# Optimizing Daylight and Visual Comfort in a Middle School, Rainier Valley, Seattle

Lakshmipriya Rajakumar

A thesis submitted in partial fulfillment of the requirements of the degree of

Master of Architecture

University of Washington

2025

Committee:

Christopher Meek

Heather Burpee

Theo Pinceloup

Program Authorized to Offer Degree:

Department of Architecture

University of Washington

## Abstract

Optimizing Daylight and Visual Comfort in a Middle School
Rainier Valley, Seattle

Lakshmipriya Rajakumar

Chair of the Supervisory Committee:
Christopher Meek
Department of Architecture

Daylighting in educational environments is not only a matter of energy performance but also a question of comfort, cognition, and well-being.Excessive glare, uneven illumination, and insufficient control over sunlight impact how students focus, learn, and thrive.This thesis investigates architectural strategies to enhance visual comfort through optimized daylight distribution and glare reduction using advanced performance simulation tools.Focusing on Aki Kurose Middle School in Seattle, WA,this research utilizes **Climate Studio to simulate and evaluate Spatial Daylight Autonomy (sDA), Annual Sunlight Exposure (ASE), Useful Daylight Illuminance (UDI), and luminance section analysis.By integrating architectural elements such as, skylights, North-facing sawtooth roofs, and clerestories,** the project offers a daylight-based school design with balanced lighting on user comfort.

Source:*besanlight*

# *Acknowledgements*

*I thank my parents and brother for being part of my journey of completing the Master of Architecture program. Thank you to Christopher Meek Professor and Director Integrated Design Lab UW Architecture, Heather Burpee Research Professor and Co-Director Integrated Design Lab UW Architecture, and Theo Pinceloup Design Professional Integrus Architecture for working hard to provide me with critical insight that kept me on the right path in my thesis project.*

*And I want to especially thank my father, K Rajakumar, for giving me the confidence that I can achieve anything if I believe in myself and for his endless support to help me get to where I am today.*

# TABLE OF CONTENTS

# LIST OF FIGURES

Figure 1. Early Childhood Center, Paraguay  Source:https://gbdmagazine.com/rktb/

# Chapter 1: Introduction

*"Imagine being a middle school student in Seattle, spending most of the school year under gray skies indoors. You might feel tired or struggle to focus. Now imagine walking into a classroom gently lit with soft daylight—calm, balanced, and uplifting. This is the vision behind this thesis: to create spaces where students feel more engaged, comfortable, and ready to learn."*

Middle school marks a pivotal phase in youth life as it involves both the social shift and the intellectual development. The atmosphere in which learners operate heavily affects their performance, concentration, and physical well-being. Among all environmental factors, sunlight is distinguishable not just as a lighting scheme but also as an active mood enhancer, attention booster, and an aid to cognitive development.

Achieving effective daylighting for buildings in the Pacific Northwest with its overcast skies lasting the better part of the school year becomes an acute design issue. Inadequate or improperly managed daylight can manifest as discomfort and glare, particularly in classrooms where students engage in focusing tasks like reading, writing, and learning from screens.

This research seeks to answer the question: What architectural design methods can improve the quality of natural daylight and decrease the level of glare within middle school classroom settings? A particularly rich case for addressing this question is Aki Kurose Middle School, which is located in the Rainier Valley neighborhood of Seattle. The school services a socio-economically diverse student population, and its location within a rapidly changing urban environment poses significant socio-economic challenges alongside environmental opportunities.Using sustainable architecture principles along with building performance simulation techniques, the research proposes a classroom model and overall school organization that responds actively, comfortably, and dynamically to daylight rather than just allowing it inside.

Figure 2. A Century-Old Bronx School Source:https://www.archdaily.cl/centro-de-la-primera-infancia-equipo-de-arquitectura

.

# Chapter 2: Literature Review

*"We find beauty not only in the thing itself but in the pattern of the shadows, the lights, and the darkness which that thing provides."*[1]

*In Praise of Shadows* by Junichiro Tanizaki

The impact of natural light in schools has been studied extensively in terms of its benefits on academic results, energy savings, and students' psychological and emotional state. Heschong Mahone Group's studies in 2003 showed that student performance was closely tied to availability of windows and natural light in the classrooms. This led designers to reconsider the opportunity of using daylight, as opposed to artificial lighting, as a dynamic feature in the design of schools.

Measurable Goals and Daylighting Standards: New simulation tools have brought forth new performance metrics which include as sDA: Spatial Daylight Autonomy, Annual Sunlight Exposure (ASE) and Useful Daylight Illuminance (UDI). These indicators are now part of the LEED v4.1 daylight credit assessment. As measurement of exceeding daylight sDA portrays the percentage area of a subject space receiving greater than 300 lux on a horizontal surface 0.76m (30”) above finished floor for 50% of the occupied time while ASE flags space for gaze revealing glare of over 1000 lux of direct beam sunlight for over 250 hours/year. UDI builds on metrics like these, describing light as usable which surpasses 100-2000 lux.

Visual Comfort and Glare Studies: Work done by Sheedy et al. (2005) and Figueiro & Rea (2016) emphasizes the negative effects of glare on visual fatigue and cognitive overload in educational settings. Glare reduces visual performance and also causes physiological discomfort. In classrooms, glare can be the result of direct sunlight, strong reflections, or extreme contrast of light on the instructional surfaces.

## Section 2.1 Architectural Strategies:

Design responses include orientation-sensitive massing, building section geometry”,” strategic window sizing, use of high-visible transmittance glazing, light shelves, clerestories, and advanced shading systems. North-facing openings and sawtooth skylights which diffuse skylight are also supported by research as providing uniform illumination. Other research highlights the contribution of surface reflectance and ceiling height to the overall daylighting effectiveness of a space.

### 2.1.1 Psychological and Emotional Well-being

The importance of daylight in fostering the psychological, emotional, and behavioral health of students in particular has been highlighted in several studies. Figueiro and Rea (2016) state that access to daylight at school helps in the regulation of circadian rhythms which in turn positively stabilizes one’s mood, energy, and alertness. Rosenthal et al. (1984) noted the lack of exposure to daylight as one of the causes of seasonal affective disorder (SAD), which can be detrimental to one’s motivation and participation in school activities. The presence of natural light improves cognitive and emotional abilities as well as provides a spatial and temporal orientation.

Figure 3. Physiological and Emotional Well being
Source:https://www.technologynetworks.com/proteomics/news/circadian-control-of-immune-cell-linked-to-clearance-of-alzheimers-protein-358437

### 2.1.2 Eye Strain and Visual Fatigue

In educational settings, poor light conditions are a common cause of eye strain. Research done by Sheedy, Smith, and Hayes (2005) indicates that negative contrast and glare are major causes of visual fatigue, headaches, and lowered understanding. These problems can be reduced with the proper use of daylight design which includes the use of soft light and appropriate shade, neutralization of glare, which also increases sustained attention and performance on tasks.

Figure 4. Eye Strain
Source:https://www.technologynetworks.com/proteomics/news/circadian-control-of-immune-cell-linked-to-clearance-of-alzheimers-protein-358437

### 2.1.3 Light and Human Consciousness

Light is important for shaping human perception, thinking, and awareness. Biological functions of light in the human circadian system and hormonal secretion control are discussed by Czeisler and Gooley (2007) as well as Foster and Kreitzman (2014). Changes in light level, its intensity as well as quality, impact the span of attention, memorizing, and educational activities performance. The presence of natural light in the morning has been shown to improve alertness and sleep—both of which support academic performance.

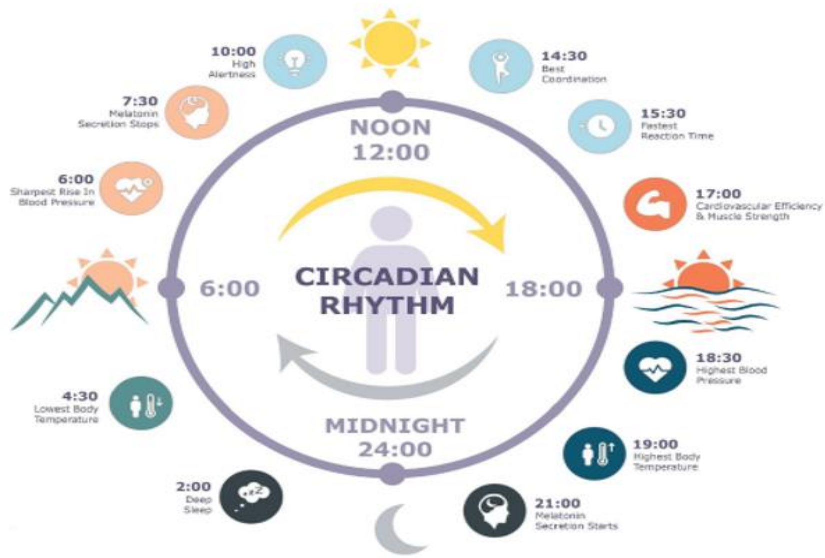



Figure 5. Relationship between circadian rhythm and the sun cycle.
Source:https://www.news-medical.net/health/Circadian-Rhythm.aspx

### 2.1.4 Biophilia and Its Role in School Design

The biophilia hypothesis proposed by Kellert and Wilson (1993) argues that humans have a natural inclination to connect with nature. In educational environments, the use of daylight, views of nature, and natural materials resonate with this instinct. According to Yin et al. (2018) and van den Bogerd et al. (2020), students' attention, creativity, and emotional control are enhanced in classrooms with natural light and green plants. These strategies aid stress levels and foster a healthier learning environment along with further supporting cognitive function.

All of these findings assist in forming strong conclusions on the evaluation of the quality of daylighting concerning its effects on health and well-being, along with learning performance—factors that should be taken into account when designing Aki Kurose Middle School classrooms.

The positive effects of daylight on health and well-being, as well as the principles of biophilic design, are interlinked. Daylight has a calming influence, improves attention, and supports health, which are all positive responses noted in biophilia. Incorporating views with dynamic changes of light as well as natural patterns further improves the classroom perceptibility.

Figure 6. Biophilia and its role in school
Source:https://stockleygardendesign.com/courtyard-garden-islington

## Section 2.2: Impact of Daylight in Middle School Education

Natural light influences children greatly. Children, being active, engage in constant movement. Natural light needs to be taken into consideration when thinking about the health of children because it influences their wellbeing as they grow up. Children need more exposure to daylight compared to adults. Curiosity also shortens the attention span of children. Providing exercises to teach children within the concentration helps grab their attention and improve focus in educational spaces. In the end, while childhood is a short-lived stage of life, the experiences encountered during it greatly impact one's future.


Figure 7. Characteristics of children
Takagi, K. (2024). *Master of Architecture thesis report*. College of Built Environments, University of Washington, Seattle.

### 2.2.1 Daylight Improves Learning Efficiency

According to the Heschong Mahone Group of California Board of Energy Efficiency (see results in fig. 28), children's efficiency in learning improves with enhanced learning. In addition, the variation in levels of light increases their attention span and also helps to stimulate elementary school students' brains.

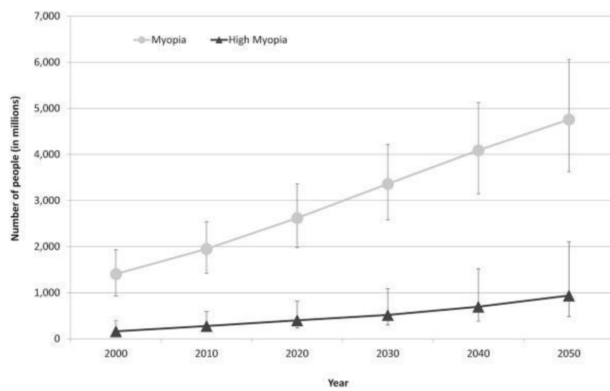
| Seattle | Analysis Results | | | | Percentage Effect | |
|---|---|---|---|---|---|---|
| ITBS Iowa Test of basic Skills NCE Scale 1-99 | Difference in Average Test Scores (NCE percentage points) | | Statistical Certainty | | Difference as a a % of District Average Score | |
| Spring Scores | Reading | Math | Reading | Math | Reading | Math |
| **Combined Daylight Model** | | | | | | |
| Daylight, Min. to Max. | 7.5 | 5.6 | 99.9% | 99.9% | 13% | 9% |
| **Separate Skylight and Window Model** | | | | | | |
| Windows, Min. to max. | 7.7 | 8.7 | 99.9% | 99.9% | 13% | 15% |
| Skylights, Min. to Max. | 3.9 | 3.4 | 99.9% | 99.8% | 7% | 6% |

Figure 8. Heschong Mahone Group, *Summary Daylight Findings for Seattle* (California Board of Energy Efficiency, 1999), 20, fig. 10.

### 2.2.2 Prevention of Myopia

Research by Arumugam Muralidharan et al (2021) has suggested that increased prevalence of myopia is associated with the lack of outdoor activity in children. Sunlight can delay, or even prevent, the onset of myopia. 9 Natural light does more than aid sight, its qualities and benefits surpass those of artificial light. Young children benefit from exposure to daylight while myopia is progressive, and during their rapid growth phase.

Figure 9. Brien, Holde a, et al, *Graph showing the number of people estimated to have*




*myopia and high myopia for each decade from 2000 through 2050.* (PubMed, 2016), fig. 2

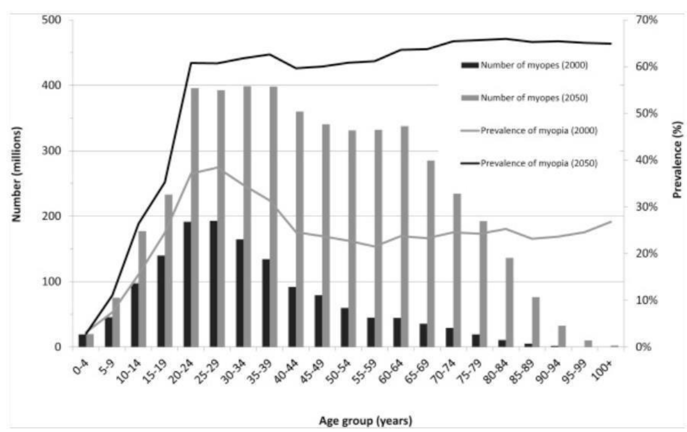



Figure 10. Brien, Holde a, et al, *Graph showing the distribution of people estimated to have myopia across age groups in 2000 and 2050.* (PubMed, 2016), fig. 3.

