PRIORITIZATION OF 31 CRITERIA FOR SCHOOL BUILDING ADEQUACY

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Table of Contents

I.	**Dr. Glen Earthman's Qualifications**	**Page 3**
II.	**Scope of the Assignment**	**Page 6**
III.	**Executive Summary**	**Page 7**
IV.	**Introduction**	**Page 15**
V.	**Health and Safety First**	**Page 17**
VI.	**The Relationship between School Building Condition and Student Achievement**	**Page 18**
VII.	**Older Buildings as a Detriment to Student Learning**	**Page 20**
VIII.	**School Building Elements that Most Impact Student Achievement**	**Page 26**

A. Human Comfort – Appropriate Temperatures
B. Air Quality
C. Lighting
D. Acoustics
E. Science Laboratories and Equipment
F. Overcrowded School Buildings

IX.	**Dr. Glen Earthman's Publications**	**Page 51**
IX.	**References**	**Page 60**

I. Qualifications

1. I am Professor Emeritus of Educational Administration at Virginia Polytechnic Institute and State University in Blacksburg, Virginia, where I have taught since 1974. At Virginia Tech, I continue to teach graduate courses on school planning and advise doctoral students in dissertation work. My continuing research interests extend to all phases of school facilities, but I have concentrated on exploring the relationship between school building condition and student achievement.

2. I have written extensively in the area of school facility planning. I have authored four textbooks on school planning during my teaching tenure at Virginia Tech; these books have been used throughout the country. I have also authored over 50 articles in periodical publications and 50 technical and research reports to school divisions and governmental agencies.

3. I have spent 40 years in the field of education serving as a teacher, principal, and Executive Director for school facility planning in the Philadelphia Public Schools. I served as a teacher and principal for thirteen years in the public schools of Colorado where I received a Bachelors and Masters degree from the University of Denver. My doctoral work was completed in1964 at the University of Northern Colorado where I served as a Graduate Fellow in the School Planning Laboratory at the University. During that time I worked on several school facility related projects as part of my program of studies.

4. Following graduation, I was employed by the University of North Dakota as an Assistant Professor and State Director for the Upper Midwest Regional Educational

Laboratory.

5. In 1966 I was employed by the School District of Philadelphia as Chief Educational Planner for the District. Subsequently I was promoted to Executive Director for School Facility Planning and directed a staff of 250 professional planners and architects engaged in all activities associated with planning school facilities. Departments that I supervised included site selection, educational programming, design work, monitoring the construction phase, and evaluation of the resultant buildings. During my tenure in that position a total of $500 million dollars of new construction was let for bid resulting in the completion of 5 new high schools, 10 new middle schools, and 20 new elementary schools, plus numerous additions to existing buildings.

6. I became associated with Virginia Tech in 1974 when I was employed as Associate Professor of Educational Administration and State Coordinator in the Office of Educational Services. In this latter position I served as liaison between the College of Education and local school divisions in providing assistive services. As part of my teaching load, I organized and taught the course on school facility planning, which is required of all superintendents in Virginia for licensing. Another part of my university load was to conduct research and supervise doctoral dissertations. I have graduated over 75 doctoral students in my years at Virginia Tech. The doctoral dissertations I supervised were in the field of Educational Administration, and some of the dissertations dealt expressly with school facilities problems and issues. The student research in school facilities has been in many ways an extension of my own program of professional research. Four research studies completed by students of mine are cited in the following report.

7. Within the last decade I have focused my own research activities dealing with the

relationship between school building condition and student achievement. This has resulted in several nationally recognized studies. Other researchers have repeatedly cited the research studies completed by Carol Cash, Eric Hines, and Linda Lemaster that I have supervised across the county. These studies, as well as my own, have been cited in publications of the United States Department of Education and the National Center for Educational Statistics (USDOE, NCES, 1999; USDOE, 2000). My personal research activities have resulted in several international presentations of the findings of my research and those of my students' research.

8. I have served as a consultant to over 70 school systems across the country and overseas helping them with various school facility problems. These activities have enabled me to practice the craft of school facility planning on a practical level. These activities have provided me with practical problems that can be brought back to the classroom and discussed by university students for a better understanding of problems in the field.

9. I have been active in professional organizations concerning educational and facility planning. I have held offices and committee assignments in both the International Society for Educational Planning and the Council of Educational Facility Planners, International (CEFPI). The CEFPI awarded me the President's Award for planning activities in 1992 and the Planner of the Year Award in 1994. Both of these awards are marks of professional recognition from my peers. I served in 1997-98 as the first Director of the Educational Resource Information Center (ERIC) affiliated National Clearinghouse for Educational Facilities sponsored and supported by the U.S. Department of Education.

II. Scope of Assignment

I have been asked by the ACLU of Maryland, which represents the plaintiffs in the *Bradford v. Maryland State Board of Education* case, to review the 31 criteria for school facilities established by the Maryland Task Force to Study Public School Facilities and to prioritize those criteria in light of the available research on the links between conditions in school buildings and student achievement.

EXECUTIVE SUMMARY

PRIORITIZATION OF 31 CRITERIA FOR SCHOOL BUILDING ADEQUACY

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I have been asked by the ACLU of Maryland, which represents the plaintiffs in the *Bradford v. Maryland State Board of Education* case, to review the 31 criteria for school facilities established by the Maryland Task Force to Study Public School Facilities and to recommend priorities for those criteria in light of the available research on the links between conditions in school buildings and student achievement. Based on my own studies, my review of pertinent research studies, and my background and experience in the field, I have recommended a set of priorities among the criteria based upon the extent to which an element impacts student academic achievement. I recommend that the highest priority be given to those elements which have a demonstrated and significant impact on student achievement and on those elements that directly relate to student safety.

Below, I first summarize generally the research generally demonstrating the link between school condition and student achievement, and the link between the age of a facility and achievement. Then, I explain why, in my opinion, it is crucial for Maryland to address issues related to student safety first, in conjunction with the criteria most directly related to student achievement. Then, I rank several of the criteria that research demonstrates are most directly linked to student achievement, and summarize some of the research related to those criteria. All of my opinions are explained in greater detail in the accompanying report.

Studies indicate a relationship between school facilities conditions and student achievement

Over the past three decades considerable research has demonstrated that there is a link between student achievement and the condition of the school building. "Poor" buildings generally are those that lack appropriate HVAC systems, have poor lighting, are old, are noisy, lack functional furniture, or have some variation or combination of these qualities. There is sufficient research to state without equivocation that the condition of the building in which students spend a good deal of their time learning does in fact influence how well they learn. Numerous studies have indicated that students in poor buildings perform less well than students in functional or acceptable buildings. Results of these studies indicate the following:

- Students in poor buildings perform less well than students in functional buildings.
- Most researchers found students in poor buildings scored between 5 to 10 percentile rank points lower than students in functional buildings, after controlling for socioeconomic status.

- The difference in scores for students in poor buildings can be as high as 17 percentile rank points.

All these studies raise the important question whether, if students are housed in poor buildings for a number of years, will the negative effect on achievement be multiplied? The research cited here and described in full in my report is simply a snapshot of conditions and relationships at one period of time, not over successive periods of time. There is a reasonable basis to believe, however, that the harmful effect of the disparity between poor and good school buildings on student test scores may be cumulative, and may continue to worsen the longer the student is in school.

Research regarding why older buildings are detrimental to student performance

A number of studies performed over the past 30 years have conclusively demonstrated a link between the age of the building and student performance, with students in older facilities performing less well than those in newer facilities. The age of the building itself is not detrimental to student achievement, but age often is a reliable indicator that the building condition is poor. Older buildings generally do not have the elements that directly relate to student achievement that functional buildings have, such as control of the thermal environment, acceptable lighting, acoustical control, and functional furniture. Results of these studies indicate the following:

- Fourteen studies compared building age with student achievement. All reported students in modern schools scored higher on achievement tests than students in older schools.
- Researchers found that students in old buildings scored 5-7 percentage points lower than students in new buildings.
- Students in new buildings significantly out perform students in older buildings in reading, listening, language, and arithmetic.

Moreover, most of the older school buildings and those buildings in poor condition are located in areas of greatest poverty. Students from such areas as a general rule perform less well than students from more affluent areas. When low-income students attend school in a building that does not have the basic elements such as safety and health as well as those elements that have been proven to relate directly to student performance, they are doubly disadvantaged. In addition to the effect that poor and old facilities have on student achievement, failure to improve

a demonstrably old and failing facility may convey a message to such students that the system values them less than it does their counterparts in more affluent areas.

It is critical to address issues related to student health first, in conjunction with the criteria that directly affect student performance

There are a number of criteria contained in the Task Force guidelines that have a direct relationship to student safety. Practitioners in the field believe the first order of importance is the health and safety of the students under their charge. Often, there is not specific research linking such safety issues to student performance. Such research has not been performed because it is self-evident to practitioners and researchers alike that students should attend school in a safe physical environment, so research efforts instead have been focused, as detailed below, on exploring the relationship between other facilities elements and student achievement.

In my experience, both as an academic and researcher and as a practicing principal and teacher for many years, the most important safety-related elements of the Task Force's 31 criteria are related to:

- Potable water
- Fire safety
- Adequate lavatories
- Security systems
- A communication system to use in emergencies.

