Solon High School
(SOLON, IOWA)
Human Factors Evaluation

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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.
Solon High School
Solon, Iowa
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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Solon, Iowa

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Evaluation Summary: Solon High School, Solon, Iowa

Solon High school is a new school with all classrooms demonstrating Cool Daylighting™ principles. Each classroom has two lower view windows and four or five upper clerestory windows. Rooms face either north or south. There are no architectural shading elements, so venetian blinds are used extensively. Electric lighting for all the classrooms is controlled by a single, exterior photosensor mounted on the North side of the building. Electric lighting is step-switched, controlled by an exterior north-facing photosensor. For more information about the site, see “Site Conditions” and Appendices.

LRC researchers visited Solon High School in mid-September 2003. 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 also interviewed on site. (See Appendix A)

Surveys showed that the luminous environment is generally well-accepted by the students. Appearance of windows was rated as comfortable, perhaps as a result of frequent use of blinds. There were few complaints of either excessive or insufficient illuminance in the classrooms. Students do however notice the photosensor-controlled switching and find it somewhat distracting.

Interviews with teachers revealed that the switching was most noticeable when the school was first occupied, in 2002. Now that the students are accustomed to the switching, most teachers say there are fewer comments from the students when the lights switch off. Automatic switching was not a major concern of the teachers.

Blinds, however, are another matter. Most teachers must darken the room for audio/visual presentations. Teachers commented that upper window blinds are difficult
to access, so they tend to leave blinds down and closed. Teachers have been asked to keep blinds up and open, but teachers have refused due to inaccessibility and the need to control solar incidence on the South-facing classrooms.

Some teachers commented that the white boards were difficult to see with the immediately-adjacent view windows. Veiling reflections are a common complaint in facilities with whiteboards, due to the reflective surface characteristics. This is another reason why blinds are kept closed.

One visiting teacher said he would prefer a larger view window, but there were no other comments about restricted view to the exterior.

To support the human factors evaluation, the LRC measured illuminances in north- and south-facing classrooms throughout the day of our visit. The lighting system successfully maintained IES-recommended illuminances of 300-500 lux even with blinds closed. (The LRC did not attempt to monitor switching pattern and frequency as these were out of the scope of this evaluation.)

LRC logged operation state of the blinds (Appendix D). Blinds on the south side tended to be down and closed. This was particularly the case with the clerestory windows. Blinds were used on the North side as well, although not to the same extent as the South side. The teachers have been instructed to keep blinds open, presumably for lighting energy reasons. However, since the lighting control photosensor is located on the exterior, the blinds do nothing to interfere with lighting energy savings. LRC recommends that the teachers continue to use the blinds as needed to control solar incidence and to darken the room for audio visual presentations.

Aside from the misunderstandings about the use of blinds, Cool Daylighting creates a pleasant environment for occupants of Solon High School.
Site conditions – Solon, Iowa

General:
- See plans, Appendix F
- This is a semi-rural school, new construction, completed Fall 2002
- Non-year-round operation
- High school aged students
- All the classrooms have Cool Daylighting; 8 classrooms on North side, 12 classrooms on South side
- There is no “base case” comparison, since the entire school has the new Cool Daylighting

Architectural:
- No overhang
- Classrooms have either North or South-facing windows
- “Punched” opening windows, not continuous
- South windows: Lower view windows, 35% visible transmittance; Upper clerestory windows, 70%
- North windows: Upper and lower both 70% visible transmittance (unverified)
- White venetian blinds for both upper and lower windows
- Plans show that walls were intended to have two-tone paint, but as-built, are all white
- Plans show that an interior light shelf was intended, but may have been eliminated due to budget restrictions. Upper windows must subsequently use blinds.

Lighting:
- Pendant uplights with 15” cable mounting, Peerless Lighting “Prima” PRM7-3-32-R12-277-GEB10-XSE-DCT-LP741-F1/18-ACG
- Three lamps in cross section, six lamps per eight-foot luminaire
- Fixture tandem-wired to allow inner lamp to switch separately from outer lamps
- Two lines of five fixtures, 4’ length each
- Photosensor is mounted on north-facing exterior wall “open loop”
Appendix A: Teacher/Staff Interviews, Solon High School

Teacher A, South-facing room, Ground floor
• She closes and opens lower blinds for audio visual presentations on TV and when using white board on West side of room
• Videos presented 2x per week
• No conditions are too dark
• Would like to shut off only half of the electric lighting to do A/V
• Blinds fix problems with glare
• Never changes upper blinds. Always closed because she can’t access them (is afraid of heights and won’t walk on countertops)
• Lower windows are most frequently blinds are open. (Today they were down and open)
• Does notice lights switching off and on, does find it distracting. Switching is more noticeable on rainy days and in the afternoons.
• Lighting not uncomfortable.
• No setting is too dark; more frequently there is too much light.
• Compared to their old building, the new lighting is better.
• The teachers are all complaining that the upper windows are not convenient enough to operate blinds.