### 2.2.3 Reduction of Seasonal Associative Depression Symptoms

Seattle suffers from seasonal depressive disorder due to insufficient Vitamin D from a lack of natural light. Seasonal Depression, also known as Seasonal Affective Disorder (SAD), is more common in children and adolescents. In Seattle, students are confined to classroom cubicles as the sun moves across the sky during winter months.

Designing classrooms with windows would help alleviate depression symptoms in students.

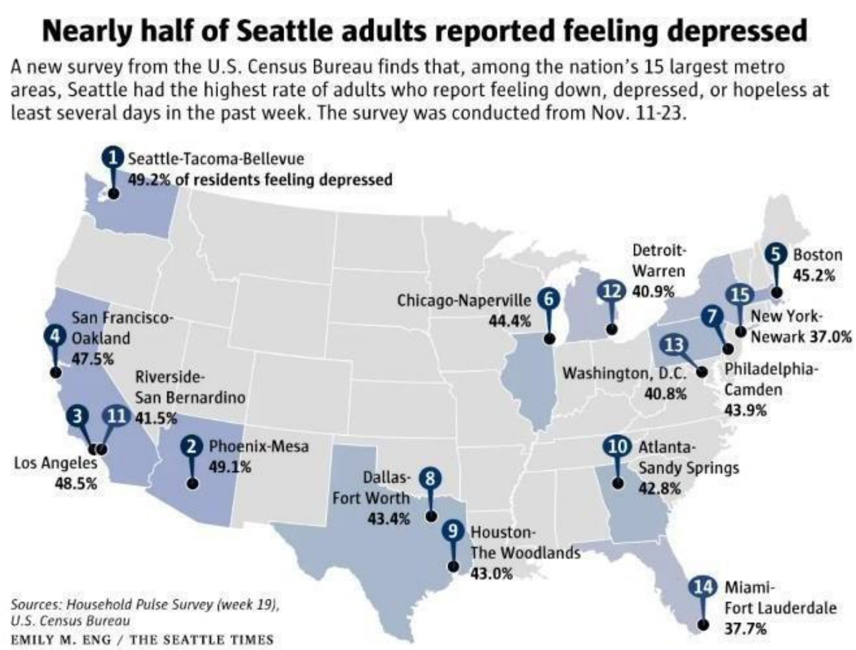



Figure 11. Eng, Emily M, *Household Pulse Survey (week 19), U.S. Census Bureau.* (The Seattle Times, 2023), fig. 2

## 2.2.4 Daylight in Schools

Before fluorescent light became common in the 1950s, schools relied on natural daylight as the main source of lighting. The California Department of Education had standards concerning daylighting for classrooms designed during the 1950s and early 1960s. To comply with regulations, architects used to design Finger Plan layouts which maximized daylight in classrooms. The buildings consist of several tiers of single classrooms with two-sided windows. Nevertheless, the regulation was dropped due to high construction costs, trenches created by construction-cutting engineers, and scant evidence supporting the arguments for the role of daylight in education.

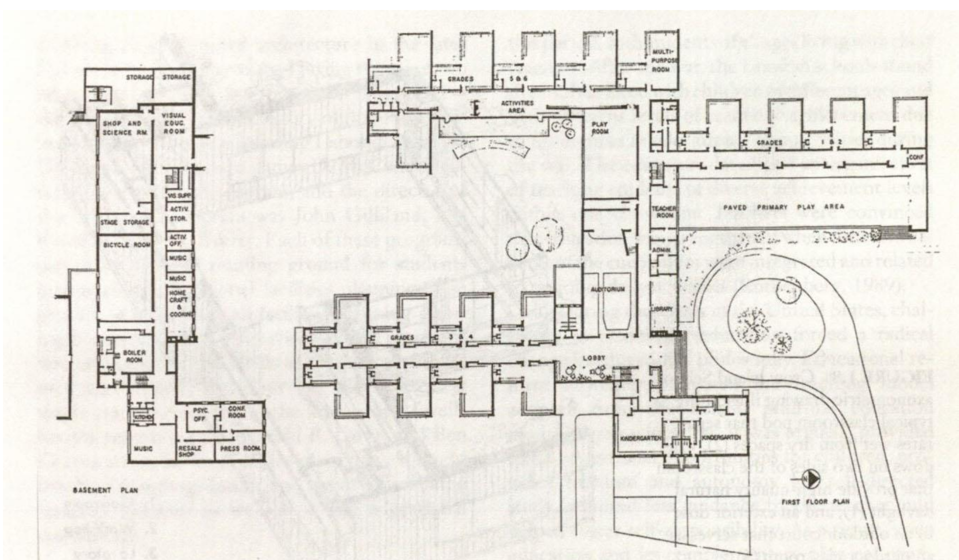



Figure 12. Finger-plan school.Source:Heschong Mahone Group. “Daylight in Schools.” *An Investigation into the Relationship Between Daylighting and Human Performance*. California Board for Energy Efficiency, 1999. 4-5.

Figure 13. Gellner, Arrol. *THE "CALIFORNIA" FINGER-PLAN SCHOOL*. April 7, 2020. *Architext*. Source:Takagi, K. (2024). *Master of Architecture thesis report*. College of Built Environments, University of Washington, Seattle.

The majority of schools constructed after the widespread adoption of electric lighting lack windows. It is more efficient to throw up four walls with little to no windows. Numerous schools in Seattle are also situated without windows. Given that clear-sky days are scarce during the academic calendar (from autumn to spring), children receive minimal exposure to daylight while at school.

Figure 14: Marbel, Joe. *The African American Academy Building in Seattle*. 2010. Source:Takagi, K. (2024). *Master of Architecture thesis report*. College of Built Environments, University of Washington, Seattle.


Figure 15: Swedes, Geeky. *The Webster School in Seattle.* 2017.
Source:Takagi, K. (2024). *Master of Architecture thesis report*. College of Built Environments, University of Washington, Seattle

Figure 16: Martin Luther King Jr. Elementary School in Seattle.
Source:Takagi, K. (2024). *Master of Architecture thesis report*. College of Built Environments, University of Washington, Seattle.

Figure 17. A classroom well-lit from daylight.

Figure 18. Callahan. “Seating Arrangements,” 2012.

Source:Takagi, K. (2024). *Master of Architecture thesis report*. College of Built Environments, University of Washington, Seattle.

### 2.2.5 Lighting in Schools: From Natural Rhythms to Artificial Uniformity

As with corporate offices or hospitals, modern school lighting has become uniformly cold and excessively bright. Productivity metrics have taken precedence over the well-being of students, which further emphasizes the issue. In contrast to this, traditional architecture gives buildings a more sensory experience where daylight gracefully transforms into shadow, providing a rhythm in repose.

Old school buildings too, once demonstrated some level of illumination through gradients. Sunlight could be seen streaming through the high clerestory windows or side lighting, which encouraged spatial awareness of time and seasons. Now, many classrooms feature three white walls, trapped in a fully recessed uniform lighting world—separated from any tactile or temporal connection to the outside world. In some cases, students are even positioned overlooking the windowless walls, resulting in disconnection from natural light, exterior views, and nature itself.

This lack of light outdoors comes as part of a larger shift. With the introduction of artificial lighting, schools were crafted with the intention of efficiency, stability, and control. At the expense of these factors, buildings limited their exposure to time cues, eliminating the ability to experience the shifting flow of daylight throughout the day. Instead, students are left staring at the clock, the only remaining marker simulating the passage of time. Without natural light or visual access, the classroom becomes a static, almost lifeless shell.

My thesis attempts to untangle the issues. At Aki Kurose Middle School in Seattle's high latitude, cloudy, my research puts dynamic daylighting back on the table as a master architectural design principle.

My research case study uses the metrics sDA, ASE, UDI, along with luminance section analysis and looks into how effective daylight control design—using skylights, clerestories, light shelves, and sawtooth roofs—can bring the classroom to life.

In accepting light's cycles, we restore its rhythm and health while transforming the learning environment to one that enhances, and responds to, the academic needs alongside the psychological and emotional wellbeing.

## Section 2.3: Architectural Lighting and Climate

Seattle’s latitude (47°N) creates unique challenges that are seasonal in nature. In the winter, shorter days and lower solar angles reduce sunlight access while in the summer, there’s an overabundance of daylight that can be harnessed for energy-efficient practices such as lighting control. In this regard, educational facilities located in Seattle need to adapt to its seasonal changes to maintain appropriate levels of comfort and visual energy efficiency throughout the year.

Classrooms and community areas can receive natural light more deeply through architectural features like north-facing clerestories, light shelves, and sawtooth roofs. Additionally, overhangs and vertical fins reduce glare while still offering views outside, which is crucial for student health and biophilic design.

In the context of Seattle's seismic activity, the protruding architectural features such as timber trusses and columns interact with natural light to produce captivating shadows and contrasts, while also adding resilience to the structure.

In educational spaces, these light gradations, which evoke the feeling of classic architectural spaces, help bring back a sense of temporal rhythm—an element often absent in spaces flooded with uniform lighting—that is so important for learning. When executed with regard to the overall design, these ideas have the potential to help shift the perception of the classroom from a static, artificial-light box to a dynamic, responsive, naturally lit space, fostering calm concentration while minimizing eye discomfort and enhancing the experience of time and place, which aims to the primary objectives of this thesis.

# Chapter 3: Methodology

This chapter outlines the holistic approach undertaken to enhance the daylighting and visual comfort for the Aki Kurose Middle School in Seattle. The procedures include context climate analysis, architectural simulations, evaluation of daylighting and glare metrics, and comprehensive design resolution. Each method was formulated with regards to learning environments on an elongated latitude with predominantly overcast skies while enhancing the architectural visual delight appropriate for the students.

The central vision of this project is to create a climate-responsive, student-centered middle school that supports visual comfort and cognitive well-being through daylight-optimized design. Located in the high-latitude, overcast region of Seattle, the project reimagines traditional school typologies by integrating biophilic strategies, solar-responsive envelopes, and performance-based analysis into a cohesive architectural solution.

## 3.1 Site Context and Justification

The chosen location is within the boundaries of Rainier Valley, a region celebrated for its cultural characteristics and availability of natural open spaces. Notably, this location is where Aki Kurose Middle School currently stands, and the design aims to preserve this location to reduce impact on community disruption.

This location has favorable conditions such as Brighton Playfield which can promote further integration with the community as well as outdoor learning. The existing zoning (SF 5000) and moderate slope topography create an opportunity for vertical planning of institutional facilities. Also, the other forms of public transportation available and the surrounding density promote safe and easy access to commute for students, further integrating the school with the city.

## 3.2 Program Development

The school accommodates a variety of programs tailored to contemporary middle school needs. The design balances academic, social, and recreational zones:

- **Academic**: 32 classrooms, reading and math rooms, science labs.
- **Social & Wellness**: Breakout rooms, meditation center, counseling space.
- **Physical**: Main gymnasium, basketball courts, fitness room.
- **Community**: Library, teaching kitchen, cafeteria (cafetorium).
- **Outdoor Spaces**: Courtyards, rooftop greenhouse, plazas.

The program is distributed to promote daylight access in all learning zones while maintaining efficient circulation and acoustic separation.

## 3.3 Site and Climate Analysis

This approach begins with analyzing the geographical macro and microclimatic aspects of the school's Gardens at the base area in Seattle's Rainier Valley. While working with Climate Consultant 6.0, I processed the EPW weather data of Seattle-Tacoma International Airport. My analysis revealed several interesting points, including:

- Geographical position and solar angles: Seattle is high latitude city at 47.6° N, thus experiencing very steep solar altitude changes. The solar altitude change Seattle has during the winter and extended daylight period summer (around 16 hours/day in June).
- Cloud incidence and the potential for daylight: The site has approximately 226 days of cloud cover per year with 164 days of overcast weather which markedly restricts direct sunlight on the site. This greatly impacted the primary daylight illumination simulation CIE sky models which rely the use of overcast sky.

**CIE Sky Models**

The CIE (Commission Internationale de l'Éclairage) sky models represent standardized sky luminance distributions for different weather conditions and sky states. The CIE Standard General Sky is comprised of 15 types of partly cloudy to fully cloudy skies, each with specific mathematical formulas that emulate real sky conditions which are necessary for precise daylight evaluation in a building design.

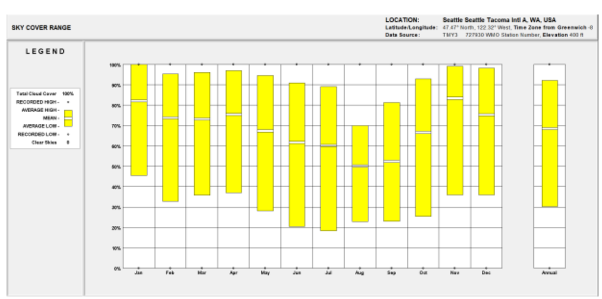



Figure 19.Sky Cover Range
Source:Climate Consultant

**Surroundings and Topography:** The urban study observed gentle slopes in conjunction with adjacent open spaces like Brighton Playfield that were capable of flooding light into the interior spaces. Zoning data SF 5000 and orientation factors affected massing and fenestration approaches.


