Energy Smart Schools:
Opportunities to Save Money, Save Energy and Improve Student Performance A Congressional Briefing to the U.S. House of Representatives Committee on Science
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The Relationship between Environmental Quality of School Facilities and Student Performance

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Congressman Udall, members of the Committee on Science, members of the audience, ladies and gentlemen, I am glad to be here with you today. I am here to discuss the state of empirical research on the impact of educational facilities on student behavior, attitudes and performance. What we know comes from research from a broad array of disciplines ranging from social and environmental psychology, education, architecture and human-factors engineering. What is the connection between school buildings and education? Is it one of simply housing children and teachers who will get on with their work independent of the condition and character of the buildings they inhabit? Or is the connection more intimate in that sound sustainable buildings designed in particular ways will aid the goals of education ñ both student social development and academic achievement? I will argue that school buildings are of critical importance to the teaching and learning process. I will review a selected number of excellent empirical studies conducted over the past 30 years that have shown an explicit relationship between physical characteristics of school buildings and educational outcomes. Historically, the assumption has been that as long as the basic physical requirements of the school building are met -- minimum standards for classroom size, acoustics, lighting, heating and air conditioning in the child's learning depends in large part on pedagogical, psychological and social variables. I will argue that buildings are much more than preliminary requirements for the learning process. I and others in the research community take the view that the factors responsible for student achievement are ecological in they act together as a whole in shaping the context within which learning takes place. The physical setting -- the school building ñ is an undeniably integral part of this ecological context for learning. There is now considerable empirical support for the argument that a variety of sustainable design characteristics that can have a significant influence on student behavior and academic achievement. Physical and environmental conditions that I will discuss today include full-spectrum and natural lighting, the reduction of noise through proper location and siting of schools, optimal thermal conditions, sick buildings and indoor air quality, school size and class size and embedding schools within their communities.

Full-Spectrum and Natural Lighting

We have known for some time that environmental lighting exerts profound biological effects on humans, in addition to providing visual stimulus by controlling several glands and many metabolic processes as well as serving as a biological timer for biological rhythms. Illumination appears to be so important that even seasonal mood changes as strong as depression have been treated successfully merely by increasing the bright, white light in a personís environment (Rovner, 1982).

In a typical study (Kleiber, 1973) testing differences between full-spectrum lighting and cool white fluorescent lighting commonly used in institutional settings, it was found that physiological measures indicated that most subjects showed less fatigue after a study session in natural light than in a traditionally illuminated instructional environment. Many students had better achievement when they were tested in classrooms with 85 or more footcandles of light, in contrast with their scores in a classroom with fewer than 65 footcandles environment; others achieved less well (Mayron, et al, 1974). Individual learning styles often can mask attempts to link performance to lighting levels. One study investigated performance based on predetermining student lighting level preferences. Students were tested for reading speed and accuracy on a reading test in an extremely bright and then in an extremely dim instructional setting. Scores on both reading speed and accuracy were significantly higher when the illuminated instructional environment matched the studentís diagnosed learning style preference for light. (Dunn, Dunn & Price, 1979). From these studies we can conclude that teachers must be able to provide a combination and variety of well-lit and dimly-lit environments for reading within a classroom. Children should be encouraged to sit where they feel most comfortable, and teachers should experiment with placing restless students into softly lit sections and reversing that procedure for listless, unresponsive students (Dunn et al., 1985). Under improved lighting conditions, using full-spectrum fluorescent tubes can show dramatic improvement in some childrenís behavior in the classroom (Ott, 1976). In one study, children were placed in four first-grade windowless classrooms, two with standard cool-white fluorescent tubes and fixtures and two with full-spectrum fluorescent tubes more closely duplicating natural daylight. Students in standard lighting were observed fidgeting to an extreme degree, leaping from their seats, flailing their arms, and paying little attention to their teachers, while the students in the full-spectrum lit classrooms settled down more quickly and payed more attention to their teachers. The two classrooms with standard white light were then replaced with full-spectrum as well. Subsequent observation found that studentsí behavior appeared calmer and more interested in their work. The results of this study were used by the researcher to indicate that hyperactivity is partly due to a radiation stress condition and that supplying that part of the visible spectrum lacking in standard artificial light sources may have some impact on relieving that condition.