Addressing such safety issues should be the first order of business. They should be addressed in conjunction with the elements described below that research has directly linked to student achievement.

Criteria that most impact student achievement

Research indicates that the following criteria, in the order listed, have a demonstrable impact on student achievement:

(1) Human Comfort – i.e., temperatures within the human comfort range as regulated by appropriate HVAC systems

(2) Indoor Air Quality – i.e., appropriate ventilation and filtering systems, also as regulated by appropriate HVAC systems

(3) Lighting

(4) Acoustical Control

(5) Secondary Science Laboratories

(6) Student Capacity- Elementary

(7) Student Capacity – Secondary

I summarize the research related to each of these ranked criteria below. The first five elements are supported by a corpus of good research that indicates that each element relates directly to student achievement. There is extensive research, for instance, demonstrating a strong correlation between a comfortable temperature range and student achievement, and air-conditioning, ventilation, and heating systems therefore should be given first priority. The installation of a good central air-conditioning system to a school building would also eliminate indoor air quality problems. Illnesses caused by a poor environment result in student absences that also result in lower performance on such measures as achievement tests. Likewise, poorly ventilated buildings can result in poor air quality and build-up of noxious odors and fumes. Again, these result in student listlessness and absence from school, which results in poor academic achievement.

The second priority element should be installation of proper lighting in the classrooms. Persistent poor lighting can cause not only poor performance by students while in school, but can also affect the sight of the student for the rest of his/her life.

The third element of importance would be adequate control of the acoustical environment. A number of studies have demonstrated a positive correlation between appropriate acoustical conditions and student achievement.

The fourth priority should be improvement of secondary school science laboratories. Several studies demonstrate that students in schools with appropriate modern science facilities, in both elementary and secondary schools, perform better than students in schools without such facilities.

The last two elements refer to the overcrowding of school buildings. There is also significant research demonstrating the ill effects of overcrowding, in both elementary and secondary school environments.

(1) Research regarding the impact of temperatures falling outside the human comfort range on achievement and/or productivity.

A number of studies have found a significant positive correlation between student achievement and temperatures falling within the human comfort zone on student achievement. According to the existing research, the thermal environment of a classroom is important to the well being and efficiency of students. Specifically,

- Review of eight research studies found a significant relationship between a controlled physical environment and student achievement and behavior.
- Review of 15 research studies identified a strong relationship between air-conditioning and student performance.
- Students in non air-conditioned buildings performed 3-12 percentile rank points lower on various measures than students in air-conditioned buildings.

All of these findings regarding the performance of students in a controlled environment indicate to educators the importance of providing a proper physical thermal environment for students and teachers.

Among other studies, the New York Commission on Ventilation performed an extensive investigation regarding the effect of thermal conditions upon students. This study revealed, among other things, that:

- Room temperatures of 75° F with 50 percent relative humidity and no air movement cause a definite increase in body temperature and pulse rate and a marked fall in vasomotor tone as measured by the Crampton Index.
- Excessively high temperatures produce harmful physiological effects.
- An effective temperature range of 67° to 73° F is desirable.
- Fifteen percent less physical work is performed at 75° F than at 68° F with 50 percent relative humidity and no air movement; at 86° F with 80 percent humidity, the decrease in work performed was 28 percent as compared to that performed at 68° F.

The findings of these experiments were sufficiently precise and strong enough that the Commission recommended that schools maintain room temperatures between 68 and 70° F and relative humidity of 50 percent with sufficient air movement to eliminate odors and stale air. Most school buildings built today use the Commission's standards.

(2) Research that regarding poor air quality.

Ample research evidence strongly indicates that poor air quality results in poor performance by students and workers. Specifically:

- The US Environmental Protection Agency estimates that more than 10 million days of schooling are lost each year by students because of asthma attacks (EPA, 2000). The New York Commission on Ventilation (1931) referred to the rate of incidence of such attacks in some of their early studies.
- Smedje and Norback reported the incidence of doctor's diagnosed asthma symptoms was higher (.05 level of significance) in students attending schools with high counts of settled dust on floor and furniture than for students in cleaner buildings.
- Myhrolvd, et al found positive correlations between CO_2 concentrations in the classroom and the reported student health symptoms and also the performance of students on academic tests.
- Wargocki, et al found that when pollution (carpets) was absent office workers improved typing by 6.5%, math scores by 3.8%, and logical reasoning by 3-4%.

(3) Research Regarding Lighting

A number of studies have demonstrated a positive correlation between appropriate lighting and higher student achievement. Specifically:

- Good lighting quality and proper foot-candles have been found to be positively related to increases in student achievement and performance.
- Conversely, in schools where the lighting is less than the minimum acceptable level and poor quality, students did not perform as well as students in properly illuminated school buildings.
- A recent study of 21,000 students found that those in schools with daylighting scored 20% higher on achievement tests than students in schools with no daylighting.

(4) Research related to Acoustics

A number of studies have demonstrated a positive correlation between appropriate acoustical conditions and student achievement. Good research indicates students simply do not learn when they can not hear well. As simplistic as this statement sounds, numerous students suffer through school in buildings that are too noisy for them to learn properly, yet nothing is

done about it. The ability to clearly hear in the classroom is vital for student learning and teacher performance. Specifically:

- A California study found that 3rd grade students in noisy buildings were .4 years behind in reading and .2 years behind in math of students in noisy buildings. Sixth grade students in noisy buildings were .7 years behind in reading.
- The noise distraction in classrooms that are at a high level results in low performance year after year by students attending these schools.
- Clear evidence from the studies point to the fact that higher levels of noise, both inside and outside the classroom can seriously hinder students from achieving their potential.

(5) Research defining the relationship between student achievement and science equipment

Four studies (Cash, 1993; Earthman, et al, 1995; Hines, 1996; Lanham, 1999) have indicated that when a school building has poor science equipment and furniture, the students do not perform as well as students in schools that have good science equipment and furniture. The evidence is very clear that when a school building has modern functional science equipment and furniture students are able to perform more to their capacity than students in buildings with less modern equipment. Specifically:

- In those buildings that had old science equipment the students scored 8 percentile rank points below students using newer, functional equipment.
- Even in the elementary schools, Cash (1993) found a significant difference between students with old science equipment and those students with newer equipment.
- Students using older science equipment, both elementary and secondary, are disadvantaged in learning about science.

(6) Research related to overcrowded school buildings

- The result of overcrowding in schools is lower student achievement on both the elementary and secondary levels
- Overcrowding also results in lower graduation rates among senior high school students.
- Long term experience in overcrowded schools negatively impacts the work of teachers as well as impacting student performance.

III. Introduction

The Task Force to Study Public School Facilities was established by legislative action to review, evaluate, and make recommendations regarding how the state could adequately support local educational programs in adequate facilities. The Task Force developed criteria for what it termed fundamental elements necessary for adequate facilities. Further, the Task Force developed an appraisal instrument that local school districts can use to evaluate their buildings. I understand that local school districts have used the instrument to evaluate their buildings and have used data resulting from the evaluation to determine costs to bring all buildings to the standards set by the Task Force. The next process is to prioritize the elements so that the state can begin the funding process based upon these elements.

The State of Maryland is taking a very intelligent approach to the improvement of the educational facilities throughout the state. Unlike so many other states that have experienced litigation and legal controversies to get to the point of actually improving the physical environment of every student, Maryland is taking the high road in working with various groups to begin a process of providing equitable and adequate facilities for every student regardless of where the child lives. The state and everyone connected with this effort should be heartily congratulated.

Based on my own studies, my review of pertinent research studies, and my background and experience in the field, I have recommended a set of priorities among the criteria based upon the extent to which an element impacts student academic achievement. I recommend that the highest priority be given to those elements, which have a demonstrated and significant impact on student achievement and on those elements that directly relate to student safety.

The task of prioritizing the list of 31 elements should be based on considerations of student's safety and the extent of impact an element has upon the academic achievement of the student. The relationship between the condition of the school building and student achievement is one that requires more research, yet there is currently sufficient research to demonstrate significant links between building condition and student achievement, and thus to give guidance to educational authorities in making decisions regarding funding of capital improvement projects. The guideline used to make the prioritization in all instances is how the element impacts upon the health and performance of a student.

In all cases of evaluation of the various elements in the list of minimum elements, the amount and quality of publishable research that is available through standard and generally acceptable sources of research were used. These sources consisted of the National Clearinghouse for Educational Facilities, Council of Educational Facility Planners, International, and the ERIC Clearinghouse.

Below, in Section IV, I explain why, in my opinion, it is crucial for Maryland to address issues related to student safety first, in conjunction with the criteria most directly related to student achievement. Second, in sections IV and V, I summarize generally the research demonstrating the link between school condition and student achievement, and the link between the age of a facility and achievement. Then, in section VII, I rank several of the criteria that research demonstrates are most directly linked to student achievement, and in the following I describe some of the research related to those criteria.

IV. Health and Safety First

It is critical to address issues related to student health first, in conjunction with the criteria that directly affect student performance. There are a number of criteria contained in the Task Force guidelines that have a direct relationship to student safety. Practitioners in the field believe the first order of importance is the health and safety of the students under their charge. Often, there is not specific research linking such safety issues to student performance. Such research has not been performed because it is self-evident to practitioners and researchers alike that students should attend school in a safe physical environment, so research efforts instead have been focused, as detailed below, on exploring the relationship between other facilities elements and student achievement.