Figure 20.Site - Aki Kurose Middle School Seattle
Source:Author (Lakshmipriya Rajakumar, 2025)

## 3.4 Spatial Programming and Design Parameters

- Design zoning: Spaces were merged based on occupancy and of participatory visual tasks. In this case, classrooms and libraries were assigned as high uniform daylighting zones.
- Orientation analysis: Block diagrams showing the spatial distribution of occupied vertical sightlines in classrooms were drawn for light entry at cardinal openings. For classes, South and North were optimized, and gym and cafeteria spaces had clerestories and skylights to bring in light from above.
- Target daylight levels: Standards IES set were defined in a range of 300-500 lux for distraction-free learning spaces. Those calculations were used

as benchmarks in simulations.

## 3.5 Attributes of Spaces of Focus

| SPACE | HOURS | NO | SF | STRATEGIES |
|---|---|---|---|---|
| Classroom | 7am – 6pm | x32 | 900 sq/per room | N – S 30% to 40% Orientation. Low E, High(VT)In south - west corner |
| Breakout rooms | 7am – 6pm | x16 | 900 sq/per room | |
| Gym/Basketball | 8am – 10pm | x3 | 15000 sq ft<br>5000 sq ft | Diffuse daylight, Sawtooth roofs, skylights, and clerestories. |
| Kitchen | 7am – 6pm | x1 | 3600 sq ft | Task lighting, ambient lighting, glare control, and adjustable artificial lighting. |
| Cafetorium | 7am – 6pm | x1 | 13000 sq ft | E–W 20% to 30% Orientation. Low-E, High (VT) in North-South Facade |

Figure 21. Attributes of Spaces of Focus

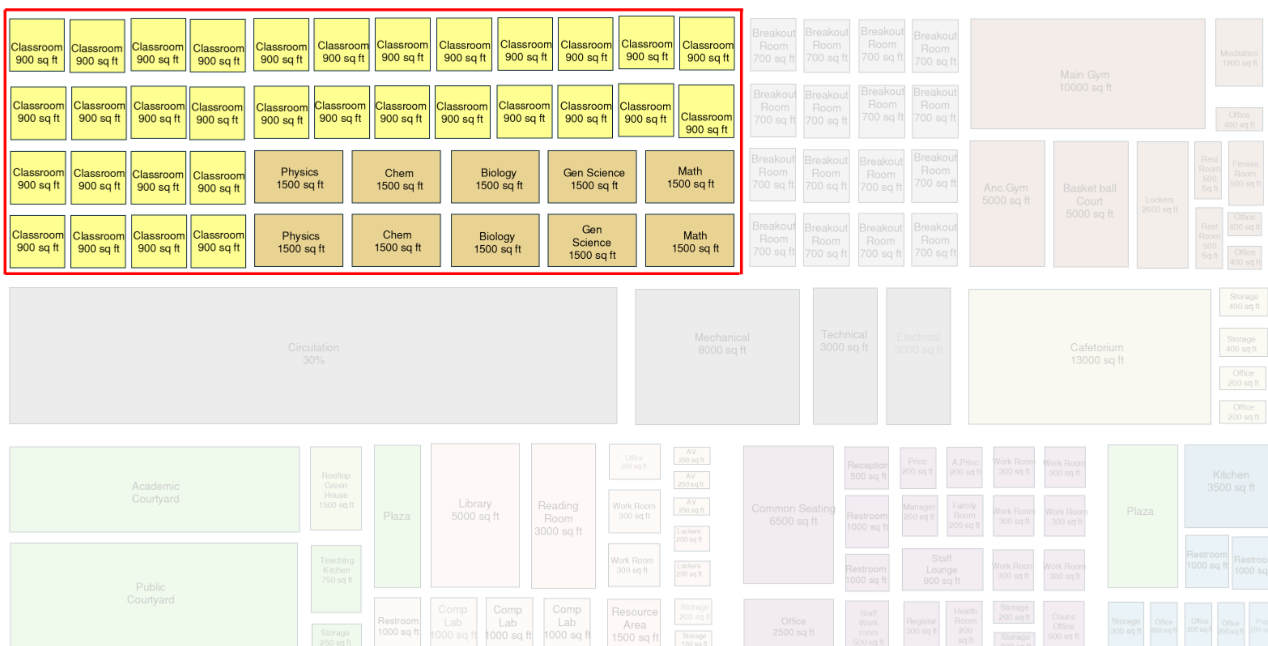



Figure 22. Programming Matrix - Breakout Room

## 3.6 Characteristics of a Classroom with Good Daylighting

Well implemented daylighting windows in classrooms improves instruction, learning comfort, performance, and well-being of students. The design of windows should take into consideration the balance between the amount of light coming into the building (natural lighting), glare, and distribution of the light within the building in relation to the movement of the students for various activities. In this part, the critical level of light quality requirements and space specification bounding the achievement of the constructive solutions for the classroom lighting systems are defined.

### 3.6.1 Light Quality Goals

The following objectives of visual comfort degree should be defined for the classroom day-lighting methods:

- **Even Light**: provides the required level of illumination ideal for visibility purposes on whiteboards and black/ digital presentation boards.
- **Focus:** required for reading and writing where low contrast and brightness is essential.
- **No Glare:** avoidance of visual discomfort-related issues arising from screen reflections, glossy surfaces, or sunlight flooding through windows.
- **Clear Text:** encourages the eyes to rest through enhanced concentration and achieving low eye strain on materials printed on paper and digital devices.

All these goals are fundamental as far as the quality of design cuts, glasses, outlines, and shields for the direct sun rays are concerned.

### 3.6.2 Special Strategies for Achieving Daylight

For accomplishing preferred performance associated with spatial daylighting, and comfortable viewing options, we propose further measures.

- Light-control elements reflect light farther into the space and at the same time provide shading for the lower windows.
- Skylight serves to bring windows that provide light from above and distributes it uniformly around the space.
- Enhanced vertical daylight availability is Improving Double Clerestory Windows; the best results are obtained with 30 percent WWR.
- These systems were tested in massing variations with 20 by 20 floor plates to test configurations for the breadth of daylight exposure.

### 3.6.3 Spatial Requirements for Daylight Performance

Design Illumination 500 lux (standard target for classrooms to support general learning tasks) teaching/supervision/adult participation in child-centered activities)

- Target sDA (Spatial Daylight Autonomy) ≥ 85% of space should receive adequate daylight for at least 50% of occupied hours
- Direct Sunlight Control Required during instruction hours to avoid glare and overheating
- Exterior Views Vital for psychological comfort, spatial orientation, and overall health and wellbeing of the building occupants
- Space Darkening Not required, given appropriate passive sun control strategies.

## 3.7 Characteristics of a Breakout Rooms with Good Daylighting


Figure 23. Programming Matrix - Breakout Room

### 3.7.1 Light Quality Goals

Daylight quality in breakout rooms is important for fostering individual concentration as well as group interactions. Other important goals include:

- **Even Lighting:** Consistency of light level across various spaces for improvement of visibility of whiteboards, group presentation materials, and other shared surfaces.
- **Glare Control:** Reduces discomfort and strain on the eyes when reading, writing, or engaging with screens.
- **Screen Visibility:** Supplements clarity of digital displays while

decreasing reflections from natural light.

- **Mood enhancement:** Stimulates a soft and gentle atmosphere contributing to face-to-face interaction and inspiring creative thinking.

**Strategy Function**

- Skylights Opening Overhead daylight for spatial zoning achieving natural light throughout the spaces.
- Double Glazing Clerestory Windows High positioned ~30% glazing ratio to diffuse vertical daylight, glare reduction, modest acoustical privacy performance obstructions.

These approaches are appropriate for the 10′ × 20′ configuration assessed for daylight sufficiency.

### 3.7.2 Spatial Comfort and Daylighting Requirements

Design Illumination 300 lux (standard for informal collaboration and discussion-based activities)

- Target sDA (Spatial Daylight Autonomy) >= 90% of the space should receive adequate daylight for at least 50% of occupied hours
- Direct Sunlight Control Required during working hours to reduce glare and thermal discomfort
- Exterior Views Crucial for occupant well being and visual relief
- Space Darkening Not required due to use of passive daylight control strategies

## 3.8 Characteristics of a Gym/Basketball Court with Good Daylighting


Figure 24. Programming Matrix - Gym/Basketball Court

### 3.8.1 Attributes of Gymnasium / Basketball Court

The design of a gymnasium or basketball court should incorporate restriced and systematic windows for letting in daylight as they facilitate numerous fast pace activities, safety procedures, and player's comfort visually. As opposed to classrooms or breakout spaces, gyms have clear requirements for lighting range and distribution within the floor space. This subsection specifies the main lighting objectives and functional area outcomes for indoor courts and gymnasiums.

### 3.8.2 Light Quality Goals

To fulfill the goals which concern lighting, the following daylighting aim must be set as a top priority:

Even Lighting: Eliminates shadows across the court surface to support safe and accurate movement.

**Soft Light:** Supports alertness while removing stress from the eyes.

**Glare Control:** That is ensuring no strain from bright reflects off surfaces while safeguarding fast pace visual clarity and sanity.

**Natural Variation:** Helps sustain an influx of calm, while providing high levels of energy during the exercise itself; which helps control the players' rest and activity cycles.

### 3.8.3 Spatial Daylighting Strategies

To achieve the high daylighting levels required from the information above and the correction to enhance player's comfort, it is best placed Defined: energizing floors and ceiling placed above level areas.

**Skylights with Light Diffusers:** As WWR ~20% are highly recommended ranged from single to 20 percent.

**Strategy Function**

High windows are placed between the 20% to 30% range of window to wall ratio to allow horizontal daylight with acoustic performance.

These features are default within the gym spatial layouts of 100′ × 85′ and 78′6′′ × 78′6′′ with highly diffused 28′ ceilings to enhance the uniformity and penetration of daylight.

### 3.8.4 Spatial Requirements for Daylight Comfort

Design Illumination 400 lux (adequate for physical activity and sports settings)

Target sDA (Spatial Daylight Autonomy) ≥ 90% of the floor area is to receive adequate

sunlight for at least 50% of occupied hours **daylight sufficient**

Direct Sunlight Control Required during operations to prevent glare and high heat accumulation. Exterior Views of Primary Importance Not vital for gym use but daylight still matters for comfort and esthetic value.

Space Darkening Due to the use of diffused skylights and high-level glazing, this is not necessary.

## 3.9 Characteristics of a Kitchen with Good Daylighting

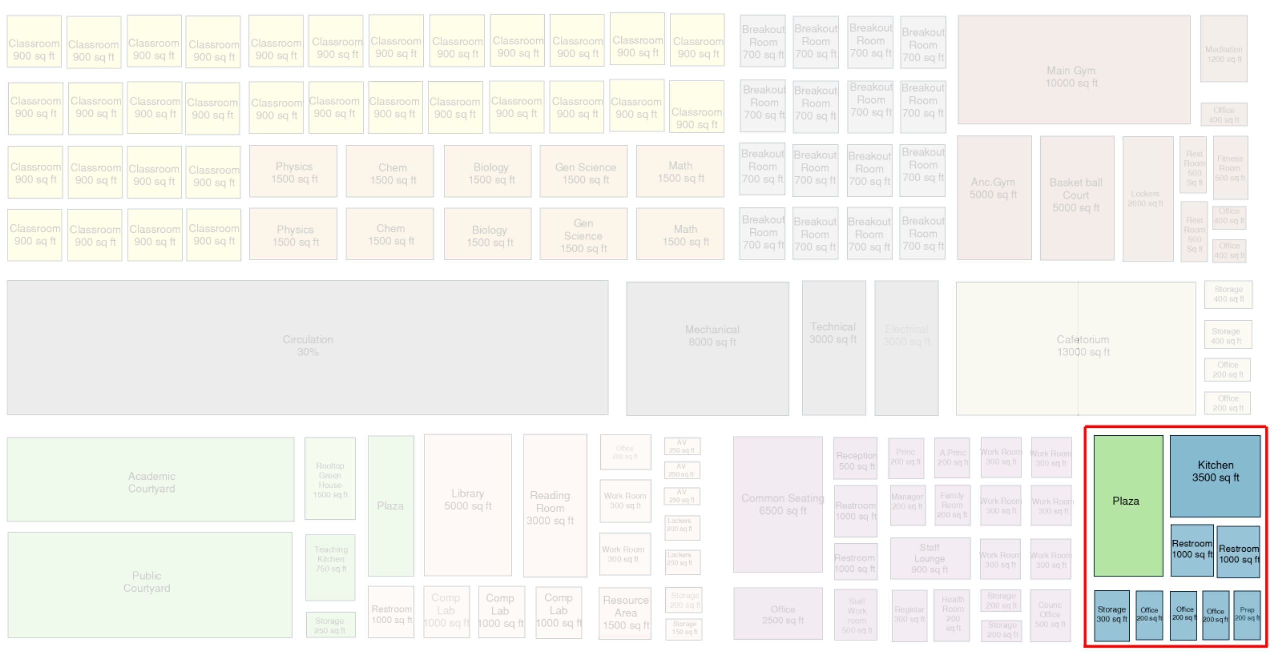



Figure 25. Programming Matrix - Kitchen

### 3.9.1 Attributes of Kitchen

Kitchens within educational or community settings require the highest quality illumination systems for accomplishing tasks because of comfort factors. Proper daylight utilization makes food preparation easy, enhances user satisfaction and wellness, and minimizes the use of electric light sources. This part describes level of light quality objectives and spatial daylighting approaches optimization relative to community kitchen setting.

### 3.9.2 Light Quality Goals

Objectives specific to the core principles of safety, clarity, and comfort consideration for operations performed under grade A daylighting in kitchen premises include the following:

- **Task Lighting:** Provides high-contrast illumination for cooking, cutting, and food preparation tasks.
- **Ambient Lighting:** Provides adequate coverage for all portions of the kitchen area so that there are no spaces that are inadequately illuminated or excessively bright.
- **Glare Control:** Mitigation of workstation and stainless steel appliance reflections to fulfill comfortable living for good cuisine enjoyment.
- **Natural Light:** Allowing for maximum entering of daylight into a room so that the room is illuminated, warm, inviting, and consumes significantly less energy at all times.