Reduction of Noise Through the Proper Location and Siting of Schools

It is well accepted in the scientific community that prolonged exposure to high-intensity noise in community or work settings is often harmful to the health and behavior of large segments of the exposed populations. Noise in the learning environment can originate from within as well as outside the school building. Both forms of noise can have major affects on student behavior and in some cases achievement. A review of a series of studies in the United States between 1980 and 1986 concluded there are significant increases in blood pressure associated with schools being near noisy urban streets (Evans, Kliewer & Martin, 1991). Other findings related to location include German and Russian studies (Berglund & Lindvall, 1986) again indicating increased systolic and diastolic blood pressure in middle school children in schools close to noisy urban streets, and abnormally high blood pressure in children residing around airports. Exposure to traffic noise at elementary schools also has been associated with deficits in mental concentration, making more errors on difficult tasks, and greater likelihood of giving up on tasks before the time allocated has expired. Furthermore, another study conducted in Los Angeles (Cohen, Evans, Stokols & Krantz, 1986) found blood pressure does not habituate or decline with continued noise exposure over time; that is, children donít get used to noise. In effect, then, the location of schools is of critical importance if they are to be sustainable for effective teaching and learning. There is increasing evidence of noise effects on human performance that persist outside of the noisy environment. It is important to note that all studies involving children are correlational. One of the deficits in achievement scores of children attending noisy schools is that noise interferes with the teaching-learning process, thus resulting in a cumulative and progressive deficit. Noise may for example decrease teaching time for forcing teachers to continuously pause or by making it difficult for the student and teacher to hear one another (Crook & Langdon, 1974). Other possible explanations include noise-produced influence on childrenís information processing strategies, feelings of personal control as well as their level of arousal (studies referenced in Cohen & Weinstein, 1981; 47).

Sick Buildings and Indoor Air Quality

One area of concern in building design has been the thermal ëtighteningí of buildings for energy conservation in the 1970s which may be one of the causes of a variety of pathogenic factors in children in so called ësickí school buildings (Evans, Kliewer & Martin, 1991). These factors may be affecting not only performance but the overall physical health of children. Children in ësick buildingsí have been found to exhibit clear signs of sensory irritation, skin rashes, and mental fatigue ñ all factors with the potential of decreasing the ability of students to perform. The strategies for improving indoor air quality such as increasing levels of fresh-air intake and increased ventilation rates in buildings have shown that these mediating factors can be eliminated insuring that students can remain concentrated on the tasks of learning.

School Size and Class Size

I have deliberately left the issue of size in both school and class for the end since they have been discussed at great length publicly and they often overshadow other extremely important environmental qualities such as lighting, thermal conditions and noise. Additionally, school and class size are explicitly social/organizational variables first, and physical variables second. That is, if we consider decreasing school size and class size, which I believe we should and are attempting to do finally, we are in effect implicitly accepting the notion that issues of density and the physical scale of our buildings are important to the student achievement as well.

