

**An Evaluation of Daylighting
in Four Schools
In the Research Triangle Area of North Carolina
*A Summary Report***



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I. INTRODUCTION

The use of daylighting holds great promise for improving the learning environment while simultaneously reducing the cost of utilities to operate the schools. This report summarizes the results of daylighting studies conducted at four schools in the Research Triangle area of North Carolina. These schools are:

- Four Oaks Elementary, Johnston County, North Carolina (see Figure 1)
- East Clayton Elementary, Johnston County, North Carolina (see Figure 2)
- Smith Middle School, Chapel Hill, North Carolina (see Figure 3)
- Rashkis Elementary, Chapel Hill, North Carolina (see Figure 4)

Additional daylighting studies are underway at five other schools. Although these studies are not included in the subject study, the results (when completed) will be shared with the Lighting Research Center.

Table 1 provides a listing of the daylighting, energy, and other relevant features of the four daylit schools in the Research Triangle area of North Carolina included in the study. From an historical perspective, the schools cover an eleven year period..... from Four Oaks Elementary, built in 1992 to Rashkis Elementary, built in 2003. The schools have a similar footprint, in that most of their classrooms are located on an east-west axis, thus maximizing the southern exposure. The schools' size ranges from 85,000 ft² at Four Oaks to 128,000 ft² at Smith Middle. Roof monitors and clerestories are the primary daylighting features, with Four Oaks and Rashkis using clerestories and East Clayton and



Figure 1. Front of clerestories at Four Oaks Elementary School. Note the lack of consistency regarding the position of the blinds.



Figure 2. South facing roof monitors on flat roof at East Clayton Elementary School.



Figure 3. A front view of Smith Middle School. Note that all roof monitors are oriented south.



Figure 4. Clerestories at Rashkis Elementary School.

TABLE 1. DAYLIGHTING AND ENERGY FEATURES OF FOUR SCHOOLS INCLUDED IN STUDY

School	Four Oaks	East Clayton	Smith Middle	Rashkis
Location	Johnston County, NC	Johnston County, NC	Chapel Hill, NC	Chapel Hill, NC
Construction Date	1992	1998	2001	2003
Size, ft²	85,000-ft ² on original building	96,710-ft ²	128,000-ft ²	-
Daylighting Features				
- Clerestories	Yes	No	No	Yes, in classrooms, gym, cafeteria, library
- Roof Monitors	No	Yes, toward rear of classroom	Yes, in classrooms, gym, cafeteria, library	No
- Diffusing Baffles	Yes, but yellowing	Yes	Yes	Yes
- Blinds	Yes	No	Yes	Yes
- Blind Controls	Yes, tangled chains	N/A	Rotational shaft at ceiling height	Pull strings at ceiling height
- Blind Control Rod with Hook	Yes, one for entire school	N/A	Yes	Yes, but not available in most classrooms
- External Shading/Overhangs	No	Some	Light shelves shade lower glass windows	8-ft wide covered walkways
- Light Shelves	No	No	Yes, anodized aluminum	No
- Light Sensors	Yes, but not operating	No	Yes	Yes, but randomly placed
- Dimming Controls	Yes, but not operating	No	Yes, in classrooms	Yes, in some classrooms
- Artificial Lights	<ul style="list-style-type: none"> ▪ Fluorescents in classroom ceiling, and ▪ Fluorescents in perimeter of cavity on separate switches 	<ul style="list-style-type: none"> ▪ Fluorescents in classroom ceiling, and ▪ Fluorescents in perimeter of cavity on same switch 	<ul style="list-style-type: none"> ▪ Fluorescents in classroom ceiling, and ▪ Fluorescents tubes at front and rear of roof monitor cavity 	<ul style="list-style-type: none"> ▪ Fluorescents in classroom ceiling, and ▪ Fluorescents tubes under baffles
- Occupancy Sensors	No	Yes	Yes	Yes
Daylit Areas				
- Classrooms	Yes	Yes	Yes	Yes
- Gym, Media Center, Cafeteria		Yes, Yes, Yes	Yes, Yes, Yes	Yes, Yes, Yes