All these illumination characteristics are vital particularly in the kitchen spaces as hygiene, security and operational productivity are key factors.

### 3.9.3 Spatial Daylighting Strategies

The kitchen design aims at complementing the sDA requirements by integrating the passive daylighting methods to achieve a functional and high performing kitchen throughout the year. The Kitchen has the architectural features as described below:

- Double Glazing Windows (30% WWR) Enhancing visibility while permitting lateral daylight entry with minimal thermal insulation and ease of cleaning.
- Sawtooth Roof with North Glazing Bubble The window is precisely at 30°–45° which enables harnessing diffuse daylight without heat gain. This is ideal for deep daylight penetration and glare control.

These features are optimized for a 70′ × 50′ kitchen footprint with a vertical clearance of 28', encourages the achievement of visual comfort while effective task lighting.

### 3.9.4 Requirements on Daylight Performance Spaces

- Design Illumination:500 lux (needed in the kitchen and food preparation areas)
- SDA sDA (Spatial Daylight Autonomy) Target value: ≥ 100% (entire space is daylit for more than 50% of operating hours)
- Exterior Views are important for positive psychological involvement in the cooking activities

## 3.10 Characteristics of a Cafetorium with Good Daylighting

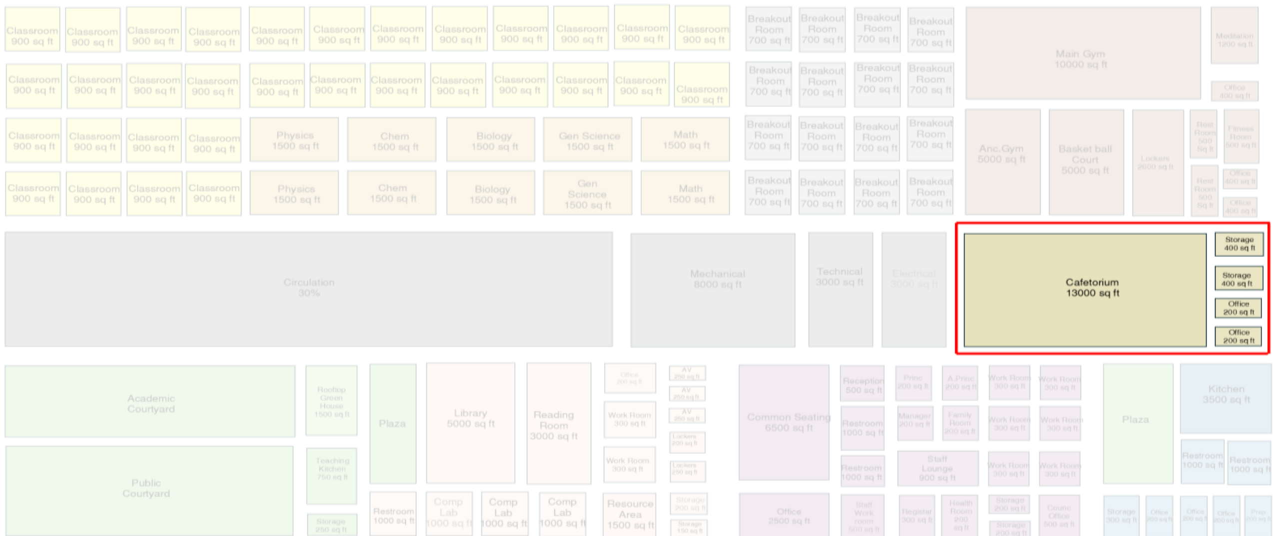



Figure 26. Programming Matrix - Cafetorium

### 3.10.1 Attributes of Cafetorium

The cafetorium is a multifunctional space designed for dining, social interaction, and various community events. It makes use of lighting strategies that promote comfort, productivity, and inviting ambiance during different times of day, thus fostering a pleasant experience at all times. The following specific lighting objectives and spatial performance parameters for a cafeteria fit the overall requirements specified above.

### 3.10.2 Light Quality Goals

The listed requirements of low discomfort glare for multi-use, multi-occupancy eating and gathering places distinguishes it in the realm of architectural design.

- **Task Lighting:** Ensures clear visibility for food service, seating arrangements, and navigation within the room.
- **Ambient Lighting:** Ensures uniform illumination of all areas and

circulation paths of dining zones without excessive or stark contrasts within the space, dimming corners and harsh spaces.

- **Glare Control:** Controls the visual surface reflections from tables, trays, and food service equipment to and from the eyes of diners for an aesthetically pleasing dining environment.
- **Natural Light:** enhances the quality of air indoors with daylight while suggesting openness, uplifting, community-centered ambiance.

### 3.10.3 Spatial Daylighting Strategies

As a result of the targets, the high volume public spaces like the cafetorium are equipped with powerful advanced daylighting features, so the designs incorporated are fully customized.

- Double Glazing Windows (30% WWR) – These windows give laterally incident diffused daylight and are jet-balanced with regards to external views and internal comfort.
- Sawtooth Roof with North-Facing Glazing – Soft, indirect light from the North is allowed into the building by this roof, which is set at an angle of 30–45°. This is advantageous for more controllable ambient illumination with less solar heating.

The above system works for a separated lighting trough design based on a dasher board cafetorium volume rectangular system with 100' × 135' × 28' dimensions. For structural and aesthetic considerations, spatial uniformity in the degree of daylight exposure is maintained.

### 3.10.4 Digital Simulation Tools

The entire set of simulations were done on the Climate Studio plugin for Rhino 8, which is a validated daylighting simulation add-on utilizing Radiance and Daysim engines. The 3D model of the school was constructed in Rhino from the architectural drawings alongside the conceptual massing to guarantee correct geometry and material calibration.

### 3.9.5 Simulation Workflow:

1. Creating the space: geometry modeling and zoning.
2. Setting the value of material reflectance and window glazing characteristics (e.g., walls 0.5, ceiling 0.8, floor 0.3, glazing VT 0.6).
3. Importing a weather file (Seattle EPW).
4. Rendering with Radiance and simulating with grid-based sensors point mid-level calculations.

### 3.10.6 Daylighting Performance Metrics

To assess daylight quality, three metrics were employed:

**a. Spatial Daylight Autonomy (sDA 300/50%)**

Evaluates the percentage of regularly occupied floor area that receives at least 300 lux of daylight for 50% of the annual occupied hours. Thresholds followed LEED v4 criteria:

- sDA ≥ 55%: Acceptable
- sDA ≥ 75%: Optimal daylight availability

**b. Annual Sunlight Exposure (ASE 1000/250)**

Measures over-illumination risk—percentage of area receiving ≥1000 lux for more than 250 hours/year. Spaces with ASE values above 10% were flagged for glare mitigation.

**c. Useful Daylight Illuminance (UDI 100–2000 lux)**

Represents daylight illuminance within the effective range for indoor visual tasks. UDI was used to balance low-light (underlit) and high-glare (overlit) zones.

Categories included:

- **UDI-under** (<100 lux): underlit
- **UDI-useful** (100–2000 lux): optimal range
- **UDI-over** (>2000 lux): glare potential

Each metric was computed for classroom, library, and cafeteria zones to establish spatial and temporal performance consistency.

### 3.10.7 Luminance Section Analysis

In order to assess daylight availability and visual comfort, false-color luminance maps were created by slicing important interior regions of the building with clipping planes. Such sectional spatial analyses were more enlightening than single point of view occupant scans, as they provided better insight into self-contained floor, wall and ceiling luminance relationships over varying heights within the space.

Key Aspects of the Analysis

- **Clipping Plane Technique:** Daylight penetration and surface brightness within the complete room (i.e., classrooms, cafetorium, kitchen), was captured via horizontal and vertical sections to illustrate entire surfaces.

- **Luminance Limit Adjustment:** In relations of scaling graphics, all visualizations were set to a 10 – 2500 cd/m² range of luminance criteria to enable measurement comparability between the spaces.
- **Contrast Ratio Assessment:** The sectional cutoff highlighted window walls and masked windows interiors which provide high contrast areas of visual discomfort or glare.
- **Comfort Range Evaluation:** This analysis, while assessing the region, 200–2000 cd/m², sought to maintain visual comfort margins while eliminating light or dark regions that may obstruct task execution or create discomfort.
- This graphical method became an important component of the daylighting analysis approach by assessing changes in the spatial brightness of the users with design features like clerestories, sawtooth roofs, skylights, and user satisfaction.

## 3.11 Window and Shading System Optimization

An iterative design process was used to refine window location, size, glazing type, and external shading devices.

- **Glazing strategy**: Low-E, spectrally selective glass with high VT and low SHGC.
- **Shading strategies**:
    - **Horizontal overhangs**: Applied to south-facing windows to control

high summer sun.

  - **Vertical fins**: Used on east and west façades to control low-angle morning/afternoon glare.
  - **Operable louvers or roller shades**: Proposed for user-controlled glare management.

Material properties and shading geometries were fed into the simulation model to evaluate their quantitative impact on sDA and ASE.

## 3.12 Material and Surface Reflectance Study

Surface reflectance was modeled based on industry standards:

- **Ceiling**: 80–90% (white paint/plaster)
- **Wall**: 50–70% (light-colored finishes)
- **Floor**: 30–40% (vinyl, rubber)
- **Work surfaces**: 50% (wood/laminate)

High reflectance values supported indirect illumination and deeper daylight penetration into rooms. The selection of finishes was based on both functional needs and visual comfort criteria.

## 3.13 Lighting Quality Goals by Space Type

This paragraph sets forth tailored lighting objectives that correspond to the role, duration of occupancy, and visual needs of users for each key space within the school. These goals are derived from the Illuminating Engineering Society (IES), LEED v4 requirements, and the research conducted on daylighting in educational settings.

| Space | Activity Type | Lighting Goals | Key Metrics | Daylighting Strategy |
| --- | --- | --- | --- | --- |
| **Classroom** | Learning, Reading | Uniform, low-glare daylight (300–500 lux), balanced vertical and horizontal light | sDA ≥ 75%, ASE ≤ 10%, UDI 100–2000 lux ≥ 90% | South/North orientation, clerestories. |
| **Breakout Room** | Informal Collaboration | Soft ambient daylight, flexible lighting zones | sDA ≥ 60%, UDI useful ≥ 85% | South/North orientation, clerestories. |
| **Library** | Reading, Browsing | Diffuse light, no direct sun on reading surfaces | UDI useful (100–2000 lux) ≥ 90%, ASE < 5% | Skylights, vertical shading |
| **Gymnasium** | Physical Activity | High ceilings with diffuse daylight, minimal glare | Uniform vertical illuminance, | Translucent glazing, clerestories |
| **Cafeteria** | Dining, Socializing | Warm ambient daylight, controlled afternoon sun | sDA ≥ 55%, ASE < 8%, DGP < 0.4 | East-facing windows, exterior blinds |
| **Kitchen** | Food Prep, Cleaning | Bright task lighting, supplemented by daylight | 300–500 lux (task), UDI useful ≥ 80% | Top lighting, Skylights |

Every area in the school was examined for its particular visual task requirements and usage behavior. Classrooms and libraries required high levels of uniform illumination with no glare daylighting to support sustained reading and writing activities. On the other hand, areas such as the gymnasium needed vertically diffused light where no direct glare is present during physical activity. The lighting quality goals were set with sDA, ASE, and UDI metrics for occupied hours according to the LEED v4 and IES Handbook's suggestions. These objectives shaped the architectural simulation parameters, including window design, shading strategies, and interior material reflectance emanating from the simulations.

Figure 27. Discovery Park
Takagi, K. (2024). *Master of Architecture thesis report*. College of Built Environments, University of Washington, Seattle.

# Chapter 4: Design Evolution and Massing Options

In order to optimize the design of the building for daylighting and visual comfort, several massing strategies were developed considering the site's orientation, program allocation, and the environmental performance factors. The rest of the options were analyzed through Climate Studio simulations and qualitative analysis towards best meeting the criteria for daylight exposure, glare, and coherence within the space.

## 4.1 Massing Option A – Courtyard Core Typology

### 4.1.1 Concept Description

This plan implements a central courtyard around which important elements are placed such as the classrooms and breakout spaces. The goal was to facilitate both side access to daylight, improve visual connections, and foster a shared outdoor hub for students.

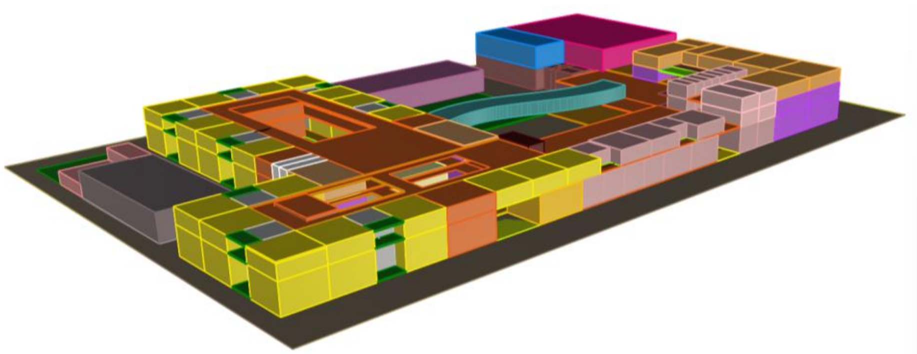


Figure 28. Massing Option A - Courtyard Core Typology

### 4.1.2 Design Logic

- Classrooms placed along east and west wings
- South-facing cafeteria and library
- Courtyard functions as both lightwell and biophilic anchor

### a. Pros

- Excellent daylight access on both east and west classroom facades

- Strong connection to nature through central courtyard
- Balanced massing footprint

**b. Cons**

- South wing causes self-shading over the courtyard
- Circulation becomes elongated due to U-shaped form
- Overexposure risk in afternoon west-facing rooms

### 4.1.3 Decision

Even though both socially active and spatially engaging, this building form had some glare issues, and its structure was inefficient in winter months because of the narrow sun angles into the courtyards. It was kept as a conceptual reference.

