The Impact of Sustainable Buildings on Educational Achievements in K-12 Schools

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Executive Summary

Tightening school budgets, rising energy costs, and increased standardized testing of students have increased the pressure on K-12 school administrators who are trying to maintain, or better yet, raise student achievement levels in the face of decreased funding. Fortunately, there is a solution that alleviates all of these concerns. That solution is sustainability.

Sustainable building is a fully integrated, "whole building" approach to design, construction, renovation, and operation. This approach differs from the traditional design/build process, as the design team examines the integration of all building components and systems and determines how they best work together to save energy and reduce environmental impact. Consideration must be given to site selection, architectural design, building method and materials, and landscaping practices for both new buildings and those undergoing improvements.

Sustainable schools, also referred to as *green* or *high performance* schools, benefit the outdoor environment, the indoor environment, and the students, teachers, and administrators who study and work in these buildings. These schools are energy and water efficient and make use of renewable energy and green materials to the fullest extent possible. These schools provide environmental benefits through reduced pollution and reduced landfill waste. Sustainable schools have also proven to be cost neutral in upfront costs compared to traditional construction and are much less costly to operate over the life of the building. This is vital in times of ever-tightening budgets and the current climate of large federal and state budget deficits.

Sustainable building practices provide optimally safe, healthy, comfortable, and productive learning environments for students and pleasant working environments for faculty and staff. If students are uncomfortable or distracted by poor lighting, heating, cooling and ventilation noise, their ability to learn will suffer. It only makes sense: a safe, healthy, comfortable environment for students, teachers, and staff will benefit student performance.

Two elements of sustainable building design, daylighting and indoor air quality, have direct effects on student performance. Studies now show that better indoor air quality in schools results in healthier students and faculty, which in turn results in lower absenteeism and further improves student achievement (CHPS, 2003). Recent studies on the effect of daylighting in schools reveal that students perform better in daylit classrooms, as well as indicate the health benefits of daylighting. Sustainable design, by definition, makes use of daylighting principles and helps improve indoor air quality, which helps to eliminate conditions related to sick building syndrome and other building-related illnesses.

This paper examines the impact of sustainable schools on educational achievements in K-12 schools.

What is a Sustainable School?

Sustainability is defined by the World Commission on Environment and Development as "meeting the needs of today without compromising the ability of future generations to meet their own needs." Sustainable building is a fully integrated, "whole building" approach to design, construction, and operation. Sustainable buildings, also referred to as *green* or *high performance* buildings, are designed to: provide optimal environmental and economic performance; increase efficiencies thereby saving energy, water, and other resources; furnish satisfying, productive, and quality indoor spaces; use environmentally preferable materials; and educate building occupants about efficiency and conservation.

Twenty percent of the U.S. population, nearly 56 million people, spend their days in elementary and secondary schools. The unique aspects of classroom environments magnify the need for healthy, sustainable school buildings. School classrooms with 25 to 35 students have a much greater occupant density than a typical office building. School buildings also include many special use classroom areas such as science labs and auto and metal shops.

Many school administrators still believe that sustainable buildings cost more and take longer to build. That is no longer the case. A recent economic analysis study, *The Costs and Financial Benefits of Building Green*, concludes that sustainable design can be incorporated into a structure with little or no increase in construction costs, and that the financial benefits of green buildings are over ten times the average initial investment required to design and construct a green building. Energy savings alone exceed the average increased cost associated with building green (Kats, et al., 2003). Furthermore, the healthier environments furnished by sustainable schools can bring money into the school by lowering absenteeism and increasing funding based on Average Daily Attendance (U.S. EPA, 2000).

K-12 schools in the U.S. spend over $6 billion a year on energy. In fact, energy costs tend to be second only to salaries in school budgets, exceeding the costs of supplies and books (ASE, 2003). According to the U.S. Department of Energy, energy-efficient renovations—replacement of inefficient boilers, lighting, and other systems—could reduce school energy costs by 30 percent (U.S. DOE, 2000). This is money that could be spent on hiring new teachers and purchasing textbooks, computers, and other instructional materials.

For sustainable school buildings, a whole-building mindset is required from the start of design through the building's entire life cycle. Integrated design is the key. As an example, sustainable building may make use of large, energy efficient windows that allow the sun's light to pass through, but nearly eliminate heat exchange. Since the rooms with high efficiency windows require less heating and cooling, the building can employ less expensive HVAC equipment. The smaller equipment also uses less energy, generating greater utility-cost savings for the life of the building, which helps to defray the increased cost of the energy efficient windows. As a result of the integrated sustainable design strategy to use more daylighting, the upfront costs remain relatively the same while the learning environment is substantially improved and operational costs are reduced for years.