Teacher B, South-facing room, Second floor
• Hard to see white dry erase boards, so closes blinds next to white board.
• Upper blinds allow light in morning
• Blinds not easy to close, so they are left closed
• Wants to avoid standing on chair.
• Notices switching, not distracting.
• Loves room, overall. It feels very “light”
• “Going from previous yellow light, this is so much nicer.”
• View window is important
• TV monitor is next to window

Teacher C, South-facing room, Second floor
• Had only been present for 3 weeks at time of visit
• Lower windows, when sunny, they’re comfortable, when cloudy, they’re too dark.
• Leaves lower open always even when writing on white board.

Figure 5: South Windows typically have blinds closed
- Upper blinds “too tall for me” so doesn’t change
- Upper windows, when sunny, comfortable. (LRC didn’t ask about cloudy)
- Never too dark, never too much light
- Does not notice the automatic switching of lights
- Overall, better than lighting (from other schools internationally)
- Lower view window area is a bit smaller than he’s used to. Would prefer bigger.

Teacher D, South-facing room, Second floor
- Lower blinds, she does close to allow view of white board.
- Upper: “We’re supposed to have them open”, but overhead projector is not visible, nor white board.
- All the way open is too much
- She is “not gonna crawl up there”
- “I’ve got news for them… I’m not going to crawl up there every day.”
- Can get student volunteers to stand on the counters to operate the blinds. (Note: there may be a liability disincentive to inaccessible controls for blinds)
- Notices electric lights changing. Is disturbing. “The kids stop and look, like when there is a lightning flash. They don’t talk about it any more, because they’re kinda used to it now.”
- Never too dark
- Sometimes too much light.
- Overall, the environment is about the same.

Teacher E, North-facing room, Second floor
- “I don’t move (the blinds) unless I’m showing a movie”
- Twice last year he showed a movie; usually the blinds are up
- He showed a movie 3 weeks before the visit, and left the blinds down
- Does notice electric lighting switching off, but not distracting any more. Kids commented at first last year, but not much this year.
- Not frequently do the lights switch on/off repeatedly; couple times a day. Lighting never shuts all the way off.
- The (sensor) don’t switch rows together (both N and S lines of lights), but rather the (North) one switches separately from the other (South) one.
- He notices the lighting going up and down, never switching completely off.

Teacher F, North-facing room, Second floor
- When he uses an overhead projector he has to close the blinds.
- Does notice lighting change; at first (last year) it did distract, but not now.
- Sometimes the lights turn off 5 or 6 times in an hour, but only 3 times per year, infrequently, when weather is overcast.
- He thinks the whole room switches off together, not the line of fixtures closest to the window.
Guidance Counselors, North facing, Ground floor
- Counselors find the illumination dim when weather is cloudy
- Switching is very disturbing
- On sunny days it is fine
- “I have a lot of questions (concern) about the automatic dimming” because switching is disturbing
- These private office do not have pendants; they have 2x4 troffers with prismatic lenses.

Bob Lesan (school principal, South facing office, first floor)
- Has not had a complaint about the lighting
- Did get complaint about upper blinds being high up
- The teachers refused to keep upper blinds open; it seemed senseless to them to have blinds but not to use them.
- People don’t notice lights switching automatically.
- “Compared to the dungeon we were in before, this is so much better.”

Facility Manager
- He is not sure who did commissioning of the system, if anyone.
- No complaints about lamp changes.
- Relamping done with spot replacement throughout the year, then group spot replacement annually during the summer, if end darkening or if lamp is out.
- He wouldn’t recommend an override-to-on for lighting in each room because teachers turn on light habitually, reducing energy savings. (LRC correction: according to plans, there isn’t an override to on, just an override to off).
- No energy management system. All lighting manually controlled to turn off, including HVAC. (The evening maintenance man reported he has to walk around the hallways after dark to turn off lights. There aren’t any occupancy sensors.)
Appendix B: Daylighting Evaluation Survey

Solon Community High School - Classroom Evaluation
Room # ______ Teacher: _______ Date: _______ Current weather: _______
During what block do you come to this classroom? _______ Class: ________________

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 this 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 this 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

Any comments about the windows, blinds, or electric lighting in this classroom?

Thank you for your feedback!
Appendix C: Survey Results

Eighty-seven students filled out the survey about windows, blinds, and the lighting system. The majority of the responses (77%) were from students in south-facing classrooms. Overall, the students at Solon High School find 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 are frequently in use. Most students (60%) reported that blinds block “Most” or “Half” of the light (Figure 8).
Bright vs. Dark:
Despite frequent use of blinds, most students (55%) thought the classroom was “Never” too dark. (Figure 9). Of those that commented that it was “Sometimes” or “Often” too dark, half (51%) 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 (55%) thought there was “Never” too much light. Of those that offered explanation for responding “Sometimes” or “Often”, most (94%) cited audio/visual needs as the reason there was too much light in the room.

