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Bringing in the Sun: The Impact of Daylighting in Schools

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Aging schools were not built with natural daylight and sun exposure in mind. This reality adversely affects the health and academic performance of today's student population.

Starting in the mid-20th century, K-12 schools across the country were constructed with minimal daylighting features in classrooms, hallways and other academic spaces. Instead of the long-held standard of daylight being the primary lighting source in schools, rows of artificial fluorescent lighting were alternatively chosen to illuminate learning environments—an approach that is still frequently used in schools to this day.

Although evidence suggests that daylight greatly amplifies student performance and attendance, school districts have not yet reintegrated natural daylighting sourced from large windows, skylights and clerestories back into their aging buildings.

Due to limited state funding, districts often struggle to budget for new school builds to replace their worn-down and aging facilities that were designed during a time when daylighting was not a priority. Furthermore, with increasing construction costs, daylighting features are commonly cut during the Value Engineering budgeting phase of school renovation projects.

To provide students and faculty with vibrant, learning environments that foster academic growth and inspiration, we must bring daylighting back into our K-12 school building designs.

THE EFFECTS OF DAYLIGHTING IN SCHOOLS

Children spend an overwhelming amount of their young lives inside of a school building. According to the National Center for Education Statistics (NCES), the average school day in America is 6.64 hours, and the average school year is 180 days. [1] As such, students will spend over 15,000 hours in schools where much of their educational, physical and emotional development is curated.

Numerous case studies show that daylighting in classrooms directly impacts students in a variety of ways, including their educational progression, health, cognitive performance, academic development and attendance rates.

Bolstering Reading and Math Scores

A growing portfolio of research has focused on daylighting in schools and its positive effect on testing scores. In a highly cited study by L. Heschong and the Heschong Mahone Group, more than 21,000 students' test scores were analyzed using rigorous statistical controls. The focus group consisted of students from three school districts (located in Orange County, CA, Seattle, WA and Fort Collins, CO) who all took exams in different classroom settings that had various daylighting conditions.

Figure 1 details the results found of participating students in Orange County's Capistrano School District: students in daylit classrooms had 20% faster progression on math tests and 26% faster advancement on reading tests than in classrooms that were the least daylit. The other two school districts had similar results and concluded that "students in classrooms with the most daylighting were found to have 7%-18% higher scores than those in the least." [2]

Improvements in test score of students in classrooms with better daylighting.

Daylighting conditions in classrooms	Average Improvement* Reading	Math
Classrooms with most overall daylighting (from skylight and windows) relative to classrooms with least overall daylighting	26% (0.1%)	20% (0.1%)
Classrooms with most window area compared to classrooms with least window area	23% (0.1%)	15% (0.1%)
Skylight A (diffused illumination with manual operation for controlling illumination level) relative to no skylight	19% (0.3%)	20% (0.1%)
Skylight B (direct illumination with no controls) relative to no skylight	-21% (5.1%)	-
Operable windows, relative to classrooms without operable windows	8% (0.4%)	7% (0.1%)

* (Probability that observed association with improved test scores is due to chance)
Conducted fall to spring in Capistrano School District

Figure 1: Daylight Study by L. Heschong and the Heschong Mahone Group.

Affecting Student Health and Behavior

Another study emphasizing the importance of daylight in schools is one by R. Küller and C. Lindsten, who researched the health and behavior of children who were in classrooms with and without windows for an entire academic year.

Küller and Lindsten concluded that learning in classrooms without windows affected the basic pattern of students' cortisol, which is a hormone related to stress. This result suggests that a lack of daylighting in classrooms could potentially alter cortisol and adversely impact children's health and concentration in a classroom setting. [3]

Altering Cognitive Performance

Additional research indicates that exposure to natural light impacts cognitive brain performance. According to a study by G. Vandewalle, P. Maquet and D. Dijk, the amount of daylight that humans are exposed to affects our circadian rhythm, which refers to the mental, physical and behavioral responses we experience in a 24-hour cycle. When our circadian rhythm is impacted, our cognitive performance may also be heavily influenced. [4]

Similarly, N. Shishegar and M. Boubekri researched daylighting and found that there are several physiological and psychological benefits resulting from light from natural sources, which can be seen in Figure 2. [5]

NATURAL LIGHT AND HUMAN BODY

Physically		Psychologically	
Improve	Decrease	Improve	Decrease
Vitamin D	Cancer Possibility	Mood	Depression
Visual System	Abnormal Bone Formation	Mental Performance	Stress
Circadian Rhythms	-	Alertness	Sadness
Sleep Quality	-	Brain Activity	Violent Behavior

Figure 2: Research by N. Shishegar and M. Boubekri

Amplifying Academic Development

Another study examining school design and its influence on learning development is The Clever Classrooms Study out of the University of Salford Manchester, which looked at the academic performance in reading, writing and math of 3,766 students in 27 different schools.