Patrick L Herron, Ed.D., Former Assistant Superintendent of Wake County Schools in Raleigh, North Carolina, offers his perspective on the benefits of an integrated sustainable design strategy, "The Durant Road Middle School project was Wake County's first experience with daylit schools, and exceeded all expectations. The project was under budget and the payback for the daylighting features were less than two years. This was due to the downsizing of the mechanical and electrical systems and the reduction in energy costs, made possible by the daylighting."

There are several criteria for designing, operating and maintaining sustainable buildings that provide economic and environmental benefits and also positively impact student health and learning (Ohio Energy Project, 2000). These criteria include:

- Sustainable site planning and landscaping design that decrease the use of pesticides and provide an outdoor learning environment for students.

- Good building envelope design such as efficient windows and high R-value insulation that reduce draftiness and increase student and teacher comfort levels.

- Proper lighting along with increased use of daylighting that improve student performance and increase their comfort levels.

- Good indoor air quality from adequate air filtration and exchange systems and the banning of idling buses or delivery trucks near buildings that eliminate toxins, allergens and other harmful pollutant sources. Incorporating natural gas, biodiesel, methanol, or solar electric buses into a district's existing vehicle fleet would also reduce harmful emissions and improve air quality in and around the school (U.S. DOE, 2001).

- The use of green supplies and materials to eliminate or minimize possible sources of toxins, allergens and other harmful pollutants such as volatile organic compounds (VOCs) or formaldehyde (U.S. DOE, 2001). Use of green supplies and materials will also reduce contributions to lung ailments such as asthma.

- Proper design and maintenance of heating, cooling, and ventilation systems that run quietly and efficiently and do not produce noisy distractions to student learning. Using certain controls can minimize noise distraction. Again, the small size of a typical classroom makes this decision more critical, because the effect of ventilation air noise is greater than in a larger space such as a gymnasium (Frenette, et al., 2003).

- Onsite renewable energy sources, such as photovoltaics, that can be used as a teaching tool to develop student interest in alternative energy sources.

Sustainable school buildings benefit the school district and community bottom lines. Economic benefits include reduced life cycle and operating and maintenance costs. Environmental benefits include increased energy and water efficiency, reduced pollution, and reduced landfill waste. Other benefits include improved health of students and staff, reduced absenteeism, improved indoor air quality, and potential for increased test scores (Ohio Energy Project, 2000). Healthier, more comfortable classrooms also help school districts recruit and retain teachers. Teachers can also incorporate sustainable school features into their curriculum to provide students with hands-on learning opportunities. As a result, society benefits from the decreased impact on the environment and the increased comfort, health, and quality of life for building users.

Gary Bailey, Vice President of Innovative Design, concurs, “Sustainable Schools create better learning environments. The concept of sustainable development reflects an understanding that we must meet the needs of the present without compromising the ability of future generations to meet their own needs. A Sustainable School not only embraces the concept of sustainability but is, in itself, a teaching tool for sustainability.”

Sustainable Schools and Student Performance

Facilities that place a priority on improving students' learning environments can save energy, resources, and money, but more importantly, there exists a correlation between sustainable buildings and improved student performance. This seems intuitive, and a growing number of scientific studies now show the relationship between a school's physical condition and student performance.

Two elements of sustainable building design that have received recent attention, and have been shown to have a profound effect on student performance, are daylighting and indoor air quality (IAQ). Daylighting refers to the wise use of natural sunlight for task illumination normally provided by artificial lighting fixtures. Air quality is concerned with chemical and biological airborne impurities that can have an adverse effect on student, faculty, and staff health.

Daylighting and Student Performance

Daylighting reduces the need for electrical lighting and cooling, and can cut lifetime energy expenses by 30 to 70 percent. It also makes school buildings more attractive, and improves students' health and productivity. Daylighting includes baffles, roof monitors, skylights, and clerestory structures, not just eye-level windows. The design must bring in diffuse light, not direct sunlight, which adds heat.

Many of the classrooms built since the 1960's have little daylighting. Schools windows were commonly built with "black glass" that allows a view out, but no useful daylight in, and many classrooms were designed with no windows at all. This was done to make air-conditioning more efficient, reduce external noise, lower maintenance costs and bolster security. More recently, schools are being built with more windows and lights, but the justification for natural lighting has in large part depended on subjective arguments.