Electric Lighting:
The majority of the students (66%) do notice the lights automatically switching off, and a significant minority (40%) reported finding the switching distracting. A few students commented that the electric lighting switched frequently in their opinion, or did not seem to be on at all. The majority (65%) did not find the electric lighting uncomfortably bright, which is sensible since the luminaires distribute the light towards the ceiling.
Overall, the majority (87%) of the students found the lighting in their classrooms “About the same” or “Better” than other schools.

![Comparison bar chart](image)

*Figure 11: Survey, Compared to Other Classrooms*
Appendix D: Window Blind Use During Site Visit

Each classroom has four or five upper clerestory windows and two lower view windows. On a sunny day in September, LRC researchers surveyed the state of each window at the school. To a great extent, blind use depends on the side of the building.

The upper graph shows that blinds in most clerestory windows (78%) on the south side were down and closed. Some south clerestory windows (19%) had blinds down and open, and few (3%) had blinds up entirely as intended with Cool Daylighting. Most view windows on the south side (59%) had blinds down but open, or down and closed (30%).

On the North side the majority (55%) of clerestory window blinds were down and closed. However, a significant minority (36%) had clerestory blinds up, as intended with Cool Daylighting. View windows showed even less use of the blinds, with 20% down and closed, 35% down and open, and 45% up entirely.

These results indicate that even if there had been architectural shading on the South side to block the direct sun, the need to darken the classrooms for audio/visual presentations still required the use of blinds. The difficulty of reaching controls for the...
blinds (particularly on the clerestory) explains why blinds are left down longer than needed.

At Solon High School the use of blinds does not impact electric light energy savings, since the photosensor is located on the exterior. There were few complaints about low light levels with blinds closed. The teachers have been instructed to keep blinds open, presumably for reasons of energy savings. However, in this case it is more important that the teachers be able to conduct their classes in comfort rather than keep the blinds open.

Although use of blinds does not affect lighting energy savings, it is possible that sunlight penetration on the south side may affect HVAC savings, since each classroom has its own thermostat and HVAC unit. Research by other parties may be able to demonstrate other energy impacts of the use of blinds.

Figure 14: One photosensor for whole wing, facing north
Appendix E: Horizontal Illuminance Measurements

Horizontal illuminances were measured at desk height of 29”. Illuminances were measured with electric lights on but as normally controlled by photosensor. Since lamps were difficult to access without use of a ladder, LRC did not attempt to monitor which or how many lamps were turned off. (Clearly some lamps were turned off during measurements, since nighttime electric-only illuminances were higher than daytime illuminances.)

Even with blinds down and closed, classrooms still meet the IES recommended horizontal illuminances of 300-500 lux. As shown in Appendix F, Point A is closest to the window, point B is the center of the room, and point C is furthest from the window.

See Appendix F for plan drawing.

<table>
<thead>
<tr>
<th>Desk height 29”</th>
<th>Room 118 - South</th>
<th>Room 104 - South</th>
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<tbody>
<tr>
<td></td>
<td>Point A</td>
<td>Point B</td>
</tr>
<tr>
<td>10:30am, Clear Sky</td>
<td>568 lx</td>
<td>617 lx</td>
</tr>
<tr>
<td>Blinds Down and Closed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29”</td>
<td>970 lx</td>
<td>819 lx</td>
</tr>
<tr>
<td>Blinds Down and Open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29”</td>
<td>1544 lx</td>
<td>950 lx</td>
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<tr>
<td>Blinds Up</td>
<td></td>
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<table>
<thead>
<tr>
<th>Desk height 29”</th>
<th>Room 105 - North</th>
<th>Night time, no daylight</th>
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<tbody>
<tr>
<td></td>
<td>Point A</td>
<td>Point B</td>
</tr>
<tr>
<td>2pm, Clear sky</td>
<td>500 lx</td>
<td>543 lx</td>
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<tr>
<td>Blinds Down and Closed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29”</td>
<td>590 lx</td>
<td>608 lx</td>
</tr>
<tr>
<td>Blinds Down and Open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29”</td>
<td>610 lx</td>
<td>631 lx</td>
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<tr>
<td>Blinds Up</td>
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Appendix F: Classroom Elevation, Plan, and Measurement Points

Typical Classroom Plan
Windows facing N or S

Typical Classroom Elevation

- 3-lamp luminaires tandem wired for step dimming
- Horizontal illuminance measurement point
- Lighting, three lamps in cross section
Appendix G: LRC Contact Information

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

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- Don Otto, School Board Member
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- Bob Lesan, Principal