Daylit Classrooms at 47N, 117W
Insights from occupation

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ABSTRACT: A post occupancy field study of daylit classrooms in three new elementary schools identifies perceptual and behavioural dimensions that impact the success of sidelighting strategies. The research utilizes multiple methods including observation, measurement, and teacher surveys to uncover a balance of quantitative and qualitative attributes. The emergent theme is that despite apparent issues associated with daylight variability and control, teachers are enthusiastic about the asset of natural light and views. Better interior management of the daylight source has the potential to improve the quality of the luminous environment and increase energy savings. Daylighting strategies should be considered within the context of orientation and end-user interactions.
Keywords: daylighting, occupancy, schools

INTRODUCTION

Daylighting is a core architectural strategy in the design of high performance K-12 schools [3,12,14]. Demonstrated benefits of natural light and views include a positive impact on human health and well being [2,10,12], potential for improved student performance [4,8,9], and electrical energy savings from reduced need for electric lighting and cooling [1]. No less important is the oft-stated desire by the occupants for "lots of natural light". Consequently, climate-specific daylighting practices are becoming customary for classroom design Standard architectural strategies are well-documented; less is known about the perceptual and behavioral dimensions that impact daylighting performance during occupation. The topic of this research is the teacher response to K-6 classrooms that have been designed with unilateral sidelighting. Specifically, are teachers satisfied with the daylit classroom despite the challenges of a highly variable and dynamic light source? Are there patterns of behavior that impact daylighting performance? The intent of the study is to gain insight into end-user interactions with daylit classrooms in order to provide more informed daylighting design assistance.

BACKGROUND

This research results from post-occupancy evaluation of classroom daylighting in three new elementary schools within a single school district in eastern Washington (47N, 117W). The work is a follow-up to daylighting design assistance provided at the request of the school district in response to a sustainable schools protocol. The three schools employ comparable daylighting strategies: sidelighting with north or south orientation, exterior sun shading and interior light shelves on the south. Differences between the schools are found in aperture configuration, daylight controls (interior shades), electric light controls (daylight harvesting), and interior elements. (Figures 1,2,3)

METHODOLOGY

Field research was conducted during a school break in early April, under variable sky conditions, typical for the season. Classrooms had been occupied for seven months and teachers had not received any specific training on management of a daylit classroom. The assumption was that the classrooms had been left "as is" for the break. Observed data includes recording of interior shades positions and spatial layouts in all classrooms, ease of operations of interior shades, and daylight harvesting controls. Measured data was taken in "typical" classrooms and includes luminance spot measurements on surfaces around the daylight aperture, illuminance grids under several conditions, and photographic analysis with high dynamic range photography and reverse color analysis.

Teacher surveys were administered anonymously through the school offices. The survey assessed satisfaction and behaviors (Likert scale, multiple choice, comments), preferences of physical attributes classrooms (simple ranking), and perceptions of the luminous environments (semantic differential). The return rate was 75% (n = 43).

Data was analyzed through graphical evaluation and descriptive statistics with comparative analysis between north and south classrooms.

Figure 1: School 1 South Facing Classrooms, horizontal mini-blinds for upper, mesh roller shade for lower, photocell with dimming

Figure 2: School 2 North and South Facing Classrooms, full window horizontal mini-blinds, switched electric lighting

Figure 3: School 3 North and South Facing Classrooms, full window vertical blinds, photocell + dimming

RESULTS

Through triangulation of the data, a central theme emerges: while teachers are very positive about the daylight resource, empirical evidence suggests there are patterns of occupation that compromise daylighting performance in terms of quality of the visual environment, access to views, and potential energy savings. Performance issues are related to particularities of orientation, daylight control challenges, and apparent lack of understanding around management of the daylight resource.