The 1990s spurred numerous studies that have shown the positive effect that daylighting has on student performance. The 1992 "Study into the Effects of Light on Children of Elementary School Age: A Case of Daylight Robbery" was conducted in Alberta, Canada by the Policy and Planning Branch of Alberta Education. Over a two-year period, the study compared children attending elementary schools with full-spectrum light versus children attending similar schools with normal lighting conditions.

The two-year study found that students under full spectrum light with trace ultraviolet (Hathaway, et al., 1992):

- learned faster,
- tested higher,
- grew faster and had 2/3 fewer cavities than expected, and
- had 1/3 fewer absences due to illness (3.5 fewer days absent per year).

These results support the conclusion that lighting systems are not neutral and have non-visual effects on people who are exposed to them over long periods of time.

Prompted by the conclusions of this Alberta, Canada study, North Carolina Innovative Designs architects, Michael Nicklas and Gary Bailey, investigated the energy costs and performance of students attending three daylit schools designed by their firm. They found that regardless of the age of the building, the daylit schools in the study indicated energy cost reductions of between 22 to 64 percent over typical

schools (Nicklas and Bailey, 1996). For a typical school in North Carolina where the study was conducted, a well-integrated daylighting scheme is likely to save $40,000 per year over what is typically constructed. And, assuming energy costs increase by 5 percent per year, the savings on just this one school, over the next ten years, would exceed $500,000.

The study results also showed that students in daylit schools, both new and retrofitted, performed better than the county norm in every case. More specifically, the students who attended daylit schools outperformed the students who were attending nondaylit schools by 5 to 14 percent, depending upon whether you consider short or long-term impacts. This study also found that "new" does not necessarily translate into better performance. A new, non-daylit school actually showed a negative impact on the students' performance.

Peggy Smith, Principal of East Clayton Elementary School in Clayton, North Carolina, agrees, " I firmly believe every child deserves an environment like this - one designed to be conducive to learning. This is a vision of what all schools should be like for every child." "You just feel energized and when children are energized, they are more apt to learn, ... that's what daylighting does."

In 1999, the Heschong Mahone Group (HMG) completed a study for Pacific Gas & Electric (PG&E) and the California Board for Energy Efficiency on the effect of daylighting on human performance—one of the largest and most rigorous studies investigating the relationship between daylighting and student performance. The study found that students in classrooms with the most daylighting progressed faster and scored higher on standardized tests than students in students with the least daylighting.

Student performance data for over 21,000 students from three elementary school districts in Orange County, California, Seattle, Washington, and Fort Collins, Colorado was compared to the amount of daylight provided by each student's classroom environment. At the Capistrano school district in Orange County, California, students with the most daylighting in their classrooms progressed 20 percent faster on math tests and 26 percent faster on reading tests in one year than those with the least daylighting. Students in classrooms with the largest window areas progressed 15 percent faster in math and 23 percent faster in reading than those with the least window area. Also, students in classrooms where windows could be opened progressed 7-8 percent faster than students with fixed windows. These results occurred regardless of whether the classroom also had air conditioning.

HMG also found that students that had a well-designed skylight in their room, one that diffused the daylight throughout the room, and which allowed teachers to control the amount of daylight entering the room, progressed 19-20 percent faster than those students without a skylight (HMG, 1999). These results could be used to support more personal lighting controls in schools. Administrators, teachers and students could be given control over the lighting dependent upon the school environment in question.

Results for the Seattle and Fort Collins school districts showed positive and highly significant effects for daylighting as well. Students in classrooms with the most daylighting were found to have 7 percent to 18 percent higher scores than those with the least.

The three school districts analyzed have different curricula and teaching styles, different school building designs, and different climates, and yet the results of the studies showed a uniformly positive and statistically significant correlation between the presence of daylighting and better student test scores in all three districts. This data consistency makes a persuasive argument that there is a valid and predictable effect of daylighting on student performance.

In 2001, HMG published a re-analysis of its 1999 report. A panel of experts reviewed the original study and was generally satisfied with the soundness of the methodology and the rigor of the statistical analysis.

The reviewers, however, expressed two primary concerns: Were "better" teachers more likely to be assigned to classrooms with more daylighting, thereby confounding the results? And would the analysis be more accurate if performed by grade level rather than aggregating data from four grade levels?

The reanalysis effort confirmed and expanded the original results that demonstrated daylight has a positive and highly significant association with improved student performance. The researchers reanalyzed the 1997–1998 school year student performance data from the Capistrano Unified School District (California) and the Seattle Public School District (Washington) to answer questions from the peer review panel. The reanalysis findings were as follows (HMG, 2001):

- Overall, elementary school students in classrooms with the most daylight showed a 21% improvement in learning rates compared to students in classrooms with the least daylight.