Educational researchers have been prone to investigate relationships between building elements and student achievement. They might be like most practitioners in the field who believe the first order of importance is the health and safety of the students under their charge. In my experience, both as an academic and researcher and as a practicing principal and teacher for many years, I believe that the most important elements of the 31 would be related to health and safety, are potable water, fire safety, adequate lavatories, security systems, and a good communication system to use in emergencies. These would be the first order of business before any other item.

To the principal in the field health and safety matters are of the most importance because of the possible harm that may come to a student. A prudent principal eliminates every possible danger or ill effect that in any manner could adversely affect a student. In this respect the practitioner would be inclined to have the building in as safe a condition as possible. There is also the possibility of litigation if some of these health and safety elements are not in the best possible condition.

Yet at the same time, practitioners also realize there are other components of the building that play an important part in student performance. On the opening days of school in September and the closing days in May/June, the principal may say this is the most important element, of course after every health and safety element was in satisfactory order. Such safety issues should be addressed in conjunction with the elements described below that research has directly linked to student achievement.

V. The relationship between school building condition and student achievement.

Over the past three decades there has been a great deal of interest on the part of educational researchers regarding the influence the school physical environment has upon student achievement and behavior. Now there is an accumulation of a large corpus of research findings that well establishes that relationship. There is sufficient research to state without equivocation that the building in which students spends a good deal of their time learning does in fact influence how well they learn. Numerous studies have indicated that students in poor buildings perform less well than students in functional or acceptable buildings. With research conducted in four different states and two major cities the research findings give ample guidance as to what needs to be done to insure a healthy and productive physical environment for all students to permit them to learn to the limit of their capabilities rather then hinder them in the acquisition of knowledge and skills (Edwards, 1992; Cash, 1993; Earthman et al, 1995; Hines, 1996; Lanham, 1997, Anderson, 1998, Lewis, 1999; Ayres, 1999; Cervantes, 2000; O'Neill, 2000, Schneider, 2000; Al-Enezi, 2002)

All of these studies used the same basic approach to investigating this relationship. Each researcher used some form of building evaluation to determine the condition of the building and was able to classify the buildings from poor to good. Following this, they compared the student achievement test scores with the building condition. All researchers used the percentage of students in the Free/Reduced Lunch Program to control for socioeconomic status of the student body. In some cases the researchers also used a measure of school district wealth to control this variable.

Each researcher found a significant difference in the achievement scores of students in poor buildings and in good buildings. The difference these researchers found ranged from 3 percentile rank scores to 17 percentile rank scores. Hines (1996) in studying large high schools found a 17 point difference on one subtest. Most researchers found differences ranging from 5 to 10 percentile rank scores and these differences were statistically significant.

These differences in achievement scores indicates that students in poor buildings are falling behind students in those buildings with the necessary elements to adequately support the educational program and permit students to learn effectively. In almost every report, the differences were statistically significant, which gives the practicing educator a good deal of

confidence that the relationship is there and can be measured. In those instances where students are in poor buildings it means that these students are being placed in situations that will disadvantage them in their school work.

In every study the researcher reported on findings that were measured at a certain point in time, i.e., the date when the test was given and the building evaluated. Researchers have not been able to determine the long term effect of the differences in student performance for obvious reasons. Nevertheless, the question still remains, does the difference in scores mean that students in poor buildings steadily perform worse the longer they stay in a poor building? Needless to say there is a strong indication that this phenomenon does indeed happen, but is not possible to quantify at the present time

Another important factor that needs to be considered when discussing the relationship between student achievement and building condition is the inequity of school facilities. Most of the older school buildings and those buildings in poor condition are located in areas of greatest poverty in each school district, either in the urban or rural areas. Students from poverty areas as a general rule perform less well than students from more affluent areas. When low-income students attend school in a building that does not have the basic elements such as safety and health as well as those elements that have been proven to relate directly to student performance, they are doubly disadvantaged. In addition to the effect that poor and old facilities have on student achievement, failure to improve a demonstrably old and failing facility may convey a message to such students that the system values them less than it does their counterparts in more affluent areas.

VI. Older Buildings as a Detriment to Student Learning

Another aspect of determining the relationship between school building condition and student achievement has to do with the age of the building. A considerable and important body of research findings has been produced within the last 30 years. Beginning in the late 1970's and extending to the present, educational researchers have been investigating the relationship between student achievement and building age. The results of these efforts have provided school authorities with ample evidence of a negative relationship between these two variables when the building does not have the necessary elements to support properly student learning.

The age of a building may not in and of itself be a direct negative factor in student achievement, but what elements the building does not have provides a direct relationship to student achievement. Most older school buildings do not possess the elements necessary for student learning. For instance, many older buildings do not have central air-conditioning in the classrooms, or they may not have the best lighting. In some older buildings spaces used for instruction do not have proper square footage to meet present day requirements and can not be enlarged because of building structural limitations. These are the factors that impact student learning more than age. Even when older buildings have been modernized, the application might not be that successful because the building can accommodate only so much change. As an example, many older buildings have high ceilings, some even 14 feet in height. When new lighting is applied the height might negate some of the advantages of the better lighting, so in effect the building itself may negate the benefit of better lighting. Many of the improvements in some of the older buildings have been completed over 50 years ago and in light of recent knowledge and application the improvements leave much to be desired.

There is a body of research indicating that older buildings have a negative influence upon student performance. Research on the age of the building is quite conclusive on the negative impact upon students. I summarize much of that research in the numbered paragraphs below.

1. Under the age variable, McGuffey (1982) reviewed seven studies (Thomas, 1962; Burkhead, Fox, and Holland, 1967; Michelson, 1970; Guthrie et al, 1971; McGuffey and Brown, 1978; Plumley, 1978; Chan, 1979). In all cases the building age was significant as a detrimental factor to student achievement and behavior. Minor differences in significance were noted on selected grade levels and subjects. Building age can also serve as a surrogate for a number of

specific variables such as condition of the building, thermal control, proper lighting, acoustical control, support facilities, condition of laboratories, aesthetic condition of the environment, just to name a few. Many studies have combined all of these factors into one assessment instrument that produces a quality of the condition of the building that can subsequently be compared to student achievement.

2. McGuffey and Brown (1978) studied 188 school districts in Georgia to explore the relationship between building age and student achievement. They used the scores on the Iowa Test of Basic Skills for the fourth and eighth grade students and the Test of Academic Progress for eleventh grade students. In comparing the achievement scores with the age of the building, the statistical analyses indicated the building age could account for .5 percent to 2.6 percent variance in scores in the fourth grade. In the eighth grade, age could explain from 0 percent to 2.6 percent of the variance and from 1.4 percent to 3.3 percent in the eleventh grade.

3. In a follow-up study, Plumley (1978) investigated the same relationship. His study population was a random sample of fourth grade students in elementary schools. The individual school was the unit of analysis, where seven dependent variables representing the scores of the six subtests and the composite score on the Iowa Test of Basic Skills. The seven independent variables were the percent of students on free/reduced lunches, student race, building modernization, partially modernized, non-modernized buildings, date of building construction, and date of modernization. Stepwise multiple regression analyses indicated non-modernized buildings accounted for 3.3 percent to 6.4 percent of the variance on three of the five subtests, and 5.3 percent on the composite score of the ITBS. Based upon these results, Plumley concluded that school building age does in fact influence student achievement.

4. Garrett (1981) investigated the impact of school age on the achievement of students in the State of Georgia. He hypothesized that when the socioeconomic status variable was statistically controlled, the age of a facility would have a significant relationship to the achievement of students (hypothesis 1). The researcher went on to say that the achievement of students taught in non-modernized school facilities would be significantly lower than those taught in partially modernized or modernized schools (hypothesis 3).

The design for the research was *ex post facto*. The data were gathered from the results of a questionnaire about the facility, which was sent to schools that had an eleventh grade, and from the results of eleventh grade students' scores on the Test of Academic Progress. Information

included in the facilities questionnaire was the original date of building construction; the total number of eleventh grade students; the number of students not participating in the free and reduced lunch program; the status of air conditioning, carpeting, and lighting; and, how recently the classrooms had been painted.

In order to allow the variables with the largest amount of variance to enter the equation first, the hierarchical inclusion method in multiple regression was used to analyze the relationship between the dependent variable, achievement, and the independent variables of building age and socioeconomic status. Hypothesis 1 was tested by the F-test to determine if the observed relationship was significant. Analysis of covariance was used to test hypothesis 3. Socioeconomic status (SES) was used as a co-variant.

When the SES variable was statistically controlled, the age of the facility made a significant difference in student achievement in composition, reading, and mathematics scores on the Test of Academic Progress (.01). The achievement of students taught in non-modernized school facilities was not significantly lower than those taught in partially modernized schools. However, achievement of students taught in partially modernized schools was significantly lower than those taught in modern facilities. Finally, when the effects of socioeconomic status variables had been controlled statistically, an analysis of covariance was used to compare the composition scores of students in modernized facilities and the composition scores of students in non-modernized schools. The differences were statistically significant.