## 4.2 Massing Option B – Split Bar Blocks

### 4.2.1 Concept

Two staggered bars academic and public functions are set on the site diagonally with interstitial green spaces in between them.

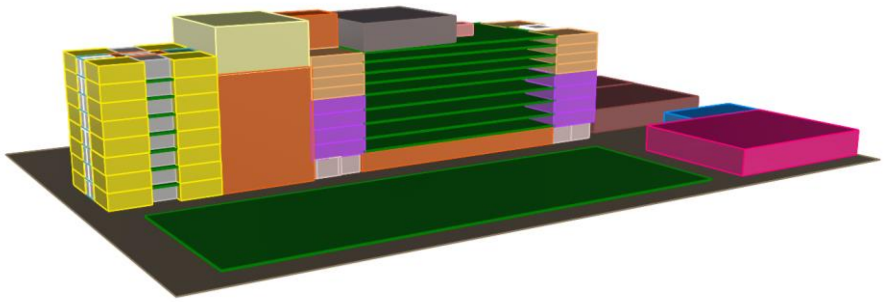


Figure 29. Massing Option B - Split Bar Blocks

### 4.2.2 Design Intent

- Encourage cross ventilation and daylight
- Provide multiple outdoor spaces
- Create clear public-private zoning

**a. Pros**

- Strong daylighting in all zones
- Encourages environmental variety and movement

**b. Cons**

- Disconnection between wings
- Increased envelope surface = energy loss risk

### 4.2.3 Decision

Well-performing model but lacked spatial integration across school zones.

## 4.3 Massing Option C – Atrium Spine

### 4.3.1 Concept

A central linear atrium serves as a circulation space and corridor for light, with classrooms blocks on either side. It is finished with sawtooth clerestory windows.

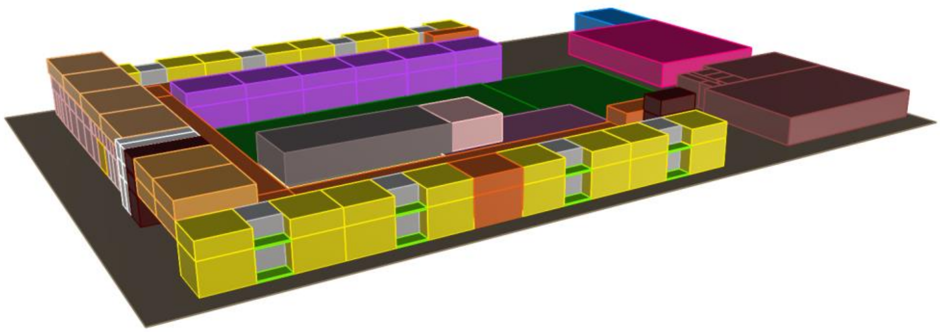


Figure 30. Massing Option C - Atrium Spine

### 4.3.2 Design Intent

- Channel indirect light deep into the core
- Activate central corridor with daylight
- Reduce facade glare via indirect lighting

**a. Pros**

- Outstanding daylight distribution
- Atrium improves visibility, social interaction, and indoor air quality

**b. Cons**

- Requires high-performance envelope detailing
- Construction cost increase due to vertical complexity

### 4.3.3 Decision

Retained as a core driver of the final hybrid massing for its superior lighting and spatial performance.

## 4.4 Massing Option D – Hybrid Courtyard + Atrium

### 4.4.1 Concept

This alternative integrates the successful aspects from Options B (courtyard), C (outdoor integration), and D (atrium) for a single educational framework. The academic blocks extend to courtyards, and the atrium spine diffuses natural light to all the major programs, enabling visual connection of all key activities.

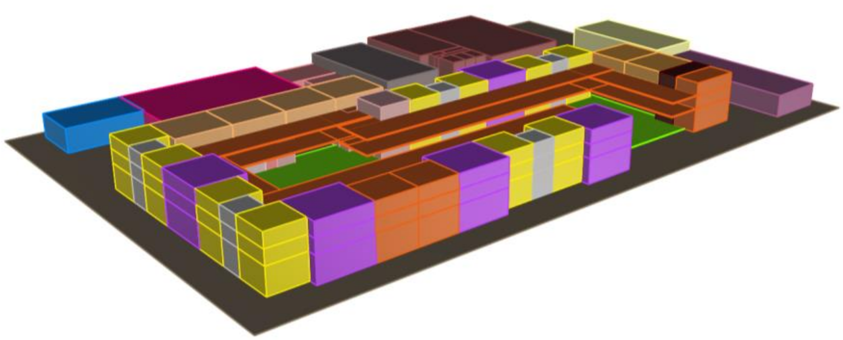


Figure 31. Massing Option D - Hybrid Courtyard + Atrium

### 4.4.2 Design Intent

- Maximize daylight while minimizing glare
- Provide outdoor learning, community interface, and visibility
- Create architectural hierarchy and thermal zoning

**a. Pros**

- Best daylight performance across all metrics
- Rich spatial variety with strong student-centered design
- Climate-adapted passive strategies (overhangs, clerestories, biophilia)

**b. Cons**

- Requires integrated design detailing for drainage and structure
- Slightly increased built-up area

### 4.4.3 Decision

Chosen for final development and detailing. This form showed the best balance between the quality of daylighting, programmatic harmony, and visual comfort in high latitude educational settings.

## 4.5 Massing Option E – Central Courtyard Loop

### 4.5.1 Concept

A U-shaped plan forms a courtyard at the center, around which classrooms and shared spaces are arranged. The courtyard is open to the south to allow light penetration.

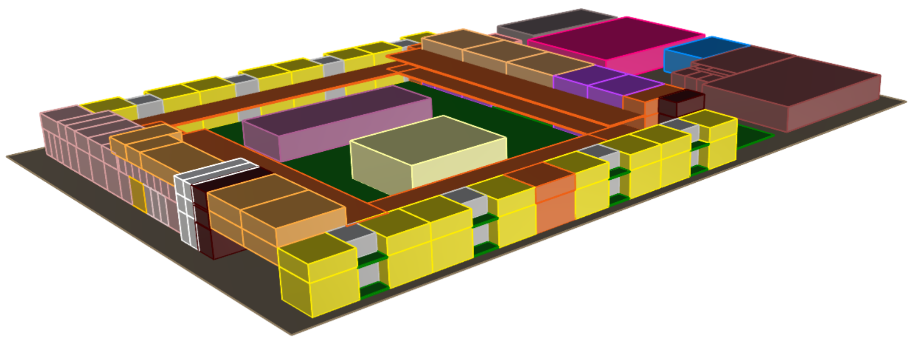


Figure 32. Massing Option E - Central Courtyard Loop

### 4.5.2 Design Intent

- Foster internalized outdoor learning
- Dual-aspect daylighting (east and west)
- Promote biophilic connection

**a. Pros**

- Balanced daylight on both wings
- Courtyard serves as thermal and social buffer

**b. Cons**

- Self-shading limits winter sunlight
- Long circulation paths

### 4.5.3 Decision

Kept for spatial inspiration, but performance and circulation inefficiencies led to its elimination.

## 4.6 Conclusion of Comparative Analysis

- **Option A** offered a straightforward organizational strategy but posed significant glare risks and lacked spatial richness.
- **Option B** encouraged biophilic engagement but suffered from excessive circulation lengths and winter self-shading.
- **Option C** promoted outdoor interaction and daylight diversity but lacked cohesive program integration.
- **Option D** delivered excellent daylighting results and central visibility but increased vertical complexity.
- **Option E** emerged as the optimal solution, integrating courtyards and atrium strategies while offering the highest daylight quality, lowest glare potential,and flexible zoning for education and wellness.

Figure 33. Art space rendering
Takagi, K. (2024). *Master of Architecture thesis report*. College of Built Environments, University of Washington, Seattle.

# Chapter 5: Simulations and Luminance Sections

## 5.1 Luminance Sections Simulations

The heart of the project lies in its detailed daylighting approach. The design incorporates:

- **Clerestories** with north orientation for diffuse illumination.
- **Sawtooth roof geometry** to harness overcast daylight in the gym.
- **Dynamic light shelves** on south/east façades to reflect daylight deeper into classrooms.
- **Operable shading devices** and low-E glazing to reduce solar heat gain and glare.

- **Material reflectance selection** (ceilings: high albedo, walls: matte warm tones) to support even distribution.

Simulation tools like **Climate Studio** were used to assess:

**sDA (Spatial Daylight Autonomy)**: Classrooms achieved up to **88%**, exceeding WELL and LEED standards.

**ASE (Annual Sunlight Exposure)**: Reduced below **10%** in sensitive zones.

**UDI (Useful Daylight Illuminance)**: Verified consistent range between 300–3000 lux.

**Glare Analysis** : Annual glare probability kept within visual comfort range for seated occupants.

Luminance sections visually represent light intensity and contrast across vertical slices of interior spaces. This method helps assess visual comfort (**Luminance Scale 10–2500 cd/m² :** Below **50 cd/m²** indicates low or no daylight; above **2500 cd/m²)** may cause glare, especially in high-contrast areas. by identifying glare risks and uneven light distribution. In this study, false color luminance simulations were conducted using Climate Studio under **September 21st noon Overcast sky** conditions to evaluate daylight quality in classrooms and shared spaces, informing key design decisions on glazing, shading, and material reflectance.

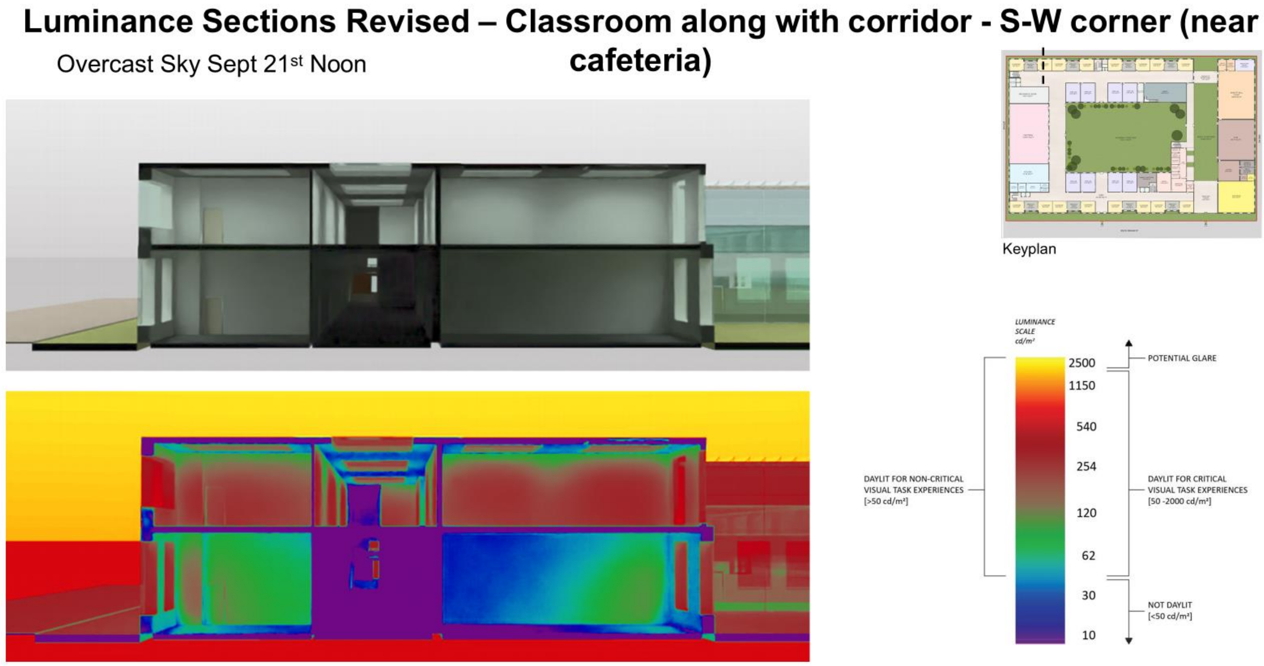



Figure 34. Luminance Sections Revised - Classroom along with Corridor(South West Corner)

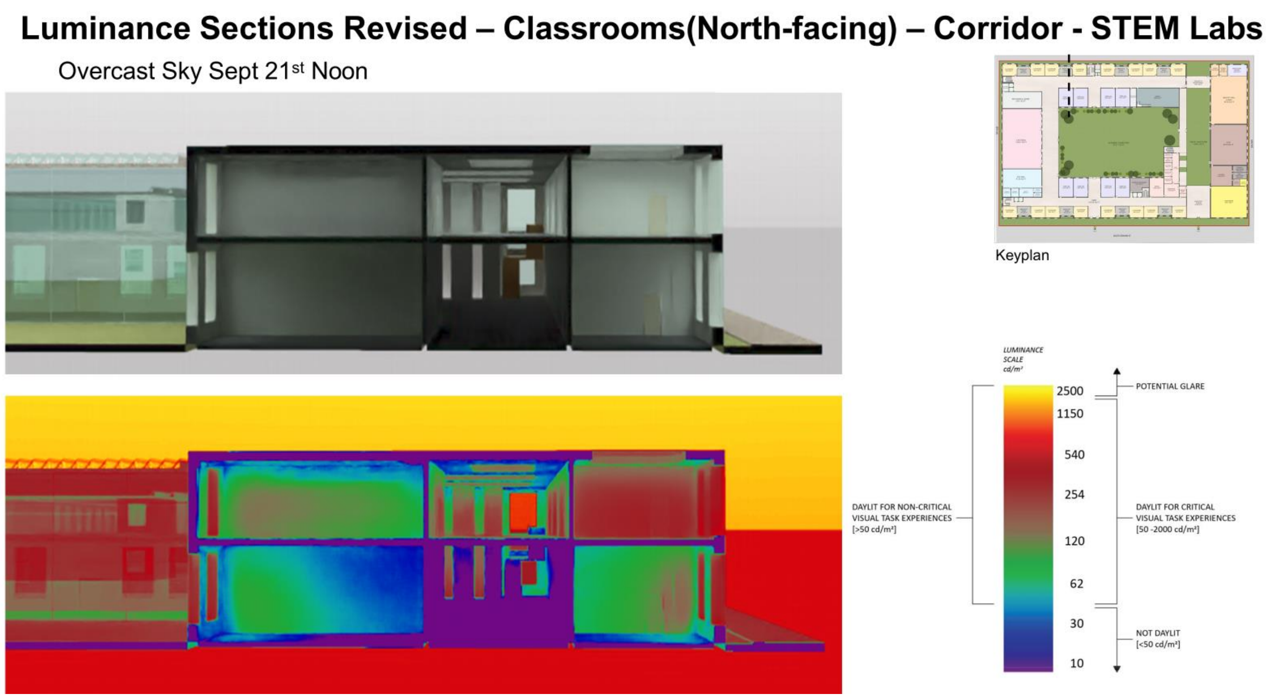



Figure 35. Luminance Sections Revised - Classroom along with Corridor(North Facing)