- A teacher survey and teacher bias analysis found no assignment bias that might have skewed the original results; more experienced or more educated teachers (“better” teachers) were not significantly more likely to be assigned to classrooms with more daylighting.

- A grade level analysis found that the daylighting effect does not vary by grade.

- An absenteeism analysis found that physical classroom characteristics (daylighting, operable windows, air conditioning, and portable classrooms) did not have an effect on student absenteeism. (This seems to contradict claims that have been made about the health effects of daylight or other environmental conditions, as reflected in absenteeism rates of building occupants, as well as the 1992 Alberta, Canada study mentioned above.)

The results of these studies, along with a rising interest in “natural” and “healthy” environments, have contributed to a resurgent interest in daylighting in schools, and have important implications for the use of daylighting in the design of schools and other buildings.

Indoor Air Quality and Student Performance

Air quality concerns are magnified for indoor environments; U.S. EPA studies indicate that indoor air pollutants may be two to five times and sometimes up to 100 times higher than the air outdoors (U.S. EPA, 2000). The significant amount of time that students and teachers spend inside schools, combined with children’s increased susceptibility to indoor pollutants, underscores the importance of good indoor air quality. However, according to the Department of Education’s National Center for Education 1999 Statistics, one-half of our nation's 115,000 schools have problems linked to indoor air quality.

Poor indoor air quality can trigger symptoms including: headache, fatigue, shortness of breath, sinus congestion, cough, sneezing, eye, nose, and throat irritation, skin irritation, dizziness, and nausea, as well as trigger asthma attacks and allergic reactions, spread disease, and expose occupants to toxic substances. These symptoms are collectively referred to as "sick building syndrome" (SBS), a term used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified. In contrast, the term "building related illness" (BRI) is used when symptoms of diagnosable illness are identified (e.g. certain allergies or infections) and can be attributed directly to airborne building contaminants (CHPS, 2003, U.S. EPA, 2003).

While the health impacts of poor indoor air quality are well documented, there is little causal research available that is specific to SBS and student performance. However, school administrators can recognize the logical inference that the physical well being of students, as well as the faculty and staff, is an

important factor in increasing student performance. Published and anecdotal reports are now exposing instances of poor indoor air quality in school facilities, and the potentially serious effects it can have on student health, absenteeism, and performance while at school (U.S. EPA, 2003).

It makes sense that children cannot perform well when they are sick or absent from school. As school funding is often based on attendance, schools with good indoor air quality are likely to receive more funding. Schools with good indoor air quality are also likely to have high teacher retention rates and will spend less on substitute teachers to replace sick members of the staff. This can improve continuity in school programs and provide students with higher quality education (CDSA, 2003).

"In order to have a good learning environment, you must have a learning environment that's conducive to education, and that means good air quality. Children don't learn well if they're too hot, too cold, or if the lack of fresh air leaves them drowsy." acknowledges Ed Melanson, Superintendent of Schools for the SAU #18 School District in Boscawen, New Hampshire.

According to the American Lung Association, asthma, which is exacerbated by poor indoor air quality, alone accounts for 14 million missed school days each year, making it a leading cause of school absenteeism. Research on asthma in schoolchildren by Smedje and Norback confirmed that asthma prevalence in schools is associated with elements of poor air quality: higher relative air humidity, higher concentrations of volatile organic compounds, and mold or bacteria. Smedje and Norback also found that reported asthmatic symptoms were less common in schools that had installed a new ventilation system, as the new system resulted in higher air-exchange rates, lower concentrations of several airborne pollutants, and lower relative humidity. Further evidence suggests that lower outdoor air ventilation rates, known to cause generally higher concentrations of the pollutants produced indoors, were related to reduced performance among occupants (Wargocki, 2000; Smedje, 1997).

Two major sources of indoor air quality problems are heating, ventilation and air conditioning (HVAC) systems, and contaminants. The HVAC system controls the circulation of air throughout a building, the introduction of fresh air into the mix, and the filtration of airborne particles. Poorly ventilated or seldom cleaned, these systems can pump contaminants through a building again and again. One of the most common pollutants contributing to these effects is mold, which can significantly impact health, but also contributes to significant building bio-deterioration and premature aging of a building’s mechanical systems. Problems can also occur when a building is operated or maintained in a manner that is inconsistent with its original design or prescribed operating procedure (CHPS, 2003). Efficient mechanical and ventilation systems are needed to ensure adequate fresh air in all occupied areas and minimize collection of dirt, moisture, and microbial growth (U.S. DOE, 2001).