As the age of the facilities decreased, there was a corresponding increase in mathematics, reading, and composition scores, indicating a negative correlation. Garrett concluded that student attitudes are affected by the quality of the learning environment and that students preferred new or modernized facilities over older classrooms, and that student productivity was affected by student comfort as facilitated by the modern environment.

5. Chan (1982) conducted a comparative study of student attitudes toward a new school versus an old school. The researcher had four hypotheses. These hypotheses were: There was no significant difference between student attitudes toward a new building and attitudes toward an old building, no difference in attitudes of males and females toward old and new buildings, no significant difference in the attitudes of students compared by race toward old and new buildings, and no significant difference in attitudes of paid school lunch participants and the

attitudes of the free and reduced price school lunch participants toward new and old school buildings.

The design for Chan's study was a non-equivalent control group design of a quasi-experimental nature. Pre-test and post-test scores on an "Our School Building Attitude Inventory" were the dependent variable. The independent variables included the physical facilities in the three school buildings, the student's sex, race, and socioeconomic status. Analyses of covariance and variance were used to examine the variables.

The control group consisted of the 119 students in Grades 2, 3, and 4 in a school built around 1936. The experimental group consisted of all 96 students in Grades 2, 3, and 4 in a 1923-constructed building who were transferred to a new school when it was completed.

After statistically adjusting the post-test scores of the control group with the corresponding pre-test scores of the experimental group, students in the experimental group scored an average nineteen points (on a 55 point scale) higher than students in the control group. The difference in attitude scores was indicated by an F-value of 19.71, which was significant at the .0001 level. The effect of sex, race, and socioeconomic status on student attitudes was examined in the pre-test and post-test scores of the control and experimental groups. Race and socioeconomic status had no effect on student attitudes toward their school buildings. However, female students in the control group scored significantly higher than males on both pre- and post-tests. All were significant at the .05 level. This study demonstrates a statistically significant difference in the attitude of students in a new facility than those in the 1936 facility.

6. One of the best studies on building age and student achievement was conducted by Bowers and Burkett (July/August, 1988). To explore the possible relationship of building age and student achievement, Bowers and Burkett investigated the differences in student achievement, health, attendance, and behavior between two groups of students in different physical environments. Two elementary school buildings, containing students between the ages of 5 to 13 years, in the same school jurisdiction in rural Tennessee were used to differentiate physical environments for this comparison. One school was recently opened and was a modern building in all respects. The other building was constructed in 1939 and had very little improvement to the physical structure. The researchers reasoned that the students and faculty in both buildings were essentially the same. The educational program and teacher competency were exactly equal.

Two hundred eighty randomly selected fourth and sixth grade students in two facilities were the subjects of the study. Principals, teachers, and socioeconomic levels of the communities were similar. The variable of age of the facility was the only difference when comparing the achievement and self-concept of the students.

ANOVA and t-tests for independent data were used to analyze the data and test the hypotheses. The Piers-Harris children's self-concept scale was administered to students in the fifth and seventh grades in the two schools.

The results were telling:

- *Students in the modern building scored significantly higher in reading, listening, language, and arithmetic than did students in the older facility*. The significance was at the .01 level which demonstrates a strong significance
- *Discipline was needed less frequently in the new facility versus the less desirable physical environment*. This was true, even though the new school had a larger enrollment. The level of significance for analysis purposes was .01.
- *Students in the newer building had significantly higher attendance records and seemed to have better health records*.
- *Self-concepts of the students in the newer facility were better than the self-concept of those of students in the older school*. Bowers and Burkett deducted that a significant difference existed between students at the two elementary schools in regard to the relationship of the physical environment and student achievement *Students in the new school building significantly out performed the students in the older building in reading, listening, language, and arithmetic*.
- *Faculty in the new building reported fewer disciplinary incidents and health conditions than faculty in the old building*.
- *Attendance likewise was better with those students in the new building than in the old school*.

Bowers and Burkett concluded that a relationship did exist between the physical environment and student achievement, health, attendance, and behavior.

7. In a very recent study of the relationship between building age and student achievement, Phillips (1997) found significant differences in the reading and arithmetic scores between upper elementary grade students in new buildings than those students in old buildings in the state of Georgia. This was a replication of an earlier study completed by Plumley (1978).

Phillips found a definite relationship between the age of the school facility and student reading achievement scores as measured by the Iowa Test of Basic Skills and a strong relationship between student mathematics achievement scores and building age. The mean mathematics scores for the treatment group (those students in new buildings) increased 7.63 percentile ranks after moving into the new facility. His study supported the findings and conclusion of McGuffey and Brown (1978), Plumley (1978), Bower and Burkett (1989), and Chan (1979).

8. School building age was an independent variable in one part of Edwards' (May, 1991) study of building condition and parental involvement in the District of Columbia Public Schools. The data from the survey of the schools indicated three variables as having significant influence: school age, school enrollment, and the PTA budget.

The age of the school building was a strong predictor of the building condition. For every ten-year period added to the age of the school, the condition of the building worsened by 0.50 on a one to three scale of overall condition. The research indicated that routine maintenance for most facilities becomes more important as a facility ages. Therefore, if funds are not expended on maintenance, major repairs, and refurbishment, the condition of the building worsens with age.

The second hypothesis was developed to link building condition to student achievement. As a school moved from the poor condition category to fair, overall achievement scores increased by an average of 5.455 points. If a facility improved its condition from poor to excellent, the achievement score increase averaged 10.9 points.

Conversely, as the condition of a school building worsens with age, the older a school was, the greater negative impact that facility would have on a student. This was significantly noted in Edwards' study, as both in the all-schools and the surveyed-schools data set, the sign of the estimated building condition coefficient was negative. Therefore, as the condition of the facility improved, so did the average student achievement scores. Berner, nee Edwards (Berner, April, 1993) in a subsequent publication summarized that, "Good infrastructure is truly at the base of quality education" (p. 28).The vast preponderance of research findings indicate that students enrolled in old, non-modernized buildings do not perform as well as students in newer, modernized building.

VII. School Building Elements that Most Impact Student Achievement

Research indicates that the following criteria, in the order listed, have a demonstrable impact on student achievement:

(1) Human Comfort – i.e., temperatures within the human comfort range as regulated by appropriate HVAC systems
(2) Indoor Air Quality – i.e., appropriate ventilation and filtering systems, also as regulated by appropriate HVAC systems
(3) Lighting
(4) Acoustical Control
(5) Secondary Science Laboratories
(6) Student Capacity- Elementary
(7) Student Capacity – Secondary

In prioritizing these criteria I have focused on the possible impact each element might have individually on student learning. I have given the highest priority to those items where published research indicates a positive relationship to student achievement. Thus, some criteria would not be high on the list of prioritization simply because there is little or no published research to indicate a relationship of some sort.

After addressing health and safety needs those elements with the most research available that provide evidence to show the relationship between the element and student achievement should be the ones the state should fund first. The first five elements are supported by a corpus of good research that indicates that each element relates directly to student achievement. There is extensive research, for instance, demonstrating a strong correlation between a comfortable temperature range and student achievement, and air-conditioning, ventilation, and heating systems therefore should be given first priority. The installation of a good central air-conditioning system to a school building would also eliminate indoor air quality problems. Illnesses caused by a poor environment result in student absences that also result in lower performance on such measures as achievement tests. Likewise, poorly ventilated buildings can result in poor air quality and build-up of noxious odors and fumes. Again, these result in student listlessness and absence from school, which results in poor academic achievement.

The second priority element should be installation of proper lighting in the classrooms. Persistent poor lighting can cause not only poor performance by students while in school, but can also affect the sight of the student for the rest of his/her life.

The third element of importance would be adequate control of the acoustical environment. A number of studies have demonstrated a positive correlation between appropriate acoustical conditions and student achievement.

The fourth priority should be improvement of secondary school science laboratories. Several studies demonstrate that students in schools with appropriate modern science facilities, in both elementary and secondary schools, perform better than students in schools without such facilities.

The last two elements refer to the overcrowding of school buildings. There is also significant research demonstrating the ill effects of overcrowding, in both elementary and secondary school environments.

I describe the specific research studies related to these various elements in the sections that follow.

A. Human Comfort – Appropriate Temperatures

A number of studies have found a significant positive correlation between student achievement and temperatures falling within the human comfort zone on student achievement. According to the existing research, the thermal environment of a classroom is important to the well being and efficiency of students.

1. Perhaps the best and most extensive research devoted to the ill effects of ranges of temperature and humidity on work and productivity is that conducted by the New York Commission on Ventilation (1931). This study examined the performance of students from various locations in the city as well as on college campuses. The Commission studies the effect thermal conditions have upon students during the periods of 1913 to 1917 and 1926 to 1929. The Commission endeavored to determine optimal air temperatures in classrooms for the most efficient learning by students. The experiments were conducted in regular city classrooms as well as experimental chambers at a local college. Students were subjected to varying temperatures while in the classroom and measures of their achievement were taken to compare with the temperatures. The findings of these experiments were sufficiently precise and strong

enough that the Commission recommended that schools maintain room temperatures between 68 and 70° F and relative humidity of 50 percent with sufficient air movement to eliminate odors and stale air. Some of the specific findings of this study were:

1. The study of the effects of room temperature showed that room temperatures of 75° F with 50 percent relative humidity and no air movement causes a definite increase in body temperature and pulse rate and a marked fall in vasomotor tone as measured by the Crampton Index (44).
2. Experimental results confirmed earlier investigations that excessively high temperatures produce harmful physiological effects and that an effective temperature range of 67° to 73° F is desirable (pp. 41-42).
3. The study of the effect of overheating on the performance of physical work showed that 15 percent less work was performed at 75° F than at 68° F with 50 percent relative humidity and no air movement; while at 86° F with 80 percent humidity, the decrease was 28 percent as compared to that performed at 68° F (pp. 45-46).