TABLE 1. DAYLIGHTING AND ENERGY FEATURES OF FOUR SCHOOLS INCLUDED IN STUDY-continued

School	Four Oaks	East Clayton	Smith Middle	Rashkis
Heating System	Hot water boiler	2 hot water boilers	2 Smith Cast Iron B hot water boilers	2 Fulton hot water boilers
- Fuel	No. 2 fuel oil	Natural gas	Natural gas	Natural gas
Air-Conditioning System				
- Chiller	Old 200-ton Carrier chiller, R-11	Trane screw chiller, R-22	2 McQuay air-cooled chillers	2 Carrier air-cooled chillers
- Cooling Tower	Yes	Yes	No	No
- Ice Storage	No	Yes	No	No
Teacher Training & Awareness	Claimed, but not evident	Could not evaluate	Quite good, requires annual update	Minimal
Top Management Support	Not evident	Principal supportive	Yes, principal very knowledgeable	To some extent

Smith Middle using roof monitors. Smith Middle also incorporates light shelves to supplement the daylighting in the south-facing classrooms.

II. ROOF MONITORS

Figure 3 shows the roof monitors incorporated into the Smith Middle School design. Roof monitors are frequently installed on flat roof single-story buildings. To be most effective, the vertical glazing should be oriented south. Figure 5 is a close-up view of a roof monitor.



Figure 5. A close-up view of a roof monitor at Smith Middle School.

III. CLERESTORIES

Figure 4 and 6 show how clerestories can be attractively incorporated into the slanted roof design at Rashkis. From inside the classroom, the daylighting effect is similar to that of a roof monitor. Because clerestories are built into the roof, clerestories for north facing classrooms also must face north. This diminishes their annual daylighting contribution by approximately 25 percent (for the same glazing area).



Figure 6. A top view shows the symmetrical arrangement of the raised dormers that create the clerestories at Rashkis Elementary.

IV. DIFFUSING BAFFLES

All schools use baffles to diffuse the daylight into the classroom from above (i.e., from roof monitors or clerestories). These baffles work reasonably well. At the older schools, the maintenance people complained that they were difficult to keep clean. At Rashkis, baffles were installed in both the south facing and north-facing classrooms, even though the north facing clerestories did not require them for light distribution. No one seemed to know why, although it was surmised that it may have been done for sound dampening and symmetry purposes.

Recommendation: For north facing classrooms, the rationale for using baffles should be discussed with the architect. If the baffles are used for sound dampening purposes, some alternative means should be explored.



Figure 7. A view looking up into the roof monitors at Smith Middle School. This view shows the diffusing baffles hanging from the ceiling of the monitor.

V. BLINDS

Most schools had blinds installed to control the amount of daylight entering the classroom. The exception was East Clayton, where blinds were eliminated to reduce cost.

VI. BLIND CONTROLS

The control of blinds is a serious problem at most schools. At Four Oaks, a control rod with a hook is required to operate the chains (which are usually tangled). And, the maintenance people could find only one control rod in the entire school. Needless to say, the blinds are closed most of the time.

At Rashkis, a control rod with a hook is required to operate pull strings accessible at ceiling height. Unfortunately, most classrooms did not have a control rod and most teachers had never seen one.

Smith Middle has a rotational shaft at ceiling height that is operated by a control rod with a hook. This system appears to work better than the others, perhaps because of the culture of Chapel Hill and the top-management support provided by the school system and the principal.

Comment: The ability to darken a classroom is particularly important in lower grades.

Comment: The present generation of blind controls is not user friendly. In today's classroom, teachers do not have the time to manually adjust blinds. This is one reason why daylighting has not achieved the results expected.

Recommendation: Further research is needed to address the daylighting control issue.



Figure 8a. Librarian using long pole to adjust the blinds at Smith Middle School.

