Zach Elementary School
(Fort Collins, Colorado)
Human Factors Evaluation

SEPTEMBER 2004

Published by the Energy Center of Wisconsin
for the United States Department of Energy
and National Association of State Energy Officials (NASEO)
PROJECT OVERVIEW

The Association of State Energy Research and Technology Transfer Institutions, Inc. (ASERTTI) and the National Association of State Energy Officials (NASEO) with the Department of Energy (DOE) and the EnergySmart Schools Program conducted a joint project that encompassed applied research, field testing and technology integration.

The following organizations worked collectively to conduct this research:

- Energy Center of Wisconsin
- Iowa Energy Center
- Lighting Research Center
- Lawrence Berkeley National Laboratory
- Dalhoff & Associates
- Fort Collins Utilities

As part of the overall project there were eight distinct tasks outlined, each with its own set of goals, activities and deliverables. This document was created as part of Task 4: Advanced Daylighting Research.
Zach Elementary School
Fort Collins, Colorado
Daylight Human Factors Evaluation

Report submitted to:

Energy Center of Wisconsin
Project J30447
Energy Smart Schools

Report submitted by:

Lighting Research Center
Rensselaer Polytechnic Institute
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## Fort Collins, Colorado

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Evaluation Summary: Zach Elementary School

Zach Elementary School is a new school with all of its classrooms demonstrating Cool Daylighting™ principles. In most classrooms, daylight is provided by north-facing view windows and clerestory windows. Windows have tinted glazing, as per Cool Daylighting principles. Typical clerestory windows do not have shading, while view windows have Venetian blinds.

Electric lighting for each classroom is controlled by a set of photosensors mounted on the roof. Electric lighting is step-switched. (For more information about the site, see “Site Conditions” and Appendices.)

An LRC researcher visited Zach School in April 2004. The LRC is charged with evaluating human factors at this and other schools as part of NASEO contract J30447. Energy use will be monitored by other parties.

This human factors study focused on acceptance of the system by the teachers and students. Extensive surveys were done to monitor student response. (See Appendix C) Multiple teachers were interviewed on site. (See Appendix A)

LRC did not attempt to verify commissioning of the lighting controls system, as this was out of the scope of this evaluation; light levels were measured over the course of a day, to verify operational patterns with the lighting controls system.

LRC logged operation state of the blinds on clerestory windows and view windows. In both cases, blinds tended to be open, although this is not important for lighting energy conservation, since the photosensors are mounted on the roof (see Appendix D). The teachers are permitted to use blinds as they wish.

Although there were initially problems with excessive daylight on the South side, these have now been ameliorated by installation of additional blinds. Cool Daylighting creates a pleasant environment for teachers and students of Zach Elementary School.
Site conditions – Zach Elementary School

General:
- See plans, Appendix F
- This is a suburban school, new construction, completed 2002
- Not year-round operation
- Grades K-6
- All of the classrooms have Cool Daylighting
- There is no side-by-side “base case” human factors comparison, since the entire school has the new Cool Daylighting
- Grades 1-6 on 1st and 2nd floors, facing North (17 rooms)
- Kindergartens, Art and Music classrooms on ground floor, facing South (5 rooms)
- Other non-typical spaces (6th grade south, Itinerant teaching, special needs, computer lab)

Architectural:
- Windows are punched openings, with tinted glass
- Perforated roller shades on south-facing view windows
- Venetian blinds were added recently
  - North classrooms, on lower view windows
  - South classrooms, on upper clerestory windows
- Ceilings are sloped
- South-facing rooms have exterior shading for clerestory windows
- Air conditioning is provided through thermal ice (“T-ice”) storage
Lighting:
- Pendant direct-indirect fixtures, manufactured by Finelite, Series 4. (The same product was used at demonstration at Congress Elementary in Wisconsin. See this separate report.)
- Perforated metal reflector “wings” can be opened to allow uplight on the ceiling; all were in open position, as shown in Figure 4 below
- Two lamps in cross section, two continuous fixture rows per classroom, mounted typically 7’-7” above finished floor.
- Lighting is step-switched, as shown in Figure 5 below
- Photosensors are mounted on the roof as per Figure 6
- Lamps: OSI T8/841, except for one demonstration room with OSI T8/850

Figure 4: Finelite Fixture, with “wings” open, and one lamp off in cross section per daylighting controls system

Figure 5: Typical Classroom Switching Diagram
Figure 6: Photosensors mounted on roof
Appendix A: Teacher/Staff Interviews, Zach Elementary School

The principal of the school does not care for the distraction of automatic switching, and would have preferred dimming. She indicated that initially there were complaints about the automatic system, but re-commissioning of the lighting control system has satisfied teachers. The automatic switching has made an impression on the children: when describing their school at the annual holiday pageant, the children revised a line the song _Twelve Days of Christmas_ to say, “Eleven Blinking Lights!”