Teacher Satisfaction and Perception The teacher surveys clearly demonstrate appreciation of the daylight resource. In a set of questions on satisfaction with the classroom luminous environment, "natural light" received the strongest satisfaction assessment with 100% of respondents satisfied. This finding echoes a post-occupancy evaluation of the Merrill Environmental Center; daylighting received the highest satisfaction rating [6]. In general, the teachers were a happy group, with most of the respondents reporting satisfaction in "overall classroom," "views", "electric lighting", and "lighting controls." Dissatisfaction was noted with the interior shades in School 3. This is likely explained by vertical shades that were ineffective for direct sunlight (per researcher notes) and "noisy" (per teacher comments).

Table 1: Satisfaction with classroom luminous environment

Likert Scale: 1= strongly agree, 3= neutral, 5= strongly disagree	Mean (n=43)	Agree	Neutral	Disagree
I am satisfied with my classroom	1.6	93%	7%	-
I am satisfied with the natural light in my classroom	1.3	100%	-	-
I am satisfied with the views to outside from my classroom	1.7	83%	12%	5%
I am satisfied with how the interior shades operate	2.3	65%	12%	23%*
I am satisfied with the electric lighting	1.7	89%	9%	2%
I am satisfied with how the lighting controls work	2.0	88%	7%	5%

*these respondents were primarily from School 3

Positive comments around daylighting include "natural light is important," "it helps all to see real light", and "I love my windows". Negative comments were few and confined to issues of glare and direct sun in south facing classrooms and flickering lamps.

While overall satisfaction around "views" was relatively strong, there was variation between north (mean=1.3) and south (mean=1.9). This might be explained by a higher incidence of preferred nature and sky views to the north and more likelihood of street /parking lot views to the south.

In the environmental attributes ranking, "plenty of space" was the clear top choice for teachers (Table 2). Twenty-one percent selected "natural light and views" as their top choice; overall, 76% ranked it in the top four choices. Interestingly, the top environmental systems attributes, "natural light, views, temp, and ventilation", are all linked to features of the aperture.

Table 2: Teacher Rankings of Environmental Attributes Important in Creating a High Quality Learning Environment

"Physical features that are important to you in creating a quality learning environment"	Top Choice	Included in the Top 4 choices
Plenty of Space	61%	94%
Natural Light and Views	21%	76%
Temp & Humidity Control	9%	88%
Good Ventilation	6%	70%
Furniture and Storage Systems	-	45%
Display Areas	3%	42%
Quality Electric Lighting and Controls	-	18%
Acoustical Control	-	15%

On the semantic differential (Table 3), the strongest perceptions of light in the classrooms were healthy, bright, relevant, friendly, and desirable. Of these, all but "bright" are evaluative in nature, characterizing a positive attitude around the luminous environment. Interestingly, issues of potency (glaring / diffuse, warm / cool) and activity (static / dynamic, passive / active) are relatively neutral, despite the dynamic and variable nature of the daylight source.

Table 3: Semantic Differential on the "luminous environment in the classroom"

	Semantic Differential					
Bright	▪▪▪▪	▪▪▪▪▪▪	▪▪▪▪	•		Dull
Friendly	▪▪▪▪▪▪	▪▪▪▪▪▪	▪▪	•		Unfriendly
Passive	▪▪	▪▪▪▪	▪▪▪▪▪▪▪▪	•		Active
Healthy	▪▪▪▪	▪▪▪▪▪▪▪▪	▪▪		•	Unhealthy
Desirable	▪▪▪▪▪	▪▪▪▪▪▪▪▪	▪▪		•	Undesirable
Glaring	▪▪	▪▪▪▪	▪▪▪▪▪▪	•		Diffuse
Static	▪▪	▪▪▪▪	▪▪▪▪▪▪▪▪	•		Dynamic
Boring	▪▪	▪▪▪▪▪▪	▪▪▪▪▪▪	•		Interesting
Pleasant	▪▪▪▪▪▪	▪▪▪▪▪▪	▪▪	•	•	Unpleasant
Relevant	▪▪▪▪▪	▪▪▪▪▪	▪▪▪	▪▪		Irrelevant
Warm	▪▪	▪▪▪▪▪▪	▪▪▪▪▪	•		Cool

The teachers' enthusiasm around natural light and views is not surprising: it is well documented in the literature that people prefer workspaces with daylight and views of nature [Heerwagen & Heerwagen, 1986; Veitch & Gifford, 1996]. It should be noted that most of these teachers previously worked in the buildings that were demolished to make way for these new, high performance buildings.