In the now classic Big School, Small School study conducted by Roger Barker and Paul Gump (1964), small schools (100-150), in comparison with large schools (over 2,000) offer students greater opportunities to participate in extracurricular activities and to exercise leadership roles. In particular, participation in school activities, student satisfaction, number of classes taken, community employment, and participation in social organizations were all superior in small schools relative to large schools. A review of over 300 subsequent studies (Garbarino, 1980) indicated that small schools (500) also have lower incidence of crime levels and less serious student misconduct. In a review of research conducted on the relationship between school size and academic achievement (Fowler, 1992) there was found to be a negative relationship between math and verbal ability tests and elementary school size controlling for socio-economic differences (Kiesling, 1967 cited in Fowler, 1992). Additionally, smaller elementary schools particularly benefit African-American studentsí achievement (Summers & Wolfe, 1977 cited in Fowler, 1992). Class size research, most notably the longitudinal research represented by the Tennessee Student/Teacher Area Ratio STAR Project and the follow-up Lasting Benefits Study, points directly to a social and physical link to achievement (Achilles, 1992; Finn & Achilles, 1990). Project STAR followed 6,500 children from kindergarten through third grade. Children in smaller classes (13-17 per room) outperformed those in regular-sized classes (22-25 per room) as measured by test scores such as the Stanford Achievement Test. In the early grades, children in smaller classes outperformed children from regular class sizes in all subjects, but especially in reading and mathematics test scores with average improvements of up to 15%. Smaller classes were especially helpful for children in inner-city schools. A follow-up study that used the same schools, students and tests has shown that students previously in small classes demonstrated statistically significant advantages two years later over students previously in regular sized classes. Performance gains ranged from 11-34%. Not explicit in the STAR Project research are the explanations for why such as relationship exists. One possible explanation is that, in addition to more and higher quality student-teacher interactions possible in a smaller class, spatial density and crowding are also reduced. In a study of younger children (Loo, 1976), an increased density can induce stress in children thereby increasing aggressive behavior and distraction in younger children.

Embedding Schools within their Communities

A broader notion of sustainable schools is that of the formation of sustainable communities within which they are embedded. Here I am being more speculative, but based on principles of sustainable community design. We know that small schools benefit students socially and academically, while smaller school buildings consume less energy. Additionally, the benefits of smaller neighborhood schools -- serving as true community centers -- offer a plethora of opportunities. The use of school facilities can be shared with a variety of community organizations fostering meaningful inter-organizational partnerships. Facilities that are close to the neighborhoods of the children they serve provide could opportunities for children to walk and bike with the added public health benefit of increasing their physical activity, rather than relying on more costly modes of transportation. Finally, school facilities that act as true community centers could serve the broader societal goals of providing the setting for meaningful civic participation and engagement at the local level.

Building Condition, Building Life-Cycle and Facility Management

Although we have been talking about critical public policy issues that must effect a change in how we conceive and design school buildings from now into the 21st century, when we think of sustainability, we must think long-term ñ we must think about the building life-cycle. A well-designed sustainable school building will certainly get us out of the starting blocks on a better footing, but a well-managed school building will ultimately be the true test of our sustainable design principles. The good proxy measure of the quality of facility management is that of building condition. School buildings deteriorate with age and since a buildingís age is a factor in building deterioration, the condition of older buildings depends to a large extent on the adequacy of maintenance and operations. A 1991 correlational study of building condition and student achievement in the Washington D.C. Schools, found that educational building conditions were hampering student performance, and estimated that improved facilities could lead to a 5.5% to 11% improvement on standardized tests (Edwards, 1991). In a study this researcher conducted a few years ago assessing environmental quality in five Baltimore City public elementary schools, a simple correlation was found between the number of high-priority environmental concerns expressed by teachers and the change in the percentage of student academic improvement during a two-year period (Lackney, 1996). The most likely explanations for this correlation may be due to concerns over physical comfort and health and classroom adaptability, both characteristics of a sustainable school. This study is only suggestive, based on self-reports of teachers, and cannot be generalized beyond the sample, however, it does suggest that we pay more attention to building life-cycle issues when talking about sustainable schools. In summary, all the physical factors I have mentioned ñ full-spectrum and natural lighting, the reduction and control of noise, the location and siting of schools, optimal thermal conditions, and school size and class size, as well as building condition -- can have a mediating effect on a variety of variables known to have a link to student achievement: time-on-task, student-teacher interactions, classroom interruptions and student participation. In addition, the quality of the learning environment is known to affect teacher behavior and teacher attitudes towards continuing to teach (Johnson, 1990), something we have not been able to touch upon here, which can have an additional mediating effect on student behavior and attitudes. To conclude, the evidence is overwhelming that school buildings are of critical importance to the teaching and learning process. It is my belief that the application of sustainable design principles discussed in this briefing, if applied early in the school design process will most certainly have a positive influence on the bottom-line indicators of quality in education into the next century.

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