Exterior shading on the south side was insufficient (see Figure 7), so Venetian blinds were recently installed.

LRC interviewed ten teachers in typical (non-specialty) classrooms about their impressions of the key Cool Daylighting features at Zach Elementary. Most teachers (8/10) felt they have enough light, and none (0/10) think there is insufficient light for their needs. Most (8/10) think that the system switches appropriately with changes in weather or time of day. Most teachers (7/10) find the lighting acceptable for white board use, and most (7/9) do not change lighting or blinds to be able to see the white board.

One teacher had slightly different luminaire arrangement (discontinuous) and lamping (5000K instead of 4100K) due to the classroom’s use as a test case before widespread implementation. This teacher was the only one who complained that her lights appeared glaring, and gave her a headache when she works after dark.

Teachers approve of the amount and type of view from their windows, and do not generally have problems with view distraction. Most find both upper (8/9) and lower (10/10) windows acceptable in brightness. Venetian blinds were recently added to clerestory windows for south classrooms, and to view windows in north classrooms. Most (9/10) are happy with the blinds, although several indicated that they do not use blinds. Of those that operate blinds, most (5/6) indicated they found access to blind controls acceptable. The teacher who was concerned with access had a south-facing classroom, with blinds on clerestory windows. The maintenance staff has agreed to adjust upper blinds during the times of year when they are necessary.

There were some complaints about the classrooms, most unrelated to Cool Daylighting. A few teachers commented that the classrooms on the extremities of the school tended to be uncomfortable in terms of thermal regulation. This may be as a result of construction technique, or may be due to reduced HVAC sizing promoted by Cool Daylighting.

Several teachers commented that they would like to have an override to time clock function for lighting, since they often work after-hours and on weekends, and are left without lights. Nearly half the teachers (40%) do not think their classrooms get dark enough for audio visual teaching needs.
Specialty teachers (art, music, librarian) are located on the South side of the buildings, and have had many of the same problems with Southern exposure daylight. The teachers in south-facing classrooms are much happier now that upper blinds have been installed. The exterior shades allow too much sun to penetrate, since they only extend to the edges of the windows, and since they are perforated (see Figure 7 below).

Figure 7: Exterior shades on south-facing windows are discontinuous and perforated, allowing excessive direct sun to penetrate. Venetian blinds were installed to ameliorate this problem.
Appendix B: Daylighting Evaluation Survey

Zach Intermediate School - Classroom Lighting Study

Room # Teacher: Date: Time: Weather: 

Please answer the following questions about your classroom.

When you look at the LOWER windows, you find them:
When sunny: Too dark Dark Comfortable Bright Too bright
When cloudy: Too dark Dark Comfortable Bright Too bright

When you look at the UPPER windows, you find them:
When sunny: Too dark Dark Comfortable Bright Too bright
When cloudy: Too dark Dark Comfortable Bright Too bright

When you use this classroom, how much of the light are the BLINDS blocking?
All Most Half A little None

How frequently is it TOO DARK in this classroom?
Never Sometimes Often Always
(if "Sometimes" or "Often") This was due to the: Type of activity Weather condition
Please describe

How frequently is there TOO MUCH LIGHT in this classroom?
Never Sometimes Often Always
(if "Sometimes" or "Often") This was due to the: Type of activity Weather condition
Please describe

Do you notice the electric lights automatically SWITCHING OFF? Yes No
Do you find the switching DISTRACTING? Yes No
Do you find the electric lighting uncomfortably bright? Yes No

Compared to classrooms at other schools, the lighting in this classroom is .
Better About the same Worse

Do you have any comments about the windows, blinds, or electric lighting in this classroom?

Thank you for answering this survey!
Appendix C: Survey Results

Approximately 140 students (ages 9-12) filled out the survey about windows, blinds, and the lighting system. Overall, the students at Zach Elementary rated the classrooms visually comfortable and as good or better than those in other schools.