In spite of the age of this research, these findings are used just as frequently today as they were three quarters of a century ago. In fact, much of the design of schools since air conditioning became common in schools, after World War II, has observed these standards.

2. Murrain (1983) investigated the relationships between the temperature of the classroom, diagnosed individual preferences for either a cool or warm learning environment, and word recognition scores of students. He used 268 randomly assigned seventh grade students from a suburban junior high school as participants in the study. The Learning Style Inventory (LSI) was administered to the participants. Based on the results of the inventory, preferences for classroom temperature were identified. Scores of 60 to 69 represented a preference for warmth; scores from 70 to 80 were considered extreme. Scores between 31 and 40 were considered preferences for cool temperatures, with scores between 20 and 30 being extreme.

Subjects were assigned randomly and equally to two treatment conditions, a warm room and a cool room. All subjects were tested twice, once in a room matching their thermal preference and once in a room incongruent with their preference. Identical procedures were followed in each setting when the word test was administered. A 2 x 2 analysis of variance compared word recognition scores in each environment.

The LSI results revealed no strong preferences for thermal conditions. However, students who evidenced any temperature inclinations had significantly (.10) higher levels of achievement when in a preferred thermal environment rather than a setting that was incongruent with their diagnosed learning style. Murrain believed data from this study suggested that temperature, even though few participants demonstrated extreme preferences, is of marked importance to individual students for whom it is an extreme preference. Ninety percent of the seventh graders in this study either preferred a warm setting or, based upon the scores of the sampled population, would evidence higher academic scores when taught in a warm instructional environment rather than a cool one.

3. According to the existing research, the thermal environment of a classroom is important to the well being and efficiency of students. Eight such studies (Herrington, 1952; Mayo, 1955; Nolan, 1960; Peccolo, 1962; Stuart and Curtis, 1964; McCardle, 1966; Harner, 1974) were included in a review by McGuffey (1982). He reported that all eight of the studies found a significant relationship between a controlled physical environment and student achievement and behavior. Even though there were methodological limitations in comparing the studies, the persistence and breath of the relationship across the studies indicates a very positive relationship.

4. Two studies in the list cited above by McGuffey investigated the relationship between the thermal environment and student performance. Peccolo (1962) used student performance on a series of tasks that simulated the work skills used in the classroom. He found a significant interaction between an ideal air temperature between 70-74ºF and completion of selected tasks such as checking numbers and names, design completion, addition, analogies, and problem solving. McCardle (1966) reported a significant relationship between a controlled temperature and the use of programmed materials by students. He also noted that in a classroom with ideal air temperature students showed faster gains in achievement than when the temperature was above 74ºF.

5. In a recent review of research, Lemasters (1997) reported on eight studies that used climate control as a variable in determining the relationship between building condition and various dependent variables. Four of the studies used climate control as an independent variable but used various student behaviors as dependent variables, not student performance scores. For example, Kaufman (1984) sought to identify what she called “stressors” for maladapted students.

Knight (1990) identified what students called their best learning style model that would enable them to perform the highest level they could under a controlled physical environment. Murrain (1983) had students identify their preference between cool and warm areas for study. Finally, Scagliotta (1980) studied student behavior and barometric pressure in classrooms.

6. Chan (1980) studied the effect four different building components had on student achievement. These four building factors were air-conditioning, carpeting in the classrooms, lighting, and windows. He hypothesized that there would be no significant difference between the academic achievement of students in an air-conditioned environment when compared with the academic achievement of students in a non-air-conditioned environment. The data were obtained from the results of eighth graders in the State of Georgia taking the Iowa Test of Basic Skills (ITBS), and from a questionnaire completed by building administrators.

After statistically controlling for the effects of socioeconomic status, the vocabulary scores on the ITBS in air-conditioned schools were significantly higher than the vocabulary scores of the students in non-air-conditioned schools (.05 level of significance). Although there were no significant findings in the reading, language, work-study, and mathematics sections, there was a consistent pattern of higher achievement in air-conditioned schools. *In fact, Chan's research indicated that air conditioning had a greater influence on student achievement than the other physical elements examined in the study.*

7. Lanham (1999) investigated the relationship between school building condition and student achievement on the elementary school level. Basically, he replicated the Cash (1993) study using 3rd and 5th graders in the elementary schools of Virginia. A sample of the elementary schools containing grades 3 and 5 were drawn from the total population of buildings. A sample of 300 buildings, which represented one-third of all school buildings, was drawn. Responses concerning the condition of the school building were received from 191 principals for a 64 percent response rate. He used basically the same instrument used previously by Cash (1993), Earthman et al (June 1996), and Hines (1996) to determine the condition of the school buildings, this was the Commonwealth Appraisal of Physical Environments (CAPE). He modified the instrument by adding four new items relating to the availability of technology as defined as access to Ethernet services, but not the presence of computer equipment. Lanham used the results of the responses to these four items in separate analyses to explore for a relationship between the presence and absence of technology and student achievement. Lanham also used

the mean of the scaled scores of the students in a building on the Standards of Learning examination. This examination is required of all schools and is published by the Virginia Department of Education. School buildings were classified as being substandard, standard, and above standard based upon the appraisal of the building conditions. The percentage of students on free and reduced lunches was used to control for the socioeconomic status and was entered into the analyses as one of the variables used to explain student achievement.

Analysis of the data included a five-step multiple regression analysis, which revealed that free and reduced lunch participation entered as the first significant variable on each equation. The factor of air conditioning entered as a factor in three of the five analyses, 3rd grade English, 5th Grade English, and 5th Grade Technology. The factor of air conditioning accounted for 1.6 percent of the total variance in 3rd Grade English, 2.8 percent for 5th Grade English, and 4.8 percent for 5th Grade technology (p 125). Other factors that entered into the analyses and were found to be significant were ceiling type, site size, a connection to a wide-area network, room structure, overall maintenance, floor type, and sweeping and mopping frequency.

Clearly, of all the building factors mentioned above, air conditioning entered the equation as a variable having the most significant impact on achievement scores. The relationships with the other seven factors were also found to be statistically significant, but on a lesser scale. The results in the Lanham study are consistent with the results of the Cash (1993), Earthman et al (June, 1996), and the Hines (1996) studies in identifying the importance of air conditioning to student learning and achievement.

A confounding dimension to all the studies cited above is the long-term influence a poor building may have upon students (Earthman, November, 1998). The longitudinal influence of the physical environment could be a very important consideration. If students are housed in poor buildings for a number of years, will the negative effect on achievement be multiplied? The research cited here is simply a snapshot of conditions and relationships at one period of time, not over successive periods of time. There may indeed be a cumulative effect upon this disparity between poor and good school buildings in student test scores that continue during the time the student is in school. None of the studies cited above address the longevity question of effect of air-conditioning on student performance.

Review of the research reports presented in this section would indicate that air-conditioning does have an influence upon students in a school building. For the most part these

studies report that proper control of the physical environment is a positive influence upon the activities tested and the biological functions examined. Educators do know that the health of students does influence their ability to perform well. Illnesses caused by a poor environment result in student absences that also result in lower performance on such measures as achievement tests. Likewise, poorly ventilated buildings can result in poor air quality and build-up of noxious odors and fumes. Again, these result in student listlessness and absence from school, which results in poor academic achievement.

All of these findings regarding the biological well being of the students in a controlled environment indicate to educators the importance of providing a proper physical thermal environment for students and teachers.

B. Air Quality

Ample research evidence strongly indicates that poor air quality results in poor performance by students and workers. Specifically:

1. The US Environmental Protection Agency estimates that more than 10 million days of schooling are lost each year by students because of asthma attacks (EPA, 2000). Students can not perform adequately if they are sick or absent from school because of illnesses resulting from poor air quality in the classroom.

2. The increase in student absences resulting from asthmatic attacks precipitated by poor air quality has been documented for quite some time. The New York Commission on Ventilation (1931) referred to the rate of incidence of such attacks in some of their early studies. Smedje and Norback studied the relationship between school environment and incidents of asthma in 39 randomly selected schools. They accumulated data for 2 years on 1732 students in approximately 100 classrooms. They classified the schools according to the amount of settled floor and furniture dust and dog allergens. The comparison of the incidence of symptoms and an assessment of the building environment was made by multiple logistic regression and controlling for atopy, gender, and age. The incidence of doctor's diagnosed asthma symptoms was higher in students attending schools with high counts of settled dust on floor and furniture than for students in cleaner buildings. The comparisons were significant at the .05 level of significance. The researchers found no difference between the reports of asthma symptoms in 1993 and those found in 1995 in those students attending the same school. Several schools had new ventilation

systems installed between the two investigations, 1993 and 1995. The students in these schools reported fewer reported incidents than before the installation.