There is no debate that poor indoor air quality can impact the comfort and health of students and staff, which in turn can affect concentration, attendance, student performance, and achievement. Indoor air quality in schools also affects the image and effectiveness of schools and administration; the school’s relationships with parents and the community; and the district’s potential for liability (U.S. EPA, 2000). If IAQ problems *are* detected, it is better and cheaper to act early. Better yet, schools should act proactively before problems result in complaints, school closures, student relocations, or lawsuits.

Sustainable design, by definition, helps improve indoor air quality and helps to eliminate conditions related to SBS and BRI. Integrated design and construction helps address indoor air quality well before the site is even selected. Highly efficient building systems that balance the exchange between indoor and outdoor air do create a healthy building environment. But the benefits of integrated design and construction arise only when schools establish “green” as a specific design goal for their building project from the very beginning.

Sustainable Building Resources

Most school administrators and district planners are familiar with the term *sustainable buildings*. But many of these same individuals lack the resources needed to implement sustainable design when planning to construct or upgrade buildings. Thankfully, leaders in the building industry have been working over the past several years to meet the challenge of creating a common set of standards that lay the groundwork for building project teams to design, construct, and operate fully sustainable buildings. School administrators and school districts can now consult several sustainable building design resources when planning new or upgraded facilities.

The leading organization for setting standards for sustainable buildings is the U.S. Green Building Council's (USGBC) LEED Green Building Rating System™—one of the most widely recognized sustainable building resources in the building industry. LEED (Leadership in Energy and Environmental Design), is a comprehensive set of voluntarily applied standards that designers, builders, and building owners can use to maximize both the economic and environmental performance of buildings. LEED for New Construction provides guidance for designing and constructing new sustainable buildings, while LEED for Existing Buildings provides guidance for upgrading existing buildings to a sustainable level of performance and operating these buildings sustainably over the long term.

LEED offers prerequisites and credits allowing buildings to gain points for meeting LEED criteria. Certification is awarded on green, silver, gold, and platinum levels. Beyond the prestigious recognition that LEED certification is becoming, LEED is evolving into a blueprint for achieving high levels of economic, social, and environmental return on sustainable building investment.

EnergySmart Schools provides another valuable source of sustainable building information. EnergySmart Schools is part of Rebuild America, a national U.S. Department of Energy (DOE) program of community-based partnerships that are committed to improving energy performance in buildings. The DOE created EnergySmart Schools to focus on improving the energy efficiency of K-12 schools, while promoting and supporting energy education within the classroom (U.S. DOE, 2003). EnergySmart Schools works to remove barriers to school energy improvements and encourages businesses to provide more energy-saving products and services tailored to schools. EnergySmart Schools has developed *Energy Design Guidelines for High Performance Schools* to assist in this effort.

Another sustainable building resource, the U.S. Environmental Protection Agency's (EPA) Energy Star rating system, measures the energy performance of schools on a scale of 0 to 100. The score demonstrates how a school building compares to other school buildings nationwide. The Energy Star performance rating system provides useful baseline information to help schools set performance targets and plan energy-efficiency improvements.

Another resource for information and materials is the Collaborative for High Performance Schools (CHPS). It aims to increase the energy efficiency of schools by marketing information, services, and incentive programs directly at school districts and building designers. The Collaborative's goal is to facilitate the design of high performance schools: environments that are not only energy efficient, but also healthy, comfortable, well lit and contain the amenities needed for a quality education. Although CHPS is focused on California schools, their ideas and resources can be utilized in any school district in the U.S.

Conclusion

Research shows that the physical environment provided by school facilities has a significant effect on learning. Spatial configuration, noise, thermal comfort, lighting, and air quality all have an impact on the students, teachers, and staff who study and work in America's schools. Sustainable schools provide a well-lit, healthy, comfortable environment conducive to learning and student achievement while saving money, energy, and resources.

Creating sustainable schools, either through new construction or existing building renovation, and then operating these buildings in a sustainable way, has the power to improve student performance, at a cost less than conventionally built schools. With the U.S. Department of Energy forecasting that 6,000 new schools will be built by the year 2010, and about 50 percent of existing schools in need of renovation, a unique opportunity exists to take advantage of the impact that sustainable schools have on student performance.

Sustainable schools allows us to go above and beyond just meeting the needs of today without compromising the ability of future generations to meet their own needs. Sustainable schools give students and teachers what they deserve: comfortable, healthy learning environments contributing to academic success and the achievement of each student's maximum potential, necessary to be responsible and productive citizens and life-long learners beyond the classroom.

The research shows that sustainable buildings increase student performance. Now it is time for decision-makers in school districts across the country to commit to providing their students with the improved learning environment provided by sustainable buildings.

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