Figure 8b. Small rings attached to blind strings for controlling blinds at Rashkis Elementary School.

VII. LIGHT SHELVES

Horizontal reflective light shelves can be incorporated into regular south facing windows. Typically, they are 18 to 24 inches deep. Sunlight is reflected off them and then onto the ceiling of the classroom. Light shelves are the next best option to roof monitors/clerestories and can be used effectively in multi-story buildings. In classrooms, they can serve as supplemental light source and are particularly helpful in providing daylight to areas of the classroom that are not directly under the roof monitor.



Figure 9. Most south facing windows at Smith Middle School are recessed approximately two feet. Note the anodized aluminum light shelf incorporated into the window arrangement.

VIII. LIGHT SENSORS

Sensors that measure the light level in the classroom are an essential element of an operational daylighting system. All schools included in the study except East Clayton utilized light sensors to varying degrees of effectiveness. For example, the light sensors at Rashkis seemed to be randomly placed, whereas the sensors at Four Oaks (the oldest school) and Smith Middle were centrally located in the roof monitors directly below the glazing. Unfortunately, the light sensors at Four Oaks were not working, thus negating the effect of daylighting.

Comment: The effectiveness of a daylighting system is very much affected by the quality and placement of light sensors.

Comment: Proper placement and maintenance of the light sensor system is necessary for daylighting to be effective.

Recommendation: More research in the design and placement of light sensors is needed.

IX. DIMMING CONTROLS

Light sensors and dimming controls are part of the overall system that controls the amount of backup lighting used in the classroom. Thus, the comments made above for light sensors at the various schools also apply to the dimming controls. There are, however, areas where sensors and dimming controls differ. In the case of light sensors, design and placement are key issues. In the case of dimming control, security and access are the overriding concerns. For example, the control boxes at Rashkis are left open for the teachers to make adjustments (even though they are not trained), whereas at Smith Middle, the dimming controls are under “lock and key” and can only be accessed by maintenance people.

Comment: Dimming controls are essential for a properly operating daylighting system.

Comment: Control boxes should be kept locked at all times, to insure that the proper settings are not disturbed.

X. FLUORESCENT BACKUP LIGHTING

Fluorescent backup lighting in the classroom is generally divided into two areas – (i) the horizontal ceiling area around the perimeter of the classroom, and (ii) the region under and inside the roof monitor cavity. In most schools, except East Clayton, these two area lighting systems were controlled by separate switches.

Comment: In most schools, backup lighting appears to be used randomly. Most teachers are not informed and/or instructed on the proper use of the daylighting systems available to them. The exception is Smith Middle, where Top Management Support is readily evident.

In most schools, hallway lights are on all the time, independent of daylighting effects (i.e., light sensors are not used in hallways). Hallway lights are generally controlled by a limited number of switches, thus making selective control impractical.

Comment: The issue of hallway lighting should be revisited.

Conclusion: Education, culture and management support are the keys to success.



Figure 10. On south facing clerestories, cloth covered baffles diffuse and reflect the light down into the classroom. Note the placement of the fluorescent tubes between, parallel, and below the baffles.

XI. OCCUPANCY SENSORS

The three newest schools all had occupancy sensors.

Comment: Occupancy sensors play a vital role in insuring that the fluorescent lights are off when the room is not in use.



Figure 11. Occupancy sensors are located in most classrooms at Rashkis Elementary

XII. EXTERNAL SHADING/OVERHANGS

At the four schools studied, most of the regular south-facing windows were open to direct sunlight. At Smith Middle, the externally mounted light shelves shaded some of the vertical windows below them. This was not perceived to have a negative daylighting effect. The Rashkis design, however, is somewhat more puzzling, in that it utilized 8 foot wide covered walkways along all south-facing and north-facing walls. These walkways shade the south-facing wall and significantly reduce the daylighting available through the regular windows. This covered walkway feature seems unusual for a school that features daylighting and seems to work at cross-purposes to the daylighting objective.