This study aimed to identify the key design elements that significantly influence students in classrooms. Figure 3 shows their ranking of light—more specifically, natural light—as the design element that has the biggest impact on a student's academic development. [6]

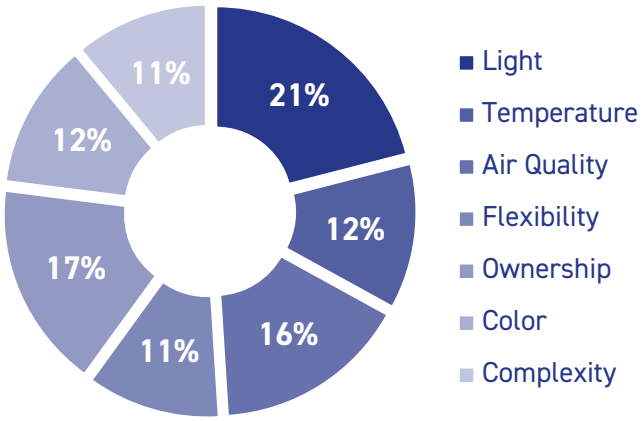

Figure 3: Research found in The Clever Classrooms Study.

Increasing Student Attendance and Decreasing Energy Consumption

Some case studies analyzing daylight have found a correlation between increased natural light with higher student attendance rates. For example, a study on the Durant Road Middle School, in Raleigh, NC—a school that took active steps to reincorporate daylighting measures into their classrooms—stated that attendance rates rose to 98% post-daylighting implementation, which was 3% ahead of the rest of the county.

In addition to increasing student attendance, this case study concluded that daylighting saves energy and money. After daylighting was integrated, energy consumption from lighting, ventilation, and heating in the school was reduced by 50-60% and the estimated annual savings from these features was $21,000. [7]

REINCORPORATING DAYLIGHTING IN A SCHOOL BUILDING

As the former Project Manager for SfL+a Architects, I led the firm's design team during the planning and construction of a new K-12 school in Trenton, NC, a town located in Jones County. The modern-day, award-winning school was designed to feature three wings separating elementary, middle and high school students, who were all previously assigned to disparate school buildings originally built in the 1950s.

This new, all-inclusive school was critically necessary for students who were used to learning in worn-down buildings with a variety of issues stemming from poor air quality, mold and minimal daylighting. Our team designed a unique take on the traditional school with central media spaces that invite substantial natural light, opening from classrooms for a modern, student-focused learning environment.

Creating a New, Daylit School on a Budget

Designing within budgetary constraints was a crucial factor during the planning stages for the new school. Jones County has a relatively low tax base, and its school district was ranked as a Tier 1, which is the lowest end of the economic well-being and distress scale in NC. A typical elementary school can cost upwards of $30 million, and in an area like Jones County, a bond for that amount could significantly raise taxes for county residents.

To circumvent any economic distress for residents, I directed several collaborative meetings with county stakeholders, including the county commissioners, county manager, school board and district superintendent. These strategic partnerships allowed us to secure various grants and tax credits needed for the school construction.

More notably, we obtained a $15 million needs-based grant from the North Carolina Department of Public Instruction, which oversees NC public school systems. With a tight budget in mind, my team sought to replace three of Jones County's aging schools with one, state-of-the-art school optimal for primary education.

The exterior of Jones County K-12 School.

Ensuring Energy-Efficiency

The Jones County K-12 School is a sustainable building that generates approximately 75% more energy than it uses. To achieve these peak energy-saving results, a variety of high-performance design systems were implemented to synergistically produce optimal energy. These systems included:

Daylighting Implementation

- Large, floor-to-ceiling windows with high-performance glass specifically selected to let daylight and natural heat in, but keep direct sunlight out
- Optimized solar orientation, daylight harvesting systems and clerestories designed to bring daylight deep into interior spaces
- LED lighting incorporated throughout the school
- Using daylight sensors in conjunction with lighting controls, the building can automatically dim lights in areas with high levels of natural daylight to conserve energy.