3. The content of CO_2 in the indoor air is only one indicator of the quality of the air, however, it is a very easily identified component and one that is detrimental to the health of students. Researchers conducted two studies devoted to examining the relationship between the concentration of CO_2 in the atmosphere of the classroom and student achievement and health.

Norwegian researchers reported on an experiment dealing with the possible correlations between the health and performance of students and the concentrations of CO_2 in the school buildings (Myhrvold, Olsen, and Lauridsen, 1996). Concentration of CO_2 in a school building indicates a malfunctioning of a ventilation system, or the lack of any significant ventilation system. Schools in several cities were to be renovated and the architects wanted to make certain the buildings had very good HVAC system that would enhance the learning environment. To measure the level of student performance, the researchers had the students perform on a concentration test SPES: Swedish Performance Evaluation System. This test consisted of three parts that dealt with (1) response speed to easily discriminate visual signals, (2) a choice reaction time task and (3) a color discrimination response reaction. The student responses to these tasks can be related to the type of activities they perform in the typical classroom setting. Students were also asked to complete a self-reporting questionnaire indicating which of 17 acute health symptoms they experienced during the experiment.

Positive correlations were found between CO_2 concentrations in the classroom and the reported student health symptoms and also the performance of students on the SPES. The strongest correlation was found on the health factors, but positive correlations were found between the student performance and CO_2 concentrations. They further reported that they found significant differences between performances of students in classrooms with respect to high (11500-4000 ppm) and low concentration levels (0-999 ppm). This would indicate that a high level of concentration of CO_2, which results from poor ventilation practices, does influence the ability of students to perform at these tasks. The study provides good evidence that lack of proper ventilation inhibits student performance on performance tasks, as well as causes health hazards. Practitioners can extrapolate from this research to the effect that these performance tasks are similar to the activities students perform in the classroom while learning.

4. In a controlled study of adult office workers, researchers compared the amount of pollution in the air with health symptoms and mental functions (Wargocki, Wyon, Baik, Clausen, and Fanger 1999). A population of 30 adult females was asked to perform various kinds of mental tasks that were typical of office work. To introduce pollution to where the females were working, 20 year old carpeting was placed in the work space in a manner where the population could not see it. The population was tested on typing arithmetic, logical reasoning, memory, and creative thinking. Measures were taken of the work of the population when pollution was evident and again when the source of pollution was removed. When the pollution was absent the workers improved the number of words types by 6.5 percent and reduced typing errors by 5 percent. The addition scores increased by 3.8 percent and logical reasoning scores increased by 3-4 percent. When the pollution source was introduced, the workers complained of headaches. In addition their performance on the measures of work was reduced.

C. Lighting

There have been more studies concerning the quality of lighting in the classroom than with any other single building component. A number of these studies have demonstrated a positive correlation between appropriate lighting and higher student achievement. Many of the studies have been conducted by the Illuminating Engineering Society in controlled environments. When considering lighting in the classroom there are two factors to consider namely the quantity of light as measured in foot-candles and the quality of light. The quality of lighting refers to the kind of lighting usually indicated by either incandescent or fluorescent lighting. Considerable research has been completed trying to determine the most favorable quality of lighting that would influence student achievement and behavior. Studies cited in this section of the report deal with the investigation of the benefits of fluorescent lighting in the classroom.

The quantity of lighting has been well established through work of the Illuminating Engineering Society. Their Criteria calls for 50 foot-candles but in addition to quantity the Task Force may want to give some consideration to the quality as studies

below indicate. Specifically studies indicate natural lighting to have the most positive affect on student achievement.

1. Nicklas and Bailey investigated the relationships between elementary and middle school student performance and natural daylighting in the facilities (1995). There were three schools, designed around a daylit prototype, in North Carolina where the study was conducted, and the performance in those three schools was compared to the countywide test results. The study also included one new middle school that was not of the daylit design.

The daylit schools were constructed to maximize daylighting through the use of south facing roof monitors that allowed controlled sunlight to enter into all major occupied spaces within the schools. The following is a description of the design:

> The roof monitors were designed to provide superior lighting (in excess of 70 foot-candles) two-thirds of the time during which the spaces were to be utilized. In all cases the roof monitors were equipped with baffles which eliminate glare into the rooms and with light sensors which control the artificial lighting. Smaller windows were also incorporated for view but were not a significant element in the daylighting strategies (Nicklas & Bailey, 1995).

Statistics from the California Achievement Tests (CAT) and End-Of-Grade Tests were used to compile the necessary summaries for student performance for pretest information for all of the county schools. This included scores from sixteen elementary and eight middle schools. These same two instruments were used to assess performance once the daylit schools were all in operation.

When using these instruments, the researchers considered improvement in performance within each school from 1988 to 1992, 1992 to 1993, and 1994 to 1995. They reviewed the relative improvement in performance between the schools they designed and the improvement in the system-wide average for similar grade levels. First year student performance at a fourth daylit school was reviewed, and the relative improvement in the performance of another new,

non-daylit middle school in the same school division was included as well. They used the percent of difference between base scores and most recent achievement scores. Students in daylit schools out performed those in non-daylit schools by 5 to 14 percent. When the student achievement results from being in a daylit school for a number of years was compared with students in non-daylit facilities; the average increase of better performance was 14 percent.

To exclude the variables that could not be controlled from school to school, such as the student and teacher composition, Nicklas and Bailey did not make comparisons between the various schools. They drew their conclusions from the relative improvement within each school.

2. A more recent study examined the effect of daylighting on student performance (Heschone Mahone Group, 1999). The study was focused upon skylighting in the classroom as a way to isolate daylight as an illumination source. Over 2000 classrooms in three states were used to gather data. Student scores on a standardized achievement test were used to make the comparison between students in daylit and non-daylit facilities. Data indicated that students in classrooms with the most daylight performed 20 percent better on mathematics tests and 26 percent on reading tests in one year than did students in non-daylit schools.

3. A case study of schools with daylit classrooms was conducted to determine the relationship between daylit schools and selected student variables (Plympton, Conway, and Eqstein, 2000). The classrooms in these schools had direct exposure to sunlight through various design features. One of the student variables was student attendance. In all of the six schools used in the study the student attendance was above student attendance non-daylit schools. The principal of one school stated, “The daylit classrooms have increased the well being of the students and teachers and it is at least partly responsible for the record high attendance rates. We are running about 3 percent ahead of the rest of the county in attendance.” The conclusion of the study was the daylit classrooms aided not only in increased student attendance, but also contributed to the improved physical well being of the students.

4. McGuffey (1982) reviewed ten studies conducted in schools in his work and in all cases, good lighting quality and proper foot-candles were found to be positively related to increases in student achievement and performance. Conversely, in schools where the lighting is less than the minimum acceptable level, students did not perform as well as students in properly illuminated school buildings.

5. Dunn (May,1985) reported on a study conducted by the U. S. National Society for the Prevention of Blindness. The Society reported that visual efficiency had a marked effect on many academic outcomes and that it was influenced by a number of factors. Some of these factors included the presence and amount of glare, the relative brightness of objects and their backgrounds, and other facility and environmental factors.

Dunn also reported that environmental lighting exerts profound biological effects on humans. He cited several studies that indicated that the lighting of a school building should be considered a key element of the design and construction because of its influence on physical and mental health.

6. Chan (1979) investigated lighting in his attempt to ascertain how the physical environment of the classroom affected the middle school student. The researcher stated that there were numerous studies involving elementary and secondary students, but studies involving students at the middle level were scarce.

There were several hypotheses tested in this study. However, the one most important to the variable light was that there would be a difference between the academic achievement of students in classrooms with fluorescent lighting when compared with the academic achievement of students without fluorescent lighting.

The findings showed that student achievement was higher in schools with fluorescent light than for students in schools without fluorescent light. Even though the statistics were too small to be significant, in the main, there was evidence to indicate a tendency of better student achievement in a fluorescent lighting environment.

7. Grangaard (April,1995) attempted to replicate a study that Wohlfarth conducted in 1981 to determine the physiological and behavioral effects of color and light on elementary students. There were three phases in the study in which the color and light of the test field were manipulated in the classroom.

To gather data for comparison of light and color on students, the researcher employed video taped sessions with children. Three two-day sessions in which children were videotaped for fifteen minutes in the morning during the same activity and for the same period of time in the afternoon were used. The students' blood pressures were taken once in the morning and once in the afternoon. The researcher was very consistent in making sure the measurements were obtained at the same time each day.

Phase I consisted of an environment where the walls were painted semi-gloss white and which included cool-white fluorescent fixtures. Phase II students were in a classroom in which the walls were painted light blue and the lights were a full-spectrum duro-test vita-light. Phase III was identical to Phase I.

Since color and light were the only known variables during the three phases, these were considered the reason for dramatically decreased blood pressures in the second phase. This phase also had greatly reduced off-task behaviors. The off-task behaviors were activities such as looking out the window, squirming in the seat, and talking with a fellow student. According to the researchers these activities would clearly preclude the students from concentrating on the lesson at hand. The research demonstrated the fact that there was a cause/effect relationship between the child and the environment.

