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Qualitative Daylighting Analysis

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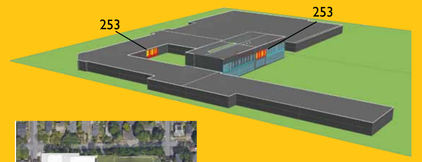
Abstract

This study evaluates the effectiveness of a combination of strategies used for analyzing daylighting qualities in the context of two classrooms. The strategies include qualitative information from observations and a post-occupancy survey, on-site light level measurements, and computer generated simulations all intended to inform a comparative analysis of the daylighting conditions and perceived daylighting qualities between the two classrooms. This composite approach takes into consideration access to daylight and views, glare problems and control strategies, use of window coverings, and perceived impact of daylight in order to identify and analyze the presence of certain biophilic design patterns. While both rooms have glazing along the east wall, the research indicates that across all the strategies employed, the new classroom significantly outperforms the old.

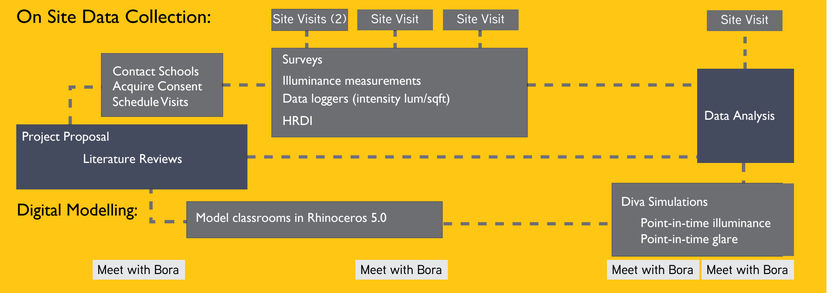
Introduction

Light, natural or artificial, is essential for the everyday activities in human life. It not only allows us to see but also impacts our physical health and psychological states. The benefits of light to human performance in work and learning environments have been widely studied and research shows that people achieve better results by having access to daylight and views during the work hours. Research across multiple disciplines continues to point to the benefits of using natural daylight over artificial lighting in classrooms. These benefits range from reduced energy use (Plympton, Conway, & Epstein, 2000) to improvements in the health of the occupants and increases in morale and academic performance. Studies have also shown that student behavior and performance improves when exposed to daylight instead of fluorescent light (Winterbottom & Wilkins, 2009). Given the well established linkages between light and human health, it is an imperative responsibility of architects to research and study how daylight plays out in design.

Two classrooms at Central Catholic High School (CCHS) in Portland, OR were studied for comparative purposes. The school, established in 1939, was recently renovated by Bora Architects in 2014-2015. The renovation included a new three-story addition with one level bellow grade and two above grade. The classrooms used in this study represent both the old and new additions to CCHS. Although both of the sample classrooms for this study receive daylight from the East, each classroom is defined by particular characteristics: room 253 is on the second floor of the new addition facing a football field, and room 112 is on the first floor of the existing building facing a courtyard. Classroom 253 is approximately 840 square feet, roughly square in shape and with daylight entering from both the East and West sides. It has 2 fluorescent light strips running North-South, alternating with two rows of three ceiling panel lights. A row of three solar tubes running along the west side of the classroom ceiling disperses natural light into the space. Classroom 112 is approximately 600 square feet, rectangular. in shape with length along the East and West walls. All glazing is in the East wall and extends from approximately 4 feet above the floor plane to about a 1.5 feet beyond the suspended ceiling.