Controls and Energy Savings Energy savings from daylighting is achieved only if electric lighting is reduced. At School 1, evidence indicated that the use of interior blinds impairs daylight harvesting mechanisms. The blinds for the daylight aperture were mostly closed, providing an input to the daylight harvesting system to turn on the lights in the daylight zone. Researchers found that upon opening the upper blinds and adjusting the lower window blinds for optimal view and glare control, the daylight harvesting systems operated perfectly, extinguishing the lights near the window and creating balanced illumination throughout the classroom. In this case, the closed upper blinds were likely due to several factors: physical difficulty with the control wand, reflected glare from a metal roof across the street, and lack of education around the purpose and operations of the upper window and shade controls. One teacher noted that the "top blinds always shut because of glare."

At School 2, the horizontal blinds were engaged in most of the classrooms; on the south, many were partially or fully closed. This was thought to be due to low-angle winter sun events. The researchers and a school resource officer "reset" the blinds for optimal April sun control, creating a brighter luminous environment with less need for electric lighting.

Visual Comfort and Daylight Controls It is challenging to create a comfortable visual environment with unilateral sidelighting. Interior blinds help manage the variability of the light source and provide for programmatic and teaching needs. The top reasons that teachers reporting using interior blinds were to control sunlight, for media presentation, and to control glare (Table 4). There is a more frequent use of blinds on the south than the north (Table 5) but it should be noted that overall, 90% of teachers reported using the blinds. This highlights the necessity of providing teachers excellent daylight control options.

Table 4: Reasons for adjusting interior blinds

Reasons for adjusting interior blinds	South	North
To control sunlight	92%	29%
To control glare sources outside the classroom	63%	7%
To control heat	30%	14%
To darken the classroom for media presentation	71%	81%
To limit views to the outside	33%	14%
For visual security	22%	0%

Table 5: Teachers report "adjusting interior blinds…"

Adjusts Interior Blinds	Frequently	Occasionally	Never
South	57%	43%	
North	15%	54%	31%
School 1	73%	27%	
School 2	38%	44%	18%
School 3	42%	50%	8%

Photometric data suggest visual comfort issues related to the interaction of natural light and interior configurations. Seventy-five percent of classroom computers were located at the window wall (Figure 4): the least desirable arrangement of visual task and window. Luminance readings taken off the north aperture of the skydome averaged 1229 cd; on the south, the average was 2435 cd. In the classrooms, readings ranged from 8-25 cd at the computer and other vertical surfaces near the aperture. This obviously creates a taxing visual environment. The researchers noted there were limited options for computer placement.

Figure 4: example of computers found at window

In general, teachers were relatively neutral on the issue of organizing their rooms around the light and views (Table 6). However, there were several comments in this area: "Desks in middle." "I have organized my classroom to help cut down on direct sunlight shining right in the eyes of my kindergarten students."

Table 6: Teachers on spatial organization and daylight

Likert Scale: 1= strongly agree, 3= neutral, 5= strongly disagree	Mean (n=43)	Agree	Neutral	Disagree
I have organized my classroom in response to light / views	2.7	33%	44%	23%

A programmatic concern is the conflict of daylight and need for room darkening to show media. There were several comments along the line of: "Too much light makes it most difficult for students to see what's projected on the screen by video projector."