Energy Efficiency

- 2,148 solar panels on the roof, which are estimated to produce 175% of the electricity required to run the school
- New geothermal wells that utilize the constant temperature of the earth to supply heating and air conditioning
- Superior building envelope to create a tighter thermal barrier
- Dashboard at all entrances showing real-time energy data for the building
- Building Automation System (BAS) that regulates air temperature and humidity levels, air purification and lighting control systems
- Dynamic Air Cleaners, which create a much healthier and superior indoor air quality and increase the HVAC system's efficiency to save energy.

Inspired by the school's energy-positive design measures, energy efficiency has become part of the school's curriculum and serves as a powerful teaching tool to drive cultural change within the students and community. For example, students now participate in the EnergyWise program that focuses on resource conservation; they also study the school's solar panels and other electrical systems with data obtained from energy dashboards installed in all three entrance lobbies.

Figure 4: Design plans for Jones County K-12 School.

Daylighting Harvesting Techniques

When tasked with designing three separate wings that would house each of the replaced schools—elementary, middle and high school—the atypical building design required our team to think creatively, especially when planning daylighting features.

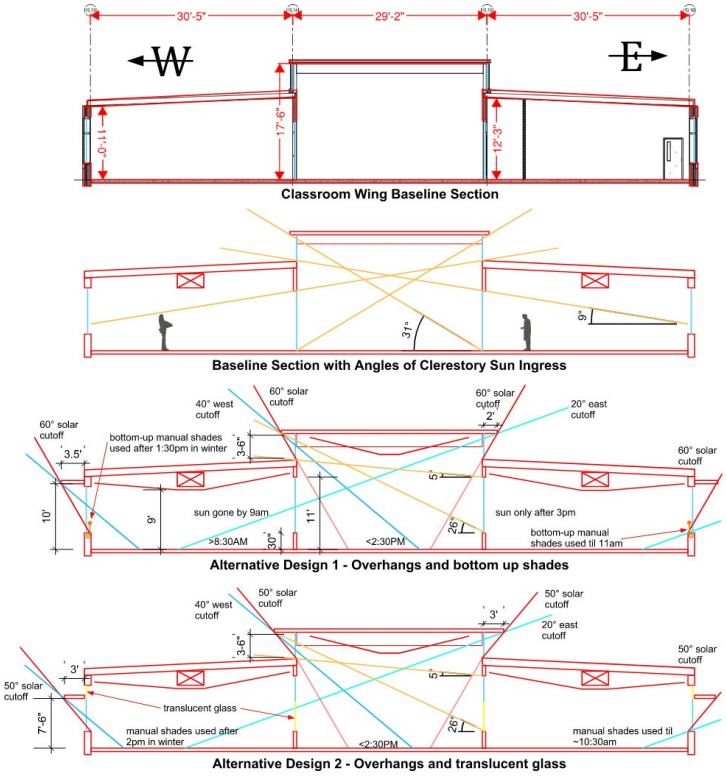

Figure 5: Iterations for controlling daylight within a classroom wing.

As shown in green on the design plans in Figure 4, the classrooms for each wing were designed to surround its respective media centers, which were individually designed as hubs for every age group. Working with lighting design specialists at Daylighting Innovations, we experimented with several iterations to develop the best combination of shading and overhanging within each classroom wing. Finding the most accurate iteration was imperative for controlling the daylight that would shine through clerestories and skylights, which were heavily used in all wings. An early iteration for controlling daylight within a classroom wing is shown in Figure 5.

Our final plans yielded several innovative daylight techniques throughout the various school spaces. In all three wings, we designed clerestories that allowed maximum East-facing light in the morning and West-facing light in the afternoon. In the gymnasium, we integrated skylights with prismatic lenses to diffuse the daylight entering the space and offer neutral lighting with minimal glare and harsh beams.

The media center in the elementary wing is a prime example of our extensive daylighting planning. As seen in Figure 6, the media center's flanking classrooms are glazed with light and its high clerestories allow natural daylight to flood into the space.