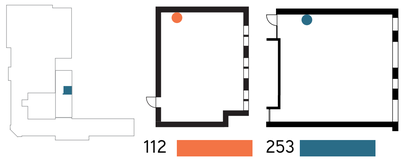
Methodology

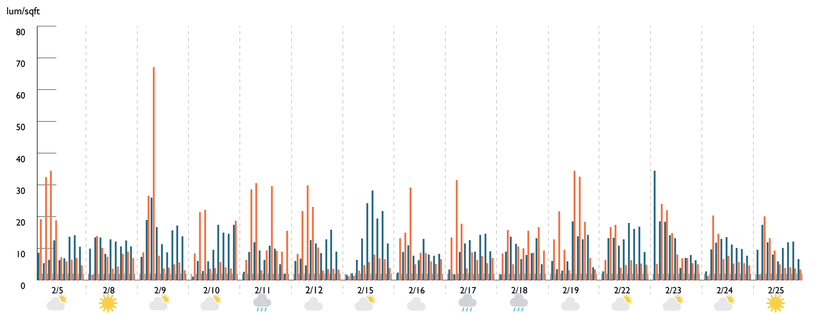


LIGHT USE

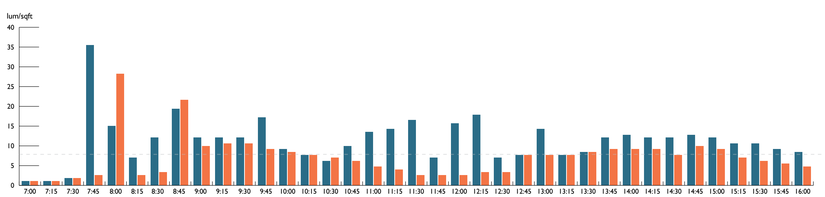
"We love the light."
- Classroom 253

"Causes glare, too bright or too dark. Cannot seem to find a middle ground."
-Classroom 112





Graph showing 15 schooldays with hourly averaged readings for classrooms 112 and 253

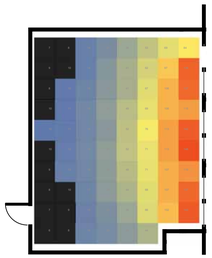


Graph showing readings from February 9, 2016 for classrooms 112 and 253

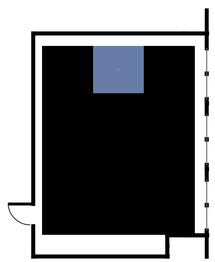
LIGHT LEVELS

The readings and simulation for this study correspond to March 1st, 2016. The conditions of the sky were cloudy.

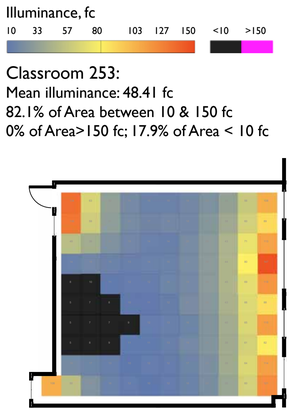
Classroom 112:
Mean illuminance 35.47 fc
89.2% of Area between 10 & 150 fc
0% of Area >150 fc; 10.8% of Area<10fc



DIVA simulation:
Nodes set at 2.5' from the ground and on a 3' grid.

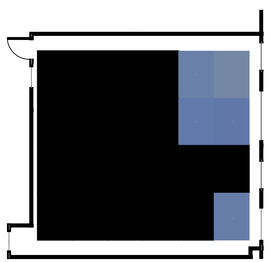


On-site Light readings:
Nodes set at 2.5' from the ground and on a 6' grid.



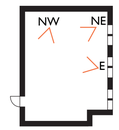
Classroom 253:
Mean illuminance: 48.41 fc
82.1% of Area between 10 & 150 fc
0% of Area>150 fc; 17.9% of Area < 10 fc

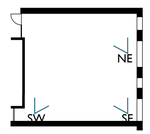
DIVA simulation:
Nodes set at 2.5' from the ground and on a 3' grid.

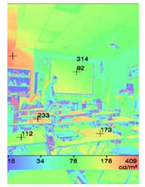


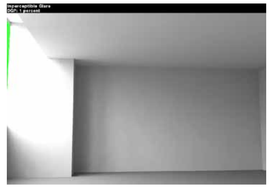
On-site Light readings:
Nodes set at 2.5' from the ground and on a 6' grid.

