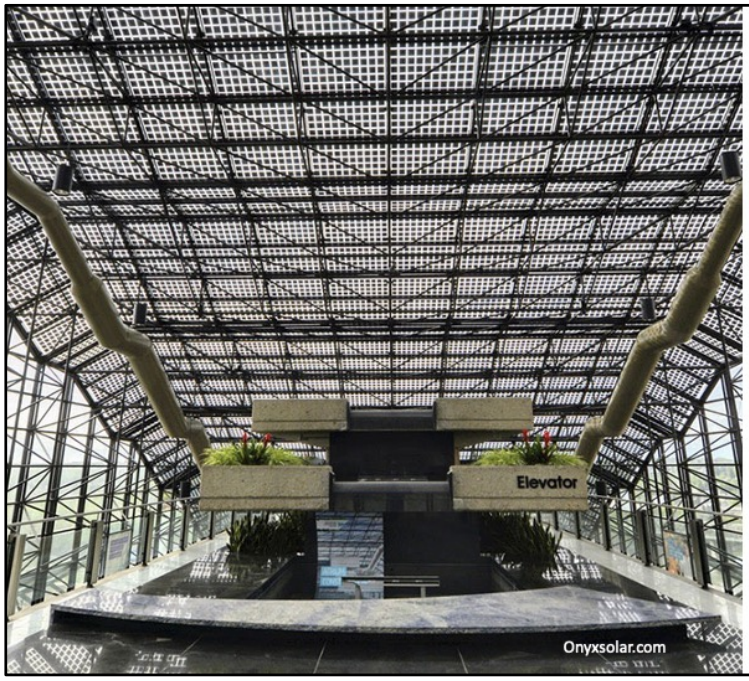
The amorphous glass systems best capture light in ambient (cloudy) conditions.



Glazing Technologies: Photovoltaic Glass

Amorphous
Silicon-Ambient Light

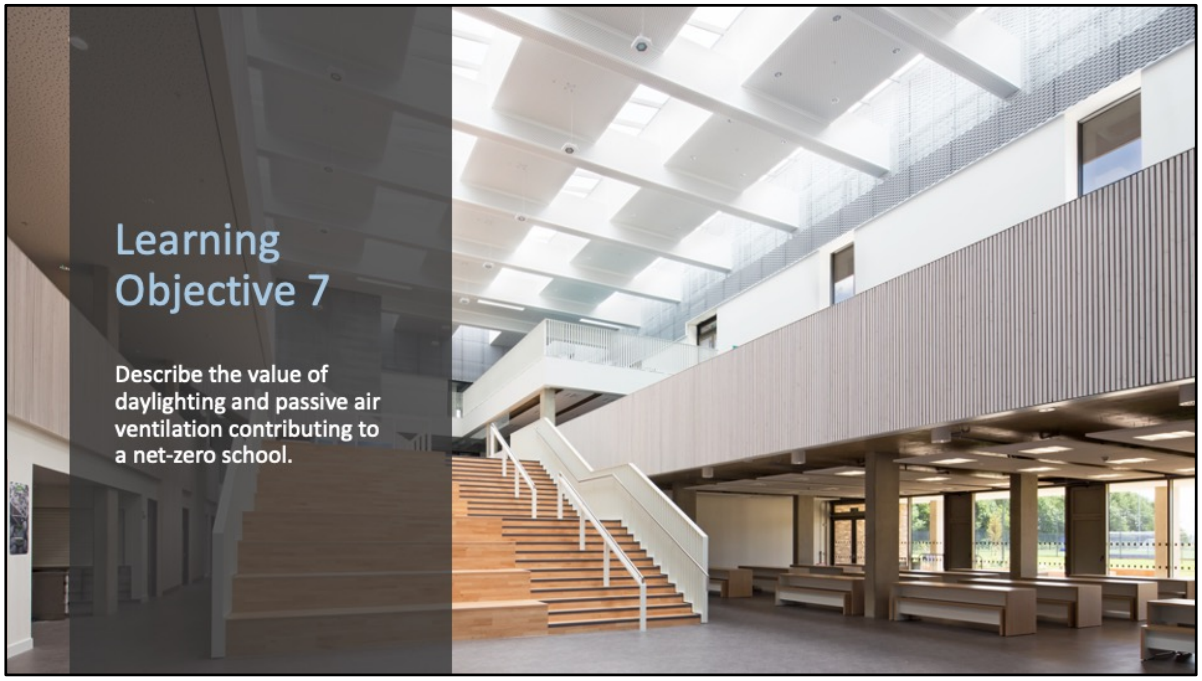
- Greater efficiency/power capacity (Wp/square foot)
- Infinite cell patterns/transparency