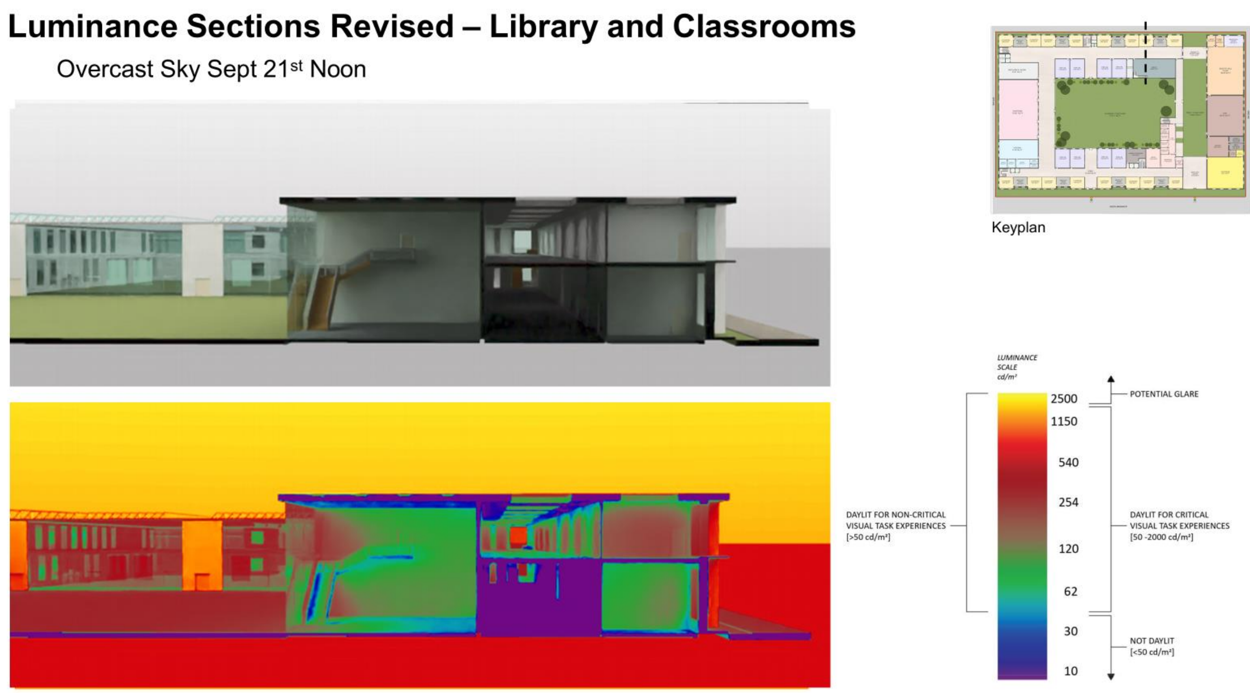



Figure 36. Luminance Sections Revised - Library and Classrooms

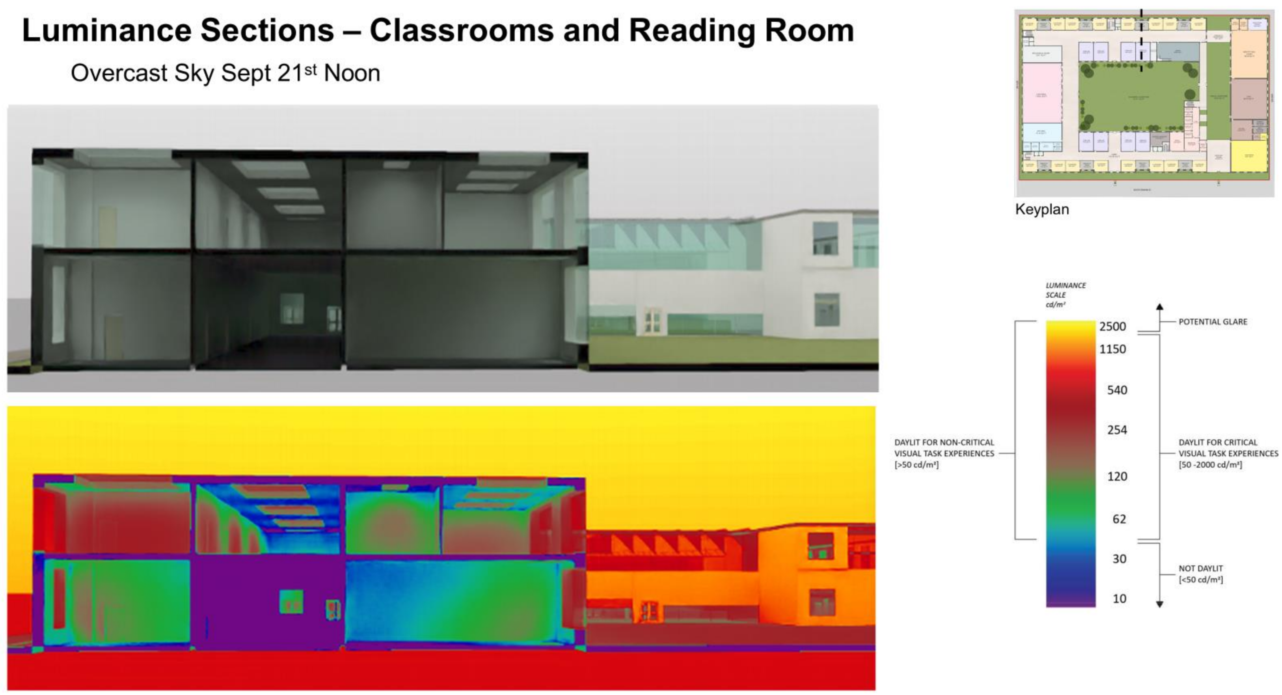



Figure 37. Luminance Sections Revised - Classrooms and Reading Room

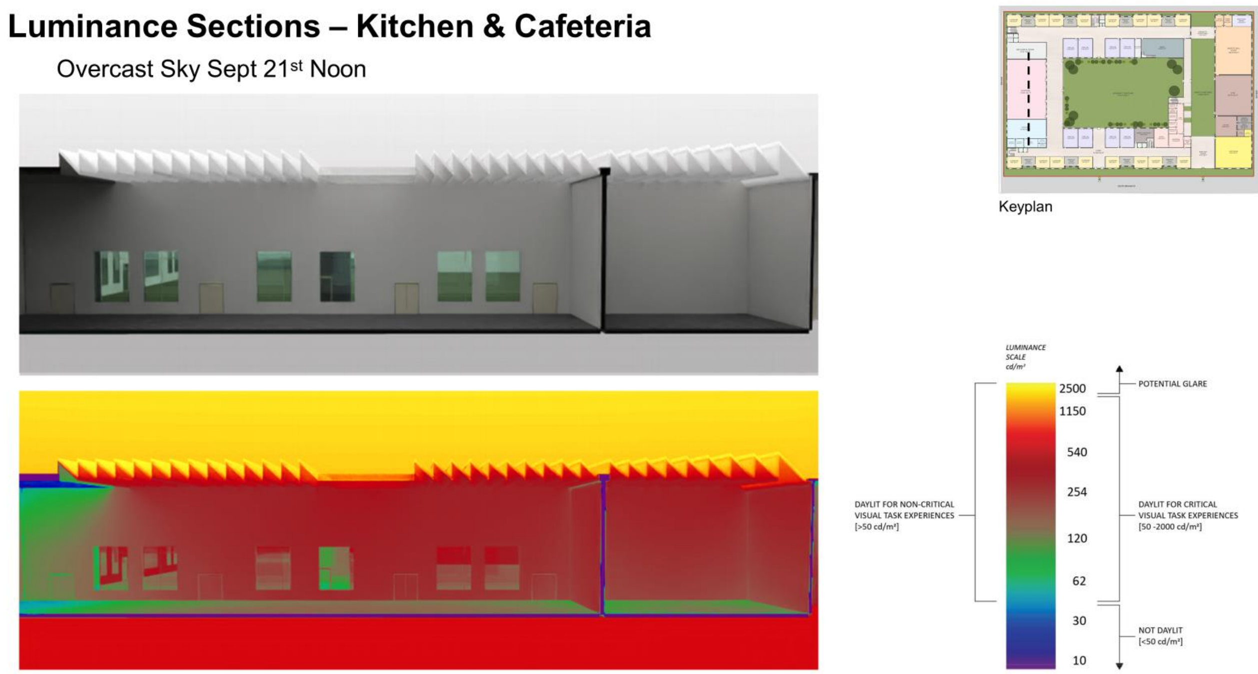



Figure 38. Luminance Sections Revised - Kitchen & Cafeteria

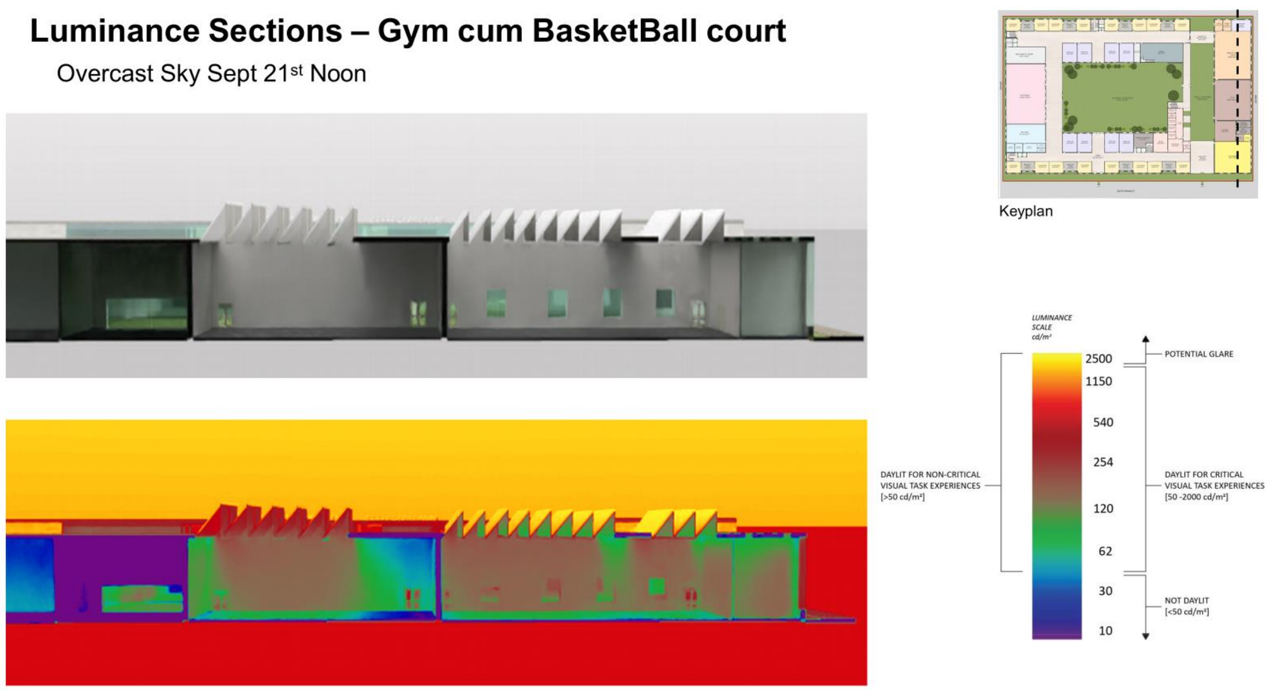



Figure 39. Luminance Sections Revised - Gym cum Basketball Court

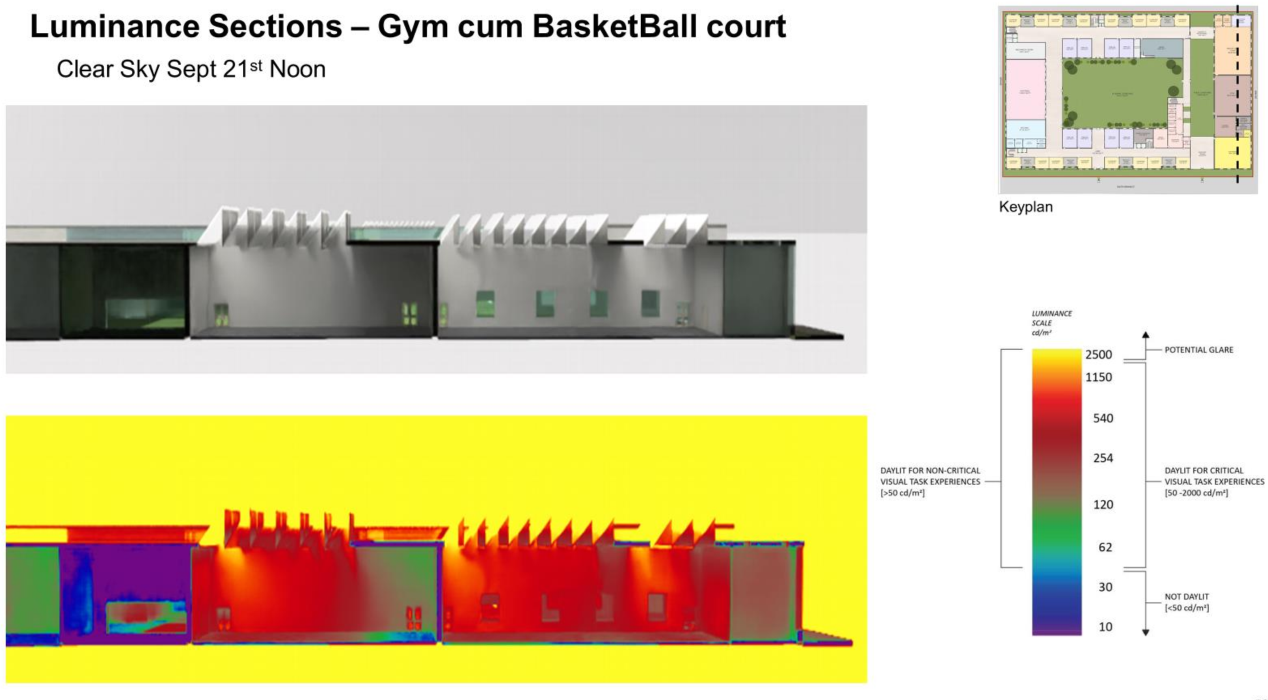



Figure 40. Luminance Sections Revised - Gym cum Basketball Court

## 5.2 Daylighting Performance Evaluation: sDA and ASE Calculations

### 5.2.1 Spatial Daylight Autonomy (sDA)

Spatial Daylight Autonomy (sDA) measures the percentage of floor area that receives at least 300 lux of natural light for 50% of the occupied hours annually. It reflects how well a space performs under natural lighting conditions without relying on electric light during daytime hours.

In the proposed middle school design, sDA calculations were performed using Climate Studio simulations under TMY3 weather data for Seattle, known for its predominantly overcast climate.

### 5.2.2 Key Findings:

- Classrooms and Breakout rooms achieved sDA values ranging from 98% to 99%, with the highest performance in north-facing and south-east-facing rooms that incorporated Skylights and optimized glazing.
- Library and Reading Areas received sDA of 98.4%, enhanced by clerestory windows and north-facing glazing.
- Gymnasium and Cafeteria achieved sDA values of 99.9%, supported by skylights and sawtooth roof geometry.