VISUAL DISCOMFORT

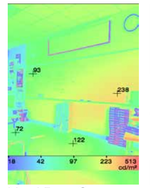


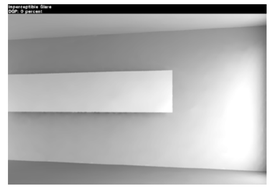




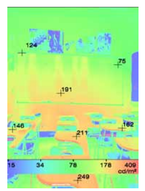


NorthEast Corner

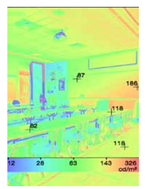


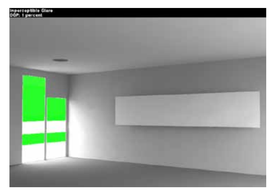


NorthEast Corner

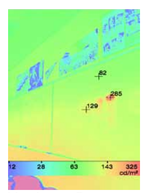


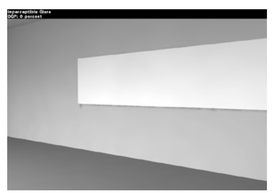
East



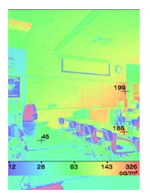


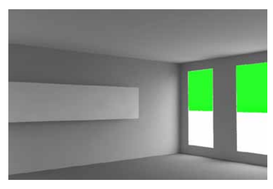
Southeast Corner





Northwest Corner





Southwest Corner

LIGHT USE FINDINGS

The data retrieved from the ONSET data loggers was averaged and grouped selectively to create the graphs. First, all the 15-minute readings were averaged to obtain hourly readings. These readings correspond to the school's regular schedule of occupancy, from Monday to Friday, 7:00 am to 4:00 pm. The first graph shows the hourly averages between February 5th to February 25th. This graph includes the readings for both classrooms as well as icons indicating how the weather was that day. We can observe that in both classrooms in most days there is an increase of intensity around 9:00 am, this could possibly be interpreted as the first time in the morning when the lights are turned on. We can also observe that the data logger in classroom 112 recorded more changes with greater variable during the morning than the one in classroom 253, which has higher readings during the afternoon.

The second graph shows all the readings, every 15 minutes, for the single day of February 9th, a typical overcast day in Portland, OR. We can observe that the intensity levels in classroom 112 are lower and less variable during the day, with the exceptions of the readings taken at 8:00 am and 8:45am, when the lights were turned on. While the lowest levels are recorded in room 112 between 10:45 and 12:45, the data logger in room 253 recorded very high intensity levels. The ONSET data loggers suggest that the windows in classroom 253 are far more effective at daylighting than the windows in classsroom 112.

LIGHT LEVELS FINDINGS

The illuminance grid visualizations from DIVA indicate that the daylighting conditions in classroom 253 are of better quality than those of classroom 112. This is evident in the more gradual gradient of the color map that transitions from high light levels along the east wall of glazing to intermediate light levels in the center of the classroom and back to higher levels along the west side. In 112, on the other hand, the color map quickly transitions from light to dark, and the ratio of under illuminated space (< 10 fc) to adequately illuminated space (10 fc - 200 fc) is significantly higher. The visualization pattern for classroom 253 suggests an under-lit area midway along the west side of the classroom. In reality, there is a solar tube located almost directly above this spot that was included in the digital model but did not read properly in DIVA.

The DIVA visualizations only loosely corroborate with the data collected on-site. Digital simulations often overshoot illuminance levels by not accounting for user modifications such as manual deployment of shading devices or wall treatments that change the reflective properties of the materials in the space. In addition, the software's capacity to predict the actual amount of light entering from the sky dome is limited and the on-site light meter readings were taken at greater distances than the nodes were set in DIVA. This was a necessary on-site adaptation given time constraints and challenges of maneuvering around furniture within the classroom.

VISUAL DISCOMFORT FINDINGS

In terms of glare feedback, the HDRI images taken on site were far more illustrative of potential glare problem areas than the DIVA point-in-time glare simulations set to simulate the same conditions. One possible explanation for this is that there is significantly more material variation in the actual classrooms than in the digital model. Potentially, more feedback from DIVA could be gained by modeling the furniture and specifying the furniture reflectance values with material assignments, however given that furniture positions often change in classroom settings, this extra attention to detail may not be worth the time it would take to model and run such simulations. Furthermore, the overall daylighting conditions of March 1st (the day when the HDR photos were taken) are low, therefore even the HDR images likely under indicate any glare issues.

While visiual discomfort from glare is increasingly recognized as an important design consideration, particularly in task specific spaces such as classrooms, there remains much room for innovation in developing tools that can adequately simulate the conditions that cause it.