As expected in unilateral sidelighting, the zone near the window is a "hot spot" and the daylight source needs to be controlled. Photometric readings show that the electric lighting systems did an excellent job of "filling in" the darker zone and balancing room illuminance. The left grid in Figure 5 is uncontrolled "daylight only" and shows a significant bright zone at the window. The right grid demonstrates the value of managing both daylight and electric light. In this case, the horizontal mini-blinds were engaged but open and the rear bank of electric lights was set to 33%. With appropriately managed daylight + partial electric light, classroom illuminance (across all schools) averaged 57 fc in south and 51 fc in north.

Figure 5: School 2 (south) Illuminance under two conditions - uncontrolled daylight (left) and integrated daylight + electric light

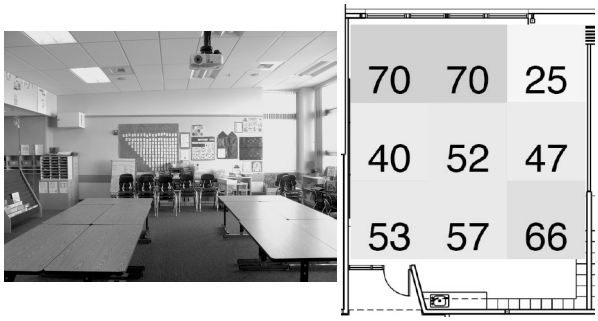

Figure 6: School 3 North Facing Classroom: integrated daylight + electric light

Daylight Controls and Views Views are an important component of daylighting, delivering critical environmental information while offering "respite from the immediate tasks and demands, thus providing a micro-restorative experience" [10]. In Heschong's studies, better views were associated with better student performance [9]. Several teachers commented on appreciation of the view: "I put my desk in a location so I could enjoy the wonderful view out my lovely windows."

The field researchers noted that views were compromised in a number of cases. For instance, it was common to find the light shelves and / or windows enlisted as pin-up area for art and classroom decorations. At School 3, the interior lightshelves in the south classrooms had not yet been installed and uncontrolled sunlight was an issue As a result, 83% of the rooms had engaged vertical blinds, blocking much of the view potential.

In School 1, mesh roller shades are used on the lower, view window. These were engaged in half of the classrooms, filtering light and view, but allowing a fair amount of environmental information. It was suspected that view blinds were closed due to glare from objects outside the window: a metal roof and parked cars. At this school, 100% of teachers reported adjusting their blinds.

Summary An emerging theme is the importance of the simple interior shade: properly specified and managed, daylight controls will contribute to the success of classroom daylighting. This includes improved energy efficiency, better quality luminous environments, preservation of views, and ability to meet teaching needs. The need to control the variable nature of daylight is supported by Heschong Mahone: "if teachers don't have control of their window, student performance is negatively affected" [9].

IMPLICATIONS

These observations around the teachers' perceptions and management of daylit classrooms have illuminated several important points that can be brought back to the design team and client.

- Daylighting is a multidisciplinary pursuit, requiring integration between architecture, interiors, lighting design, facility management, and end-user.
- In sidelit classrooms, both daylight and electric light must be managed for optimal visual environments and energy efficiency.
- Daylight controls (interior blinds) are of utmost importance, particularly for the south. They must be orientation appropriate, easy to operate, and should allow a variety of options for light interception, room darkening and view preservation.
- Uncontrolled site issues can derail daylighting success.
- Seasonal adjustment of interior shades may result in improved daylight management.
- Daylight is well received and highly valued by the occupant, even when faced with issues around control and management.
- Daylighting should include end-user education.

CONCLUSION

This research demonstrates the value of an assessment loop between occupancy and design. Daylighting strategies should be considered within the context of orientation and behavioral patterns. There appears to be potential in the concept of partnering with the teacher to improve classroom daylighting design. Their enthusiasm around the natural light source might be leveraged into more aggressive, better performing daylighting schemes. Commitment and knowledgeable involvement in classroom daylight management has the potential to increase energy efficiency and enhance the spatial and visual environment.

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