Recommendation: Some follow-up discussions with the architect are recommended.

Comment: Although Rashkis and Smith Middle had the same primary architect, the daylighting systems at Smith Middle were designed by a **daylighting specialist**, whereas the Rashkis design did not.



Figure 12. A close-up view of the covered walkway and its shading effect at Rashkis Elementary School.

XIII. DAYLIGHTING OF GYM, MEDIA CENTER AND CAFETERIA

The success of daylighting for these areas varies with the school and its age. At Four Oaks, for example, leaks around the original skylights in the gym forced a roof replacement with skylights omitted. At Smith Middle, the daylighting from the roof monitors in the gym was so effective that back-up lighting was often not required. A similar experience was noted in the cafeteria, where north facing monitors (without baffles) provided excellent daylighting. At Rashkis, however, the daylighting experience was not nearly as effective, since the clerestory windows were smaller and the baffles on the north-facing clerestories had the unnecessary effect of reducing the daylighting contribution. In the media center at Rashkis, the back-up lighting circuits (and switches) were inadequate to properly provide light only where it was needed.

Recommendation: The architectural community needs more education in daylighting to provide the proper mix of daylighting and back-up light circuitry so that the full benefits of daylighting can be realized. Also, the use of baffles for north facing roof monitors/clerestories in large high spaces should be eliminated.



Figure 13. Roof monitors and baffles do an excellent job of daylighting the gymnasium at Smith Middle School.



Figure 14. Baffles located on north facing windows high above the gymnasium floor do not serve a useful purpose and block light from entering the building at Rashkis.



Figure 15. North facing roof monitors without baffles provide daylighting for the cafeteria at Smith Middle School.

Figure 16. Skylights were covered when the roof was replaced on the gymnasium at Four Oaks Elementary School.



XIV. Maintenance

Maintenance is a problem at most schools. Problems range from insufficient funds to the number and quality of the maintenance staff. Under these circumstances, adding daylighting to the list of maintenance items simply exacerbates an already serious situation.

Comment: Over a period of six years, Johnston County went from being a supporter of daylighting to rejecting the concept all together. The primary reason for this change of heart was “maintenance costs.” Typical problems/concerns cited by the Johnston County Schools System Administration included the following costs:

- replacing dimming ballasts,
- repairing sensors and dimming controls,
- fixing control chains for controlling blinds,
- cleaning glazing and baffles,
- repairing leaks, etc.

Recommendation: Simplify the operation and maintenance of the daylighting systems with the thought of making them as trouble-free as possible.

Recommendation: Consider the establishment of a daylighting service organization dedicated to the improvement and maintenance of the daylighting systems. The outgrowth of such an organization may well be an organizational model and/or set of skills that will assist school systems in effectively dealing with typical daylighting problems.

XV. TOP MANAGEMENT SUPPORT AND TEACHER TRAINING & AWARENESS

“Teacher Training and Awareness” and “Top Management Support” really go hand-in-hand. The former does not occur without the latter. This fact was very obvious in the four schools evaluated in the study. Top management support may have existed fifteen years ago in Johnston County, but that is no longer the case. In fact, daylighting is viewed rather negatively today and the Four Oaks and East Clayton reflect that neglect, even with a very supportive principal at East Clayton.

The situation is quite different in the Chapel Hill School System, where the school system administration is very supportive, establishing energy-use goals for the schools, and providing quarterly updates on their energy use. However, the actual situation at the individual schools like Smith Middle and Rashkis Elementary is quite different. At Smith Middle, for example, most teachers are knowledgeable and enthusiastic about daylighting. They love the experience and believe it improves learning. They know how to use the daylighting systems and the back-up lighting is off when the classrooms are not in use. This school was, by far, the most positive experience.

After visiting and evaluating Smith Middle, the experience at Rashkis was somewhat disappointing. The daylighting systems were not as well designed and the teaching and maintenance staffs were not well informed on daylighting principles and practices. This was quite surprising, since the two schools belong to the same school system and Rashkis was actually designed and built after Smith Middle.