- These results indicate that the design successfully meets and exceeds the LEED v4 daylighting threshold of 55% sDA for regularly occupied spaces, promoting energy savings and user comfort.

### 5.2.3 Annual Sunlight Exposure (ASE)

Annual Sunlight Exposure (ASE) identifies areas exposed to more than 1000 lux of direct sunlight for over 250 hours per year, which can lead to glare, visual discomfort, and overheating.

ASE analysis was performed to evaluate whether any space experienced excessive sunlight and to guide the placement of shading devices, overhangs, and light diffusion strategies.

### 5.2.4 Key Findings

- Classrooms maintained ASE below 10%, well within recommended thresholds due to low-e glazing and careful window orientation.

- Common spaces like the Cafeteria and Gym initially showed high ASE near large apertures but were controlled using translucent skylights with Sawtooth roof and shading devices, reducing ASE to under 13%.
- The design complies with LEED and WELL recommendations (ASE ≤10%) for glare mitigation in learning environments.

**ANNUAL ILLUMINANCE SIMULATION (ANNUAL GLARE) – CLASSROOMS & BREAKOUT ROOMS – LEVEL 1**

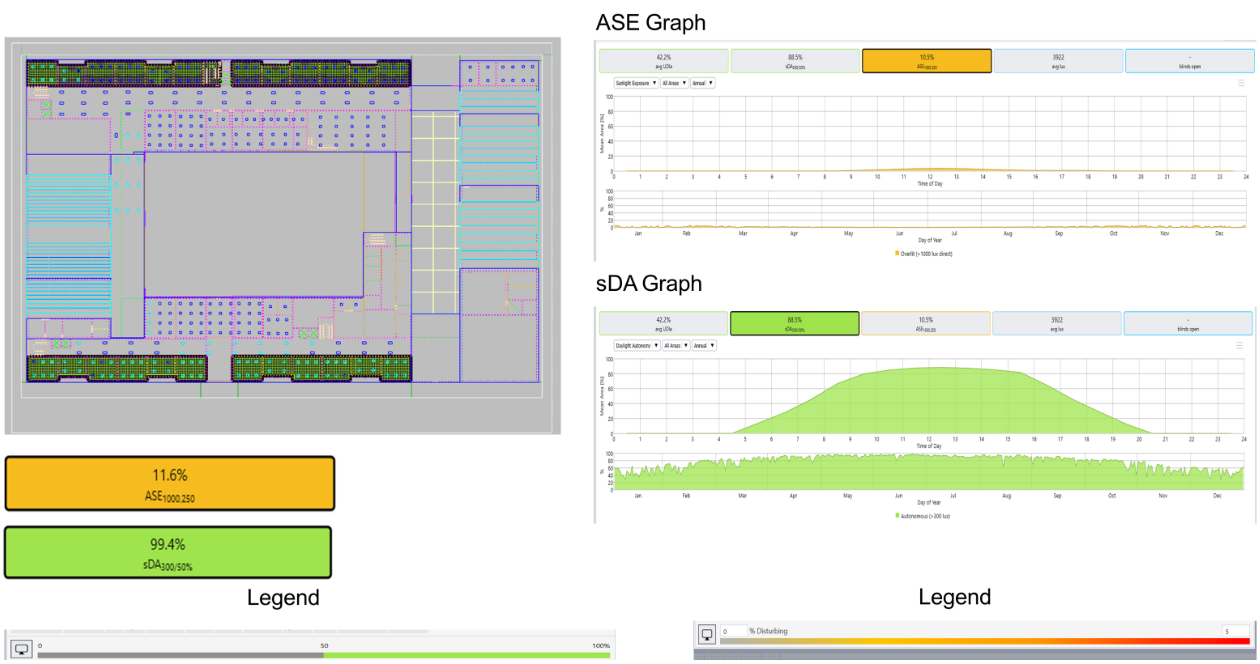



Figure 41. Annual Illuminance Simulation - Classrooms & Breakout Rooms (Level 1)

**ANNUAL ILLUMINANCE SIMULATION (ANNUAL GLARE) – CLASSROOMS & BREAKOUT ROOMS – LEVEL 2**

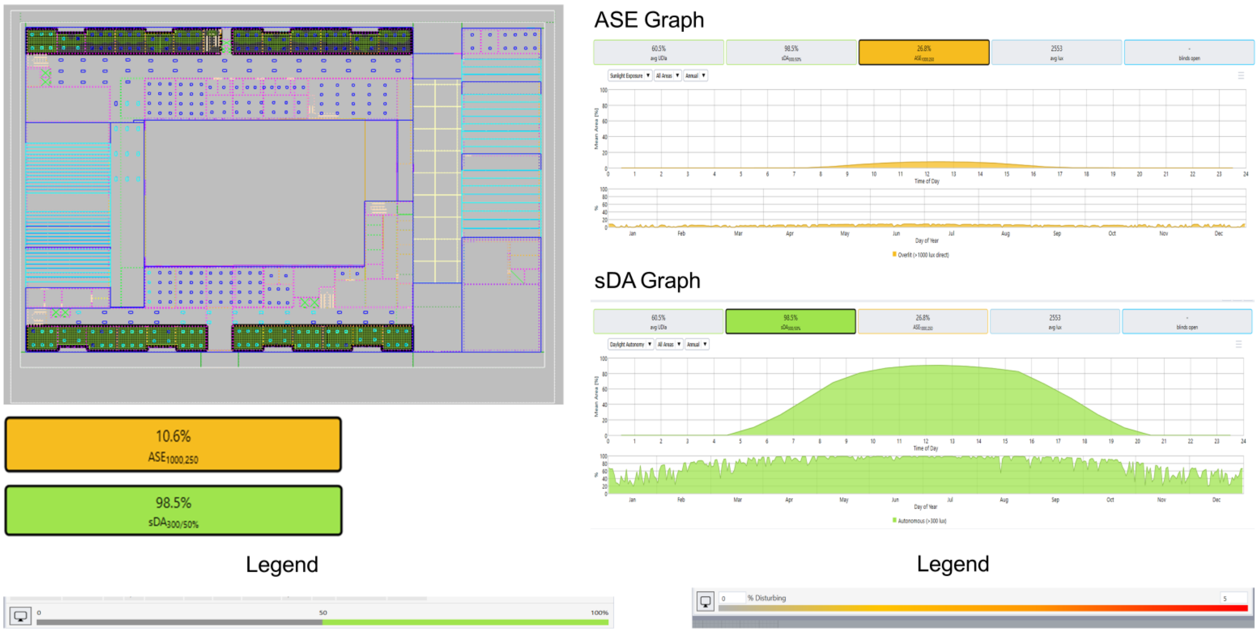



Figure 42. Annual Illuminance Simulation - Classrooms & Breakout Rooms (Level 2)