Figure 6: The elementary wing media center.

Implementing daylight was also key when designing the large “main street” hallway that connects all three wings. Capitalizing on its length, we integrated soaring clerestories on the highway’s South façade to allow more daylight to be pushed further into the hallway.

We also installed a combination of louvers and a product called *LightLouver* on the windows to diffuse glare and control the daylight streaming in. The *LightLouver* creates glazing light that is directed back up to the ceiling to push it deeper into the building, which is demonstrated in Figure 7.

As shown in Figure 8, the *LightLouver* uses patented slat designs to allow natural light in from various angles.

With daylighting harvesting being such an integral part of the school’s overall layout, design and structural selections, each technique was incorporated within the budget at the project’s onset to limit further cost increases. Considering their low life cycle costs and the significant value they add to students’ education, these high-efficiency features offer a short return on investment for the school. And for a building that was designed to operate for at least 60 years, the decision to invest in daylighting techniques will pay off for generations to come.

Figure 7: The LightLouver in action.

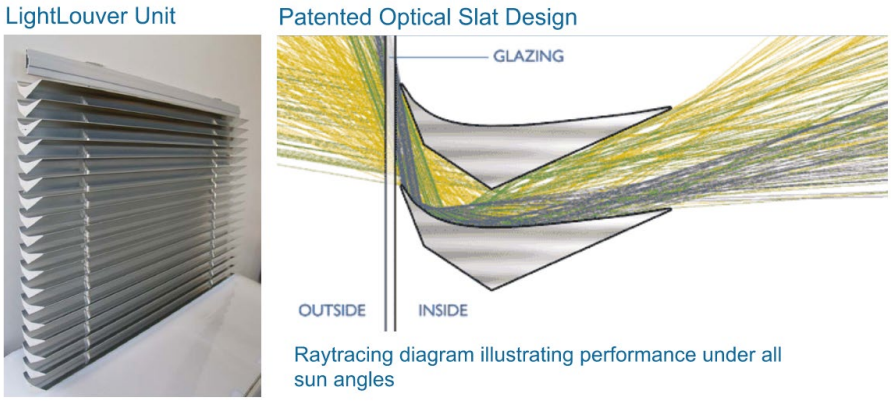

Figure 8: The LightLouver slat design.

BRINGING DAYLIGHT BACK INTO SCHOOLS

The consistent findings across numerous case studies show the significant impacts of daylighting in an educational setting. These studies strongly suggest there are physical and psychological health benefits from increased daylighting in schools, as evidenced by the enhanced test scores and student attendance.

Furthermore, the daylighting techniques implemented in the Jones County K-12 School yielded a modern building with reduced energy consumption, low energy bills and most importantly, a healthy, safe and superior learning environment for students and teachers.

The academic, financial and environmental benefits of bringing daylighting into schools far outweigh any upfront design costs. While increased daylight is integral, school design and construction standards are still catching up to this modern and effective approach. Designers, School Boards of Education and key district stakeholders alike should collaboratively prioritize the reincorporation of daylighting features back into our children's schools.

References
[1] "National Center for Education Statistics," [Online]. Available: https://nces.ed.gov/surveys/sass/tables/sass0708_035_s1s.asp.
[2] Heschong Mahone Group, "Daylighting in Schools," *Pacific Gas and Electric*, 1999.
[3] R. Küller and C. Lindsten, "Health and Behavior of children in classrooms with and without windows," *Journal of Environmental Psychology*, vol. 12, pp. 305-317, 1992.
[4] G. Vandewalle, P. Maquet and D. Dijk, "Light as a modulator of cognitive brain function," *Trends in Cognitive Sciences*, vol. 13, pp. 429-438, 2009.
[5] N. Shishegar and M. Boubekri, "Natural Light and Productivity: Analyzing the Impacts of Daylighting on Students' and Workers' Health and Alertness," in *International Conference on Health, Biological and Life Sciences*, Instanbul, Turkey, 2016.
[6] P. Barrett, Y. Zhang, F. Davies and L. Barrett, "Clever Classrooms: Summary report of the HEAD Project," University of Salford, Manchester, 2015.
[7] P. Plympton, S. Conway and K. Epstein, "Daylighting in Schools: Improving Student Performance and Health at a Price Schools can Afford," National Renewable Energy Laboratory, 2000.