Conclusion: Even in a supportive school system, the hands-on principal plays a vital role.

Recommendation: The development of a brief daylighting and energy conservation manual or tutorial would be very helpful in educating the teachers on the use and benefits of the daylighting systems available at the school.

XVI. SUMMARY

Daylighting is a promising new technology that can have an important impact on the educational experience of our students. If properly applied, it can improve the educational environment, while simultaneously reducing energy usage. The subject study identified a number of areas (and specific issues within each area) that must be addressed for daylighting to reach its full potential. They are:

Relative to the Architectural and Building Community

- Three of the four daylit schools evaluated have serious design flaws (e.g., regarding the use of light shelves, baffles, and overhangs). **There is a real need for an educational program for the architectural and building community that stresses the proper application of daylighting in buildings.**

Relative to Daylighting Components and Systems

- The daylighting components must be well-designed and effective. This means:
 - The **light sensors** must be properly located and they must work,
 - The **dimming controls** must work and be compatible with the light sensors,
 - Better methods for **darkening the classroom** must be developed,
 - The daylighting controls must be made more **user-friendly**.

Relative to Top Management Support and Training

- **Top management support** from the school system administration down to the principal is absolutely essential. Specific actions growing out of this support are:
 - The school system must support the **training** of teachers and other school personnel on the purpose and proper operation of the daylighting systems,
 - The school system must provide the **financial support to properly maintain** the daylighting systems,
 - The school system must recognize that a **high teacher turnover** means that daylighting instruction is a continuous (at least annual) activity,
 - The school system must **publicize** its support of daylighting in the schools through energy and “green” projects and displays. Student projects can help keep the “green” philosophy alive among the entire school community

Relative to Cultural Change

Implementing a daylighting system in a school or a school system will involve a “Cultural Change” – a different way of doing business. These changes will not occur easily or quickly. People at all levels will have to buy into it. However, once accomplished, the rewards can be significant.

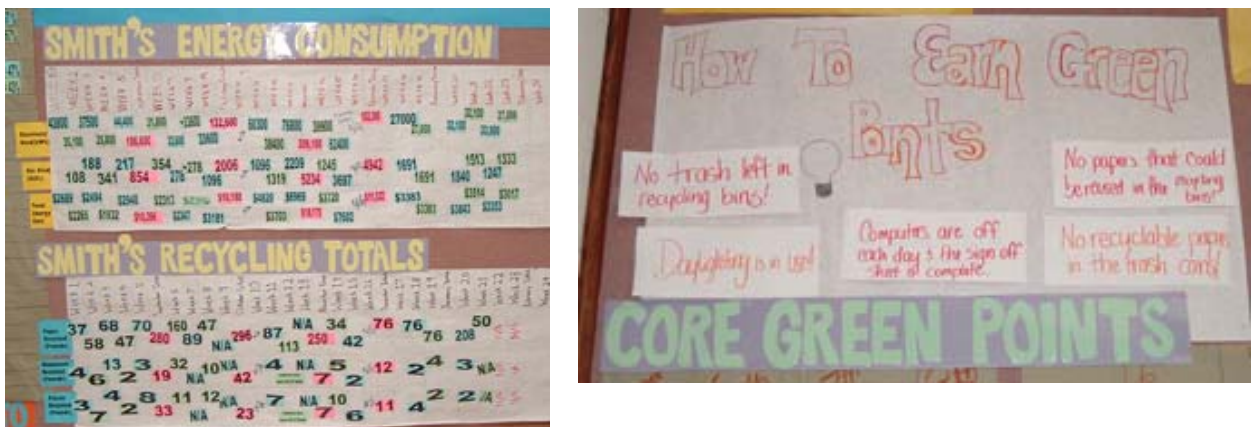


Figure 17. Student posters and charts indicate the level of student involvement in energy related projects at Smith Middle School.