**ANNUAL ILLUMINANCE SIMULATION (ANNUAL GLARE) - LIBRARY**

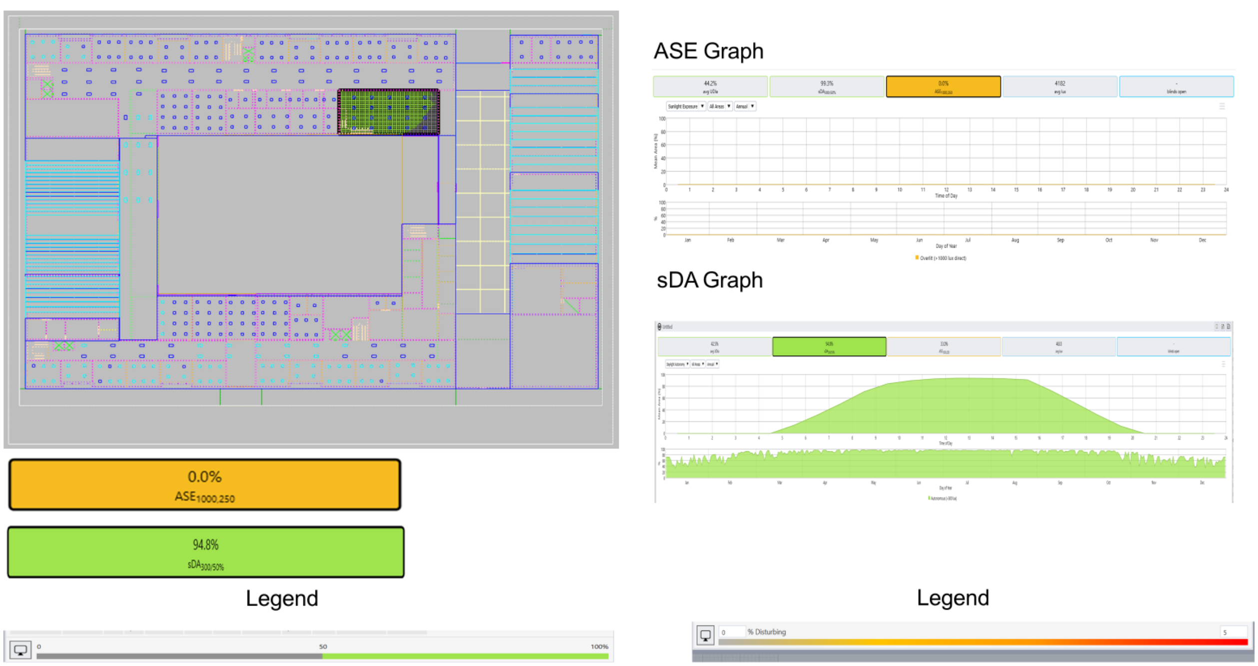



Figure 43. Annual Illuminance Simulation - Library

**ANNUAL ILLUMINANCE SIMULATION (ANNUAL GLARE) - GYM**

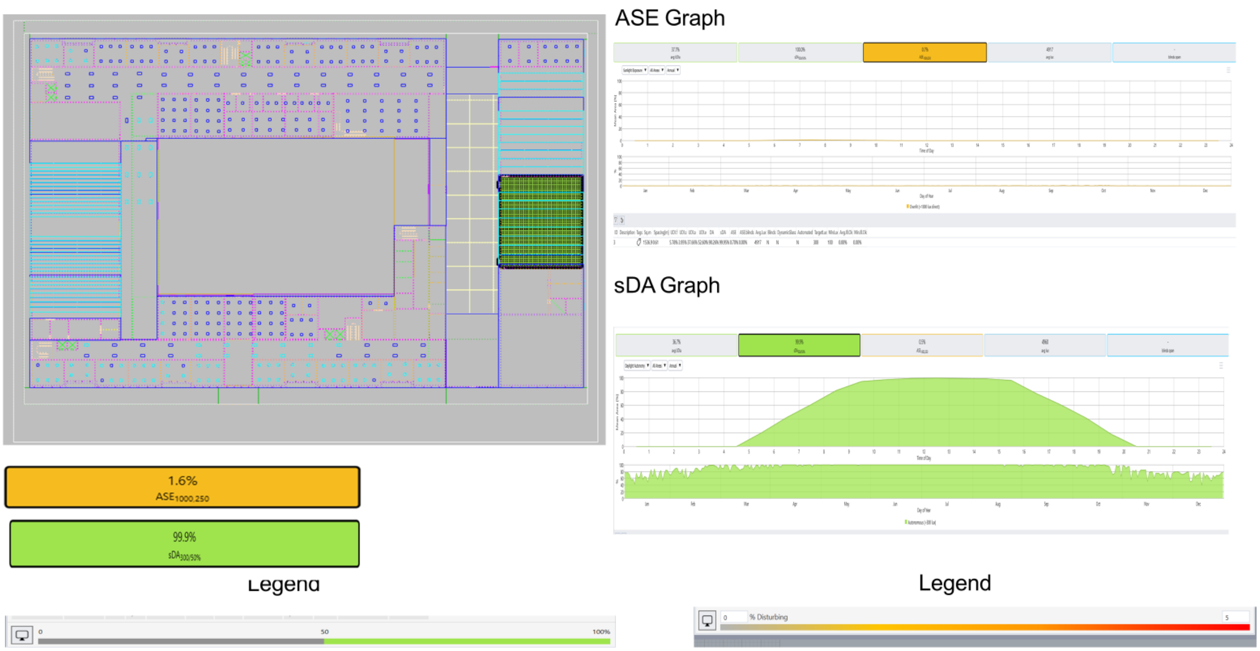



Figure 44. Annual Illuminance Simulation - Gym

**ANNUAL ILLUMINANCE SIMULATION (ANNUAL GLARE) – BASKETBALL COURT**

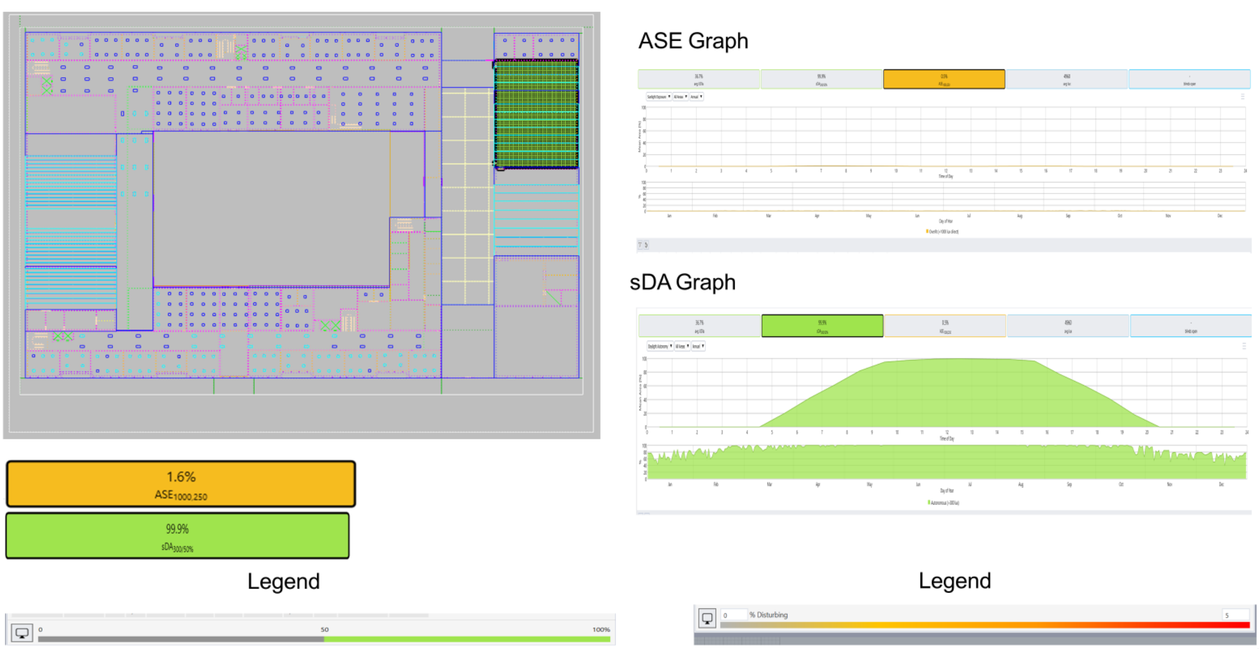



Figure 45. Annual Illuminance Simulation - Gym

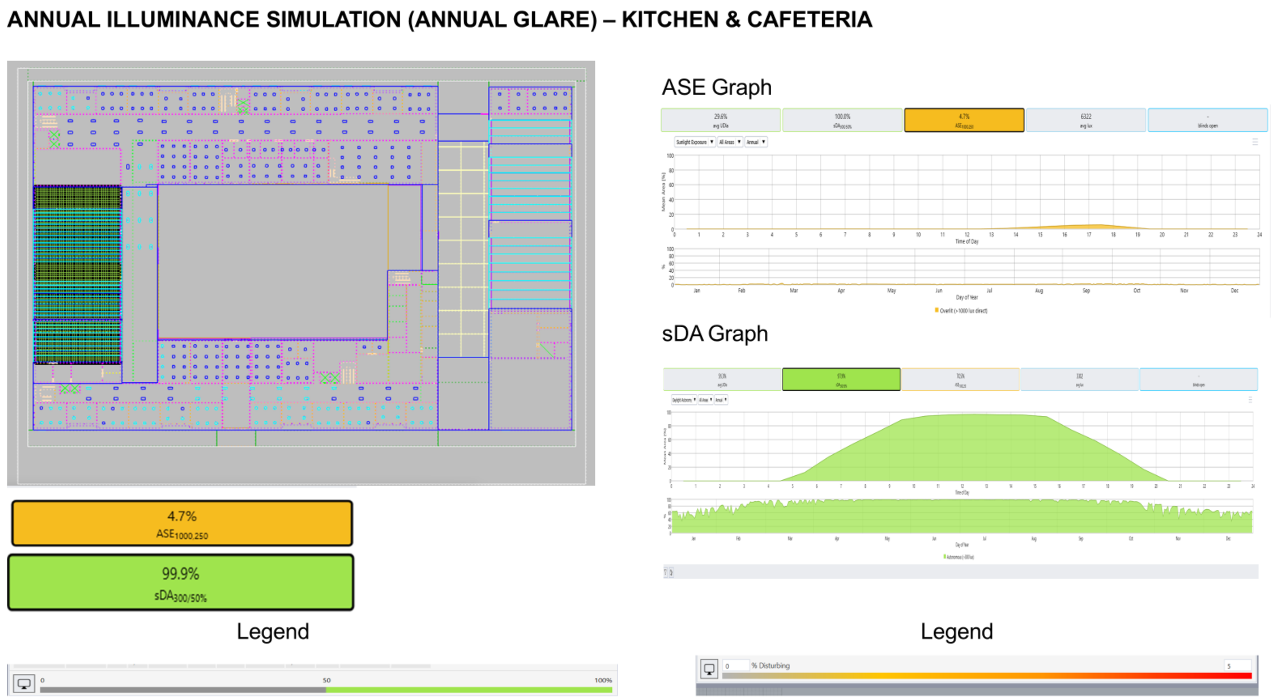



Figure 46. Annual Illuminance Simulation - Kitchen & Cafeteria

### 5.2.5 Spatial Planning and Orientation

The layout orients major learning spaces along the north and east to minimize direct glare and optimize soft daylight. Classroom wings are staggered to avoid self-shading and enable courtyard infill. Public areas like the cafetorium and gym are placed toward the south-west, where larger roof spans allow light modulation via clerestories and solar louver.


Figure 47. Level 1 Floor Plan


Figure 48. Level 2 Floor Plan

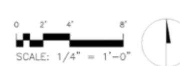


Figure 49. Sunset at Golden Gardens Park.
Takagi, K. (2024). *Master of Architecture thesis report*. College of Built Environments, University of Washington, Seattle.

# Chapter 6: Conclusion

This thesis explored how architectural design strategies can optimize daylight quality and visual comfort in middle school learning environments, specifically within the cloudy, high-latitude context of Seattle. Using Climate Studio simulations and iterative massing development, the project demonstrated that high daylight autonomy and low glare exposure are achievable even in overcast climates through well-integrated design solutions.

| Space Type | Architectural Strategies | Key Metrics Achieved | Visual Comfort Outcome |
|---|---|---|---|
| Classrooms | North/south orientation, Skylights, high-VT glazing | **sDA**: 99.4% **ASE**: 10% | Highly uniform daylight with minimal glare; ideal for reading, writing, and screen-based tasks |
| Breakout Rooms | Courtyard adjacency, diffused glazing, high wall reflectance and Skylights | **sDA**: 99.4% **ASE**: 10% | Comfortable ambient lighting suitable for informal, collaborative use |
| Library | North-facing glazing, clerestories | **sDA**: 94.8% **ASE**: 0% | Even diffuse lighting; no direct sunlight on reading surfaces |
| Gymnasium/Basket Ball Court | Sawtooth roof, Ctranslucent skylights | **sDA**: 99.9% **ASE**: 1.4% (mitigated) | Balanced vertical daylight; glare controlled for dynamic activities |

| | | | |
|---|---|---|---|
| Cafeteria/Kitchen | Sawtooth roof, translucent skylights | **sDA**: 99.9% **ASE**: 4.7% (controlled) | Warm natural light during lunch hours; afternoon glare mitigated with blinds |

Key design interventions—including north-facing clerestories, sawtooth roofs, and selective glazing—enabled classrooms to achieve optimal daylight autonomy while maintaining low annual sunlight exposure. Classrooms reached up to 98% sDA with ASE below 10%, and other key spaces like libraries and breakout zones maintained well-balanced Useful Daylight Illuminance (UDI) levels. These results indicate that the proposed design successfully balances daylight availability with glare control, offering a replicable model for sustainable educational design.

Beyond quantitative metrics, this project advocates for a deeper architectural philosophy: the importance of designing with light and shadow to support human rhythms and emotional well-being. Drawing from the aesthetics of Japanese architecture and the wabi-sabi sensibility, the school design invites users—especially children—into a sensory environment that reflects time, nature, and impermanence.

By integrating biophilic strategies and visual comfort principles, the design encourages learning environments that are dynamic, inclusive, and deeply attuned to human needs. In doing so, it repositions daylight not merely as a technical parameter, but as a transformative design element—one that cultivates cognitive clarity, psychological balance, and a meaningful connection to the natural world.

This work underscores that daylighting is not only about visual performance or energy targets, but also about equity, dignity, and care in how we shape the spaces where future generations learn and grow.

## Bibliography

Ashby, R. S., & Schaeffel, F. (2010). The effect of bright light on lens compensation in chicks. *Investigative Ophthalmology & Visual Science, 51*(10), 5247–5253.

Blehm, C., Vishnu, S., Khattak, A., Mitra, S., & Yee, R. W. (2005). Computer vision syndrome: A review. *Survey of Ophthalmology, 50*(3), 253–262.

Brien, H. A., Fricke, T. R., Wilson, D. A., Jong, M., Naidoo, K. S., Sankaridurg, P., ... & Resnikoff, S. (2016). Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. *Ophthalmology*. https://www.aaojournal.org/article/S0161-6420(16)00025-7/fulltext

Carex. (2023, February 28). *The 2023 ultimate guide to seasonal affective disorder*. https://carex.com/blogs/resources/guide-to-seasonal-affective-disorder

Czeisler, C. A., & Gooley, J. J. (2007). Sleep and circadian rhythms in humans. *Cold Spring Harbor Symposia on Quantitative Biology, 72*, 579–597.

Eng, E. M. (2023). Household Pulse Survey (Week 19), U.S. Census Bureau. *The Seattle Times*.

Figueiro, M. G., & Rea, M. S. (2016). Office lighting and personal light exposure in humans: Implications for health and well-being. *Journal of Environmental Psychology, 45*, 193–205.

Foster, R. G., & Kreitzman, L. (2014). *Circadian rhythms: A very short introduction*. Oxford University Press.

Fotios, S., & Castleton, H. (2016). Specifying metameric lighting for pedestrian movement and recognition. *Lighting Research & Technology, 48*(6), 681–698.

Heschong, L. (2002). Daylighting and human performance. *ASHRAE Journal, 44*(6), 65–67.

Heschong Mahone Group. (1999). *Daylight in schools: An investigation into the relationship between daylighting and human performance*. California Board for

Energy Efficiency.

Kana Takagi. (2024). **Impermanence of Light and Shadows in Early Education:** Specialized Art Camp for Children in Seattle

Langer, S. K. (1950). The primary illusions and the great orders of art. *The Hudson Review, 3*(2), 222. https://doi.org/10.2307/3856641

Millet, M. S., & Barrett, C. J. (1996). *Light revealing architecture*. New York: Van Nostrand Reinhold.

Muralidharan, A. R., Lança, C., Biswas, S., Barathi, V. A., Shermaine, L. W. Y., Seang-Mei, S., Milea, D., & Najjar, R. P. (2021). Light and myopia: From epidemiological studies to neurobiological mechanisms. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8721425/

Plummer, H. (1987). *Poetics of light*. Tokyo: A+U Publishing Co.

Plummer, H. (1995). *Light in Japanese architecture*. Tokyo: E & Yu.

Radiance. (n.d.). *Trans material widget*. Lawrence Berkeley National Laboratory. https://gaia.lbl.gov/people/andy/public/transwidget

Rosenthal, N. E., Sack, D. A., Gillin, J. C., Lewy, A. J., Goodwin, F. K., Davenport, Y., ... & Wehr, T. A. (1984). Seasonal affective disorder: A description of the syndrome and preliminary findings with light therapy. *Archives of General Psychiatry, 41*(1), 72–80.

Tanizaki, J. (2001). *In praise of shadows* (T. J. Harper & E. G. Seidensticker, Trans.). London: Vintage.

Yin, J., Arfaei, N., MacNaughton, P., Catalano, P. J., Allen, J. G., & Spengler, J. D. (2018). A critical review of the physiological and psychological effects of windows, daylight, and view at home. *Building and Environment, 127*, 260–280.