8. Hathaway, Hargreaves, Thompson, and Novitsky (February, 1992; Winter, 1993: March/April, 1995) undertook to replicate the findings of an earlier study which investigated the effects of classroom lighting on student achievement, health, and behavior and to test the differential effects of lighting types on students. Five study sites were selected that included a school with indirect high pressure sodium vapor lamps, a school with full-spectrum fluorescent lamps, two schools with full-spectrum fluorescent lamps with UV enhancement and fixtures that

contained aluminum reflectors and aluminum grid diffusers or open egg-crate diffusers, and a school with cool-white fluorescent lamps.

Data were collected on fourth grade students including age, sex, nutrition histories, fluorine levels, dental histories, attendance histories, general health, growth and development histories, scholastic achievement histories, skin types, and vision histories. The histories were compared with the data collected over a two-year period of the students' exposure to the five sites. There were no significant differences in the ages or daily nutrition of the students at the different sites, supporting the fact that the students at the five sites were quite comparable. Even the drinking water supplies were adjusted to have similar amounts of fluorine.

On the basis of an analysis of attendance records, full-spectrum fluorescent light with UV enhancement did have an effect. This light affected the health and general development of the students. Conclusive differences were found to include age at the onset of menarche, height gains, weight gains, and gains in body fat. When comparing achievement records, the UV enhanced light had an effect on the rate of achievement.

On the basis of an analysis of vision records, light did not have an effect on changes in vision. However, there were indications that the rate of change in uncorrected vision at two of the sites was affected by the quality of lighting systems.

9. Once again, different types of lights were used in the classroom to ascertain the effects of distorted spectrum fluorescent light (DSF) and full-spectrum fluorescent light (FSF) on students. London (November,1987) maintained the null hypothesis that there would be no difference in the effects of DSF and FSF.

In order to conduct the study, the DSF lights in three classrooms of an elementary school in Vermont were replaced by FSF lights (Vitalite) during a school holiday. These three classrooms of students between the ages of five and nine were chosen primarily because their rooms were on different sides of the building.

At the end of the school year, London tabulated from the attendance records the total number of daily absences due to illness during September, October, November, and December

(seventy days), before the Vitalites were installed. The same was done for January to the end of June (105 days), after the FSF lights were in place. The study was not a blind study; however, neither the students nor the staff had any expectations that the FSF lighting might affect sickness absences.

Before the FSF lighting was introduced, the illness rate in the designated classrooms was not significantly different from that in the rest of the school or in the three classrooms that were paired with them. There was no evidence that students in the experimental rooms began the study any healthier than the other children.

When the FSF light was in place, the sickness rate in the experimental classrooms was lower than that in the rest of the school and in the three paired classrooms. When compared with the rest of the school, the significance was < .01, and in the three paired rooms the significance was < .05. This effect was a reverse of the usual seasonal pattern in the school, wherein sickness absences increased during the winter and spring months. As expected, in classrooms without FSF lighting, the rate of sick days increased significantly from January through June, compared to the time of September through December. In the FSF classrooms, the sickness rate fell slightly during this same time period.

It should be noted that the DSF lighting raised the serum cortisol level more than the FSF did, and glucocorticoids suppressed cell-mediated immunity. London went so far as to suggest that perhaps FSF light, which is used to treat seasonal affective disorder, may be useful in the treatment of immune disorders.

The teachers found the FSF lighting brighter, more natural, and more pleasant. They did not wish to return to the DSF lighting.

10. Wohlfarth (July,1986) conducted a study in Canada to ascertain the effects of light and color on elementary students in a northern climate. As explained earlier in this research, the independent variables were exposure to full-spectrum light and prescribed warm or cool colors. Grade five students were exposed to ultraviolet light, and electromagnetic radiation was eliminated for a sample of grade three students.

Wohlfarth had the greatest findings in the area of light. There was a strong effect found between ultraviolet light and absences due to illness. Elimination of electromagnetic emissions from fluorescent lights resulted in a decrease in classroom off-task behaviors for classroom groups, but not for triad groups that had been selected for hyperactivity. These findings were of profound practical significance.

11. Harting and Delon replicated a study done previously in Canada, Vermont, and Florida (spring,1990). Four Missouri school districts and two fluorescent lamp manufacturers conducted the study involving fifty-two classrooms, thirty-nine experimental and thirteen control. These researchers set up an equal number of experimental classrooms fitted with three different types of enhanced-spectrum fluorescent lamps. The experiment was conducted blindly in five designated schools. Neither the teachers nor the researchers knew which classrooms contained the special lamps until the study's completion.

For two months, the school administrators collected absentee data for each of the classrooms. During the semester break, maintenance crews installed the three different types of enhanced-spectrum lamps and ultraviolet light-transmitting lenses. The control classrooms remained equipped with conventional cool-white fluorescent lamps. School personnel, again, collected absentee data, along with information regarding which lamps the teachers preferred.

Chi-square tests of independence were completed to identify any relationships between student absences and types of lighting. The light meter reading produced continuous data from which means and standard deviations were calculated. Pearson product-moment correlation coefficients were generated to examine relationships between light intensity and absences.

Although, there were no controls to ensure that students attending windowless schools constituted a sample that was equivalent to those in the schools with windows, the findings indicated that the rate of student absenteeism was significantly ($\underline{p} < .01$) higher in the windowless schools than in schools with windows. In three of the four schools, there was ample evidence that classrooms having conventional cool-white fluorescent lighting, or other lighting

sources not providing an ultra-violet component, had higher absence rates than in those with light sources that supplied this component.

Student absence rates seemed to be unrelated to light intensity in the classroom and did not appear to be related to grade level for students in grades one, two, and three.

Although the study seemed to reinforce the findings of similar studies, Harting and Delon suggested continued research with artificial lighting.

D. Acoustics

Research indicates that the ability to clearly hear in the classroom is vital for student learning and teacher performance.

1. The Department of Health Services of the State of California completed a rather extensive study of the effects of noise on academic achievement and behavior (DOHS, September, 1981). Students in grades 3 and 6 in schools that were near highways and expressways were compared with similar students in schools in quiet neighborhoods on the California Test of Basic Skills (CTBS). Eighty-one classrooms in 15 identified schools were included in the study. Economic, racial and language differences were controlled by matched pairings of schools. Measures of community noise and classroom noise were taken throughout the study period. At least 267 daily observations were made in the school classrooms. The mean grade equivalent achievement scores of all students in socio-economically matched noisy and quiet schools were compared. The third grade students in noisy schools were .4 years behind students in quiet schools in reading and .2 years behind in mathematics. For the sixth graders, students in the noisy schools were .7 years behind in reading. Sixth grade students in the noisy schools scored .2 years ahead of students in the quiet schools. Researchers attributed the mathematics score as an anomaly resulting from the high performance of students in one school.

The conclusion of the DOHS was that a negative relationship exists between classroom noise levels and reading achievement and that this study supports previous studies such as Bronzaft and McCarthy (1975) and Cohen, et al (1981) who found similar results. The

researchers also found a high correlation between community noise levels and classroom noise levels. Findings on reading scores between the 3rd graders and the 6th graders indicate the student academic achievement deficits of the early years become progressively worse as student's progress through the grades.

2. Lemasters (1997) reviewed more recent work on the level of noise in the school and was able to state that researches have reported a significant relationship between noise level and student achievement. Construction, jet aircraft, sound systems, television, radio, automobiles, trucks, and many other elements bombard the airways with noise. Music rooms, gymnasiums, crowded hallways, cafeterias, and crowded classrooms comprise an environment of sound at school.

3. Hyatt's study questioned the effects of jet aircraft noise on achievement tests and attitudes of students in noise affected schools (1982). The school district used in this study had a kindergarten through twelve program with an average enrollment of 18,622 students. The school division surrounds the Seattle-Tacoma International Airport, which processed over two hundred twenty flights per day during the time of the study. The schools selected for the research were those in Zone I (lowest level of noise) and Zone III (highest level of noise).

Hyatt used achievement test data from the regularly scheduled testing program of the school division. This program called for testing at grades two, four, six, nine, and eleven. For the years of the study, 6,340 students completed the battery of tests.

The noisy and quiet schools were demographically matched using ten factors to describe the immediate households of the students: professional or technical workers, managers, or administrators; intact families; persons twenty-five or older having a high school diploma; living in the same house for five years; families not on public assistance or welfare; families with income above the poverty level; and, others.

Summaries of student achievement in noisy versus quiet schools were computed for significance using T-scores. The same was computed for the summary of student achievement in demographically matched noisy versus quiet schools.

The opinion questionnaire that was used was developed for a lawsuit against the Port of Seattle and was revised by a testing firm. A total of 1,014 students were surveyed at grades six, nine, and eleven. This questionnaire was intended to measure student attitudes toward the classroom environment in noisy versus quiet schools, and to discover if that attitude affected achievement.

The findings indicated that there was significantly (.01 level) greater achievement for grades two and four in the quiet schools. The level of significance for grade eleven was .05. There was no statistical relationship at grade six, and a negative relationship was derived at grade nine. When schools were demographically matched, student academic achievement was significantly higher in quiet schools at all levels except grade nine.

Students perceived the noisy schools to have noisier classrooms, to be more confusing, and to have more interference. Students said the teacher was difficult to hear, the teacher needed to speak loudly, and the outside noise interfered with learning.

Students attending schools in Zone I scored higher on achievement tests than those attending schools in Zone III. The only exception was grade nine, which may have been due to a soundproofing project that was in progress at the time of the study.