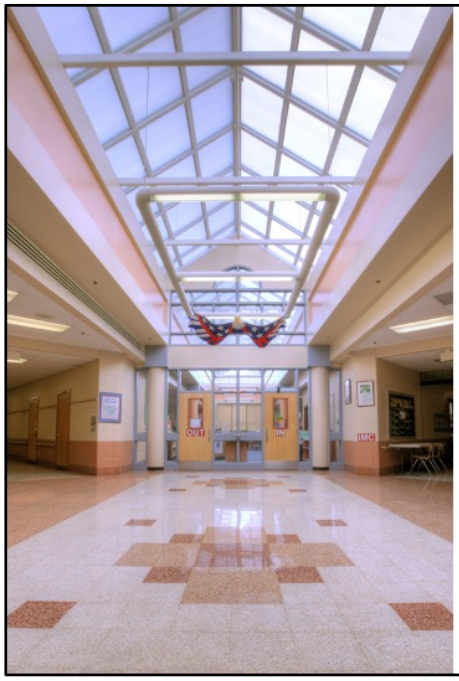
Glazing Technologies: Photovoltaic Glass

Crystalline Silicon-Direct Light

- Unobstructed views
- Efficiency 5–10 percent
- Higher performance in shadows, overcast sky



More schools are being designed to be net zero, which means they generate as much energy as they consume with renewable energy.



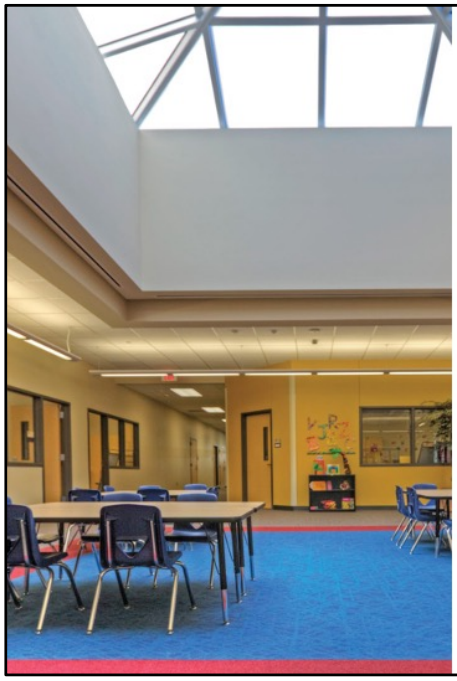
Achieving Net Zero

Net-zero schools feature both the passive ventilation systems for natural ventilation, dedicated outdoor air systems (DOAS) and demand-control ventilation along with effective daylighting strategies.

According to the New Buildings Institute:

- "Schools represent the third largest sector of commercial building energy usage in the United States. School building energy consumption costs U.S. school districts more than $8 billion per year."
- "A child will spend 1,000 hours a year (Center for Public Education) in their school, making a healthy indoor environment of utmost importance."

High-performance and zero-energy schools improve student performance, health and wellness.



Achieving Net Zero

- "School buildings do achieve zero energy and can lead the way for more zero energy/zero carbon buildings in their communities."
- "Zero-energy (ZE) schools have an energy use intensity that is approximately one-third of the average conventional school. ZE schools not only reduce operating costs; they also reduce the carbon footprint of our schools through their use of renewable power."

According to the New Buildings Institute, the number of zero-energy educational facilities has more than doubled since 2014, most of them K–12 schools.

Source: https://newbuildings.org/nbi-key-markets/getting-to-zero-in-schools

Net-Zero Energy: Incorporating Daylight and Ventilation

Modular skylight systems were used on the Creagh School (EU) illustrating aggressive daylighting of side and top daylighting (reducing the light power density) and photo voltaic panels for renewal energy on-site.

Source: https://www.veluxusa.com/professional/products/modular-skylights/reference-cases-longlight-sorting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