Windows:
When students look at both the upper clerestory and lower view windows, they find them comfortable to look at. Weather conditions do shift opinion slightly, but overall, the students find the windows comfortable.

Blinds:
Student surveys indicated that blinds block little or none of the light.
**Bright vs. Dark**
Most students thought the classroom was “Never” too bright or too dark (Figure 10). Of those that commented that it was “Sometimes” or “Often” too dark, most (57%) explained this was simply due to weather conditions, rather than type of activity, blind settings, or electric lighting control. Students were also asked whether there was too much light. Once again, most thought there was “Never”. Of those that offered explanation for responding “Sometimes” or “Often” too much light, nearly half (47%) cited weather as the reason there was too much light in the room, as opposed to audio/visual needs. A few children (5/47) commented that the lights seemed to stay on unnecessarily when the weather was sunny.

![Figure 10: Survey, Too Dark and Too Much Light](image)

**Electric Lighting:**
As shown below, the majority of the students notice the lights automatically switching off, and a significant minority find the switching distracting. The majority of students did not find the electric lighting uncomfortably bright.

![Figure 11: Survey, Lighting Controls](image)
Overall Rating
Overall, the majority of the students rated the lighting of their classrooms “About the same” or “Better” than other schools.

Figure 12: Survey, Compared to Other Classrooms
Appendix D: Window Blind Use During Site Visit

On a sunny weekend day in April, LRC surveyed the state of the various shades at the school. Most classrooms have North-facing upper clerestory windows with no shading, and lower view windows with recently-installed Venetian blinds. South-facing classrooms have perforated roller shades on view windows, and recently-installed Venetian blinds on upper windows. The upper blinds were all adjusted by the building manager on the day of LRC’s visit, so it may not represent actual use as directed by the individual teachers.

As shown in Figure 13 below, most blinds were open when LRC visited Zach School. However, this is not important for energy savings because the photosensors are mounted outside.

* All clerestory blinds (South windows) were pulled up before LRC evaluation, thus are excluded.

Figure 13: Status of Blinds on day of visit

Figure 14: Blinds in North (left) and South (right) classrooms
Appendix E: Horizontal Illuminance Measurements

In order to examine the degree to which the photosensor maintained constant illuminance, horizontal illuminances were measured over the course of one Saturday in early April 2004. (See Appendix F for location of measurement points.) Weather was mostly sunny. Electric lights were allowed to switch normally as controlled by roof-mounted photosensors. Measurements were taken on the top of the student desks (24” - 27” tall) in the four classrooms being monitored for energy savings by other collaborative research teams (Lawrence Berkeley National Laboratories). Two classrooms were north-facing, the other two were Kindergartens, both south-facing.

Classrooms on the North side do slightly exceed the IES recommended horizontal illuminances of 300-500 lux. As shown in Table 1, the lighting control system succeeded in maintaining illuminances throughout the day in north-facing classrooms.

<table>
<thead>
<tr>
<th>Time</th>
<th>A</th>
<th>B</th>
<th>C</th>
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<td>1192</td>
<td>955</td>
</tr>
<tr>
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<td>4 pm</td>
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Kindergartens are located on the South side of the school, and have a third row of luminaires (see Figure 15 and Appendix F). Illuminances in the Kindergartens exceed IES (300 - 500 lx) recommendations by two-fold. At midday, illuminances near the windows were very high, due to the new upper blinds being retracted (see Figure 7 page 7). Clerestory blind setting was not an indication of teacher preference, since adjustments were made during the LRC visit, on the weekend, when teachers were not present. On a followup visit three months later, LRC noted that a few clerestory blinds on the Kindergarten windows were put back down.

Maintenance staff are aware that the Kindergartens are currently over lighted, and plan to re-commission the system to increase lighting energy savings. The system was re-commissioned once already, to reduce complaints of frequent switching.
Figure 15: Kindergartens have three rows of luminaires and currently operate on a less aggressive control pattern
Appendix F: Classroom Plans and Measurement Points

(See Appendix E for illuminance measurements)

Typical North-facing Classroom (Such as rooms 121 and 123)

Typical South-facing Kindergartens (Rooms 140 and 141)
Appendix G: LRC Contact Information

The following parties can be contacted for more information as follows:

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Researchers from LRC wish to express their appreciation to the following individuals for their assistance in the evaluation at Zach School:

- Stu Reeve, Energy Manager, Poudre School District
- Kim Nohava, Principal, Zach Elementary School