It should be noted that, although the ninth grade was the only grade without a level of significance in the difference between test score means, the ninth grade students perceived the greatest differences in their school environments. Along the same line of thought, students in the noisy schools with high achievement scores rated their classrooms as being more noisy that did students with low test scores. Students in the quiet schools had the opposite results.

4. Kaufman (1984) hypothesized that there are certain situations in the classroom and in the home that create stress in children identified as potentially at risk or maladjusted. The study used naturalistic research methodology. Observations were made twice weekly for two to four hours per day in third grade classrooms of selected elementary schools in a suburban area of southwestern United States. This was done to provide initial observations for selection of the children for later participation.

Certain children were identified and observations continued in three third grade classrooms for another thirty hours. On the basis of these observations and informal interviews with the children, a list of seven children was identified for characteristics such as social isolation, low task orientation, distraction on academic work, and noncompliance with teacher requests.

Contacts were made with parents of four of the seven children. They were selected to participate during the next school year; however, one student moved away during the summer. Thus, three students were used in the in-depth study. Observations began the next school year.

Kaufman (1984) identified noise as a "stressor" with the three children. Indeed, non-related, ambient classroom noise was observed to cause great stress.

The conclusions that the researcher drew from this study focused on the importance of studying children in depth when analyzing the construct of stress in children. Kaufman said that educators need to look deeply into the lives of children and make more allowances for human variation in classrooms.

5. Zentall and Shaw (1980) hypothesized that hyperactive children would not respond or perform any differently than the control group when employing (a) a familiar class task; (b) classroom noise selected to be high in linguistic content, administered at levels representative of actual classroom levels; and, (c) high and low noise conditions administered in a counterbalance order.

Twenty-four hyperactive students and twenty-four control students were selected from seven second-grade classrooms based on their hyperactivity scores on the Conners Abbreviated Teacher Rating Scale. Test groups of eight children (four hyperactive and four control) were drawn from two randomly selected classes per test day and were randomly assigned to a treatment session.

During the sessions, students were escorted from their classes to a small, pale green room that contained a teacher's desk and chair, a bookshelf and filing cabinet, and a circular table with eight small chairs for the children. After an adaptation period, an arithmetic task was introduced

to the students, and the exercise was timed. Correct responses were measured for use in the statistical data of this study.

Approximately two weeks later, low levels of noise were administered while these same students performed similar math problems. The remaining students received noise levels in the reverse order.

A three-way repeated-measures analysis of covariance, using achievement as the covariate, was performed on the activity and performance scores for the main effects of groups, treatment, time, and interactions were obtained. An ANCOVA was employed, even though the groups did not differ on IQ or achievement.

Zentall and Shaw concluded that hyperactive students were more active than control students overall; however, hyperactive children were more active in high noise environments and less active in the low noise setting than the control children, who exhibited the opposite pattern.

High-linguistic-noise appeared to have the greatest negative effect on hyperactive children. Both groups became more active during the second test session without a pursuant loss in performance.

Differences between groups consistently showed that the hyperactive students demonstrated greater activity and fewer correct problem solutions, even though there was an apparent equivalency between the groups in IQ and general achievement scores.

This study was not intended to exemplify an effect of the physical environment; however, its findings on noise in the classroom are important.

6. Zentall and Shaw conducted a second experiment to test the generality of classroom noise effects by presenting the noise in a more natural way, while children were performing repetitive tasks involving auditory memory processing. This study involved reading, rather than math skills, and an attempt to reduce social interaction.

Four new children were added to this sample so that each group had twenty children. Hyperactive and control children were randomly assigned to test groups, with the constraint that four hyperactive and four control children were tested at the same time. Groups of eight children

were randomly assigned to a test day. A new recording of classroom noise was used. Sound-pressure-level reading varied little from desk to desk. Ambient sounds of chairs moving, whistling, laughing, desktops slamming, howling, and background talking were included on the tape with distinct verbal behavior produced by children. The low level recordings were made during work time in the classroom.

The hyperactive children were significantly more active than controls and were observed off task more frequently than controls. There was a non-significant tendency for both groups to omit more letters and to make more total errors under high noise conditions. Control children exhibited more total errors in low noise, while the opposite was true for the hyperactive students.

There was some evidence to suggest that high levels of noise were less disruptive when encountered while performing familiar tasks rather than new. Classroom noise appeared to add to the challenge for the hyperactive child, especially when the task required some auditory processing of information.

7. The results of a recent study confirm the findings of a long list of studies dealing with un-wanted noise in the classroom. Maxwell and Evans (1997) investigated the results of noise on 110 students in the 1st and 2nd grades of two New York City public schools. One school was in the flight pattern of a local airport and had peaks of 90 decibels every 6.6 minutes as a result of flights. The other school was in the immediate neighborhood, but not in any flight patterns. Students in the noisy school scored 20 percent lower on a reading test than students in the quiet school. Data demonstrated a causal relationship between noisy facilities and student achievement. Such a linkage is considered more significant than a correlation or association relationship because it shows why the difference occurs.

8. Clear evidence from the studies cited above point to the fact that higher levels of noise, both inside and outside the classroom can seriously hinder students from achieving their potential. The distraction of noise negatively impacts upon the ability of students to perform well. The noise distraction in classrooms that are at a high level results in low performance year after year by students attending these schools.

E. Science Laboratories and Equipment

The evidence is very clear that when a school building has modern functional science equipment and furniture students are able to perform more to their capacity than students in buildings with less modern equipment. Students who are in poor buildings perform less well than students in better buildings. The research that delineates the relationship between science equipment and furniture and student achievement is embedded in the research dealing with the condition of a school building (Edwards, 1992; Cash, 1993; Earthman et al, 1995; Hines, 1996; Lanham, 1997).

1. Hines (1996) investigated the relationship between school building condition and student achievement. He used large high schools as his population and compared the condition of the building to high school test scores. Part of the assessment of the school building was regarding the condition of science equipment. There were two items asking the principal to rate the condition of the science equipment and furniture. In those buildings rated as poor, the science equipment was also rated as poor and out-of-date. He used two items in the instrument to measure the science equipment, one was an evaluation of the condition and the other asked about when they were last updated. He then compared the science equipment assessment with the scores on the science section of the achievement test. His findings relating to these items found there was a difference of 8 percentile rank points on the first item and 1 percentile rank points on the second item favoring the students in schools where the science equipment was in good order and modern. This same kind of difference between students in schools with older science equipment and modern equipment was found in the other studies cited above.

2. Even in the elementary schools, Cash (1993) found a significant difference in science achievement scores between students in buildings rated poor and those rated standard.

F. Overcrowded School Buildings

The over utilization of a school building results from more students being assigned to the building than the number of students for which it was designed. Clearly this is an administrative

decision that negatively impacts upon the performance of students. Overcrowding a building is not the fault of the building, but the fault of the decision makers in the school system. Nevertheless, the end result of overcrowding students into a building for which it was not designed results in negative impact upon student achievement.

Most school districts that experience overcrowded conditions are able to rectify the situation within a year or two. Consequently it is difficult to measure the long term effect overcrowding has upon students. One school district has experienced long term overcrowded conditions in a high percentage of the schools. Studies emanating from this situation are perhaps the best evidence of the effect of overcrowding conditions on student achievement.

1. During the period of time between 1990 and 1996, the New York City Public Schools experienced severe overcrowding throughout the city. Two major studies were conducted for the school district to determine the effect of overcrowding on the student population and the city school organization (Public Advocate for the City of New York, 2000; Rivera-Batiz & Marti, 1995).

The first study dealt with the causes of overcrowding conditions and offered some remedies. This report focussed on school crowding, physical conditions of buildings, and class sizes. Also included in this report was the impact overcrowded conditions had upon student achievement. The researchers summarized by reporting that academic achievement of students remained poor – 66 percent of the 3rd graders and 71 percent of the 6th graders read at the State Reference Point (SRP) which is one grade level below their expected level of performance. For mathematics, the percent of students meeting the SRP were 87 and 80 percent respectively. During this period of time the percent of students meeting SRP decreased by 10 percent for grade 3, 9 percent for grades 6, and 2.8 percent for grade 8.

During this period of time the graduation rates for all high schools declined by 5.3 percent to a 48.3 percent level. Students in New York can apply for a Regent's Diploma

by completing a more rigorous plan of study. The decline in number of students receiving this kind of diploma was 15.2 percent during this period of time.

2. Riveria-Batiz and Marti (1995) completed the other report dealing with the consequences of overcrowding. The researchers reported some of the comments of teachers in overcrowded classrooms. The teachers felt that overcrowding negatively affected both classroom activities and instructional techniques. Crowded classrooms not only make it difficult for students to concentrate on their lessons, but inevitably limited the time teachers can spend on innovative techniques such as cooperative learning and group work. Individual student-teacher contact is almost impossible in crowded classrooms. The researchers also reported that teacher burnout is much more common in overcrowded buildings than in underutilized buildings.

In spite of the fact that the results of studies dealing with overcrowded conditions were limited to the New Your City Public Schools, the findings regarding the effect of overcrowding on student achievement provides substantial evidence that overcrowding conditions are a negative influence upon students and teachers regardless of where the school district is located. Students in overcrowded conditions, even for one year, are terribly disadvantaged and short-changed on their education.

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