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THE INFLUENCE OF INDOOR AIR QUALITY (IAQ) ON STUDENT TEST PERFORMANCE

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Dedication

To my loving, supportive husband, Michael, without whom I never could have accomplished this. Thank you for always standing beside me and supporting me in all my endeavors. Your patience, understanding and help through this incredible journey will never be forgotten. You are a wonderful partner and I am lucky to be your wife. I love you very much.

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Chapter I

INTRODUCTION

The *No Child Left Behind Act (PL 107-110, 2001)* stipulates that students in public schools in the United States must demonstrate yearly progress based on standardized assessments; however, the indoor air quality (IAQ) in learning and testing environments may not be conducive to, and in some cases, may even be detrimental to student success. The Department of Education at the federal level has yet to address the critical issue of poor IAQ or implement ventilation standards for students in public schools; yet compulsory attendance laws require that students attend schools regularly. Poor IAQ in school environments deters student achievement and even impedes their good health. Turner (2005) stated:

> Poor IAQ compromises the ability of students to learn and teachers to teach. Students in schools in poor condition can be expected to fall 5.5 percentage points below those in schools in fair condition and 11 percentage points below those in excellent condition. (p. 27)

The State of New Jersey has implemented IAQ standard N.J.A.C. 12:100.13 and this code covers IAQ in existing buildings occupied by public employees, including public schools (as cited in Pediatric/Adult Asthma Coalition of New Jersey, 2007). Legislation such as this is needed to be enforced at the federal level in order to protect the children and teachers in all 50 states. The New Jersey Indoor Air Quality (NJIAQ) Standard enforces ventilation, microbial contamination, preventative maintenance and issuance of advance notice for any renovation or remodeling standards to an existing public facility, but does not cover preventative measures for dangers of air pollutants such as carbon dioxide (CO_2). Public Employees' Occupational Safety & Health Act, devised by The Pediatric/Adult Asthma Coalition of New Jersey (PEOSH) provides protection to New Jersey's public employees to improve the working environment by addressing safety hazards and health hazards (Pediatric/Adult Asthma Coalition, 2007).

CO_2 levels above 4,000 ppm are very injurious to pupil and student health and retard learning (Achilles, Prout, Finn & Bobbett, 2004-2005). According to Occupational Safety and Health Administration (OSHA, 2007), Permissible Exposure Limits (PELs) have been established as the maximum levels of CO_2 and carbon monoxide (CO) that an adult may be exposed to in an 8-hour day. The PEL for CO_2 is 5,000 ppm and the PEL for CO is 50 ppm. These PELs are alarming because they have been established for adults, not children. So if schools have poor IAQ and CO_2 and CO levels have maxed out at the PEL, how much harm is being inflicted to children's learning and health, as children are much smaller than adults and have major developing organs and faster respiration rates?

Because school-age children typically spend 90% of their day indoors (Pike-Paris, 2005), IAQ conditions need to be monitored and analyzed, not only to ensure students' academic success, but more importantly, to ensure the health and safety of students and teachers. Safety issues arise in the school setting when chemicals or toxic substances are in use and cannot be vented and therefore pose a health risk (Viser, 2004). A report from the U.S. General Accounting Office (GAO) (1995) had shown that more than half of America's schools have problems that affect IAQ (as cited in *NEA Today*, 1997). "Children are often exposed to a myriad of environmental hazards, often simultaneously, in varying doses at different stages of their development" (Landrigan & Carlson, 1995, p. 41).

In 2000, Prout conducted an initial study in six urban schools to characterize the changes in levels of CO_2 in classrooms throughout the school day, relative to the numbers of students in each classroom, cubic feet (ft^3) per classroom, as well as cubic feet (ft^3) per student. In addition, researchers (Prout, 2000) monitored three other variables throughout the school day that were simultaneously assessed with the CO_2 levels: carbon monoxide (CO), relative humidity (RH), and temperature (T). Researchers suggested that the study be replicated and expanded in order to learn more about the possible effects of IAQ in the school environment, including how air quality may influence behavior of students, teachers and overall student performance. One recommendation was that "high-stakes testing" should occur in large, well-ventilated rooms with good IAQ conditions, as opposed to how and where tests were/are generally administered, such as in rooms with doors and windows closed, with many students in rows for extended durations of time.

In the present study, the researcher assessed CO_2 levels at regularly scheduled testing times of a standardized, high-stakes test, to determine if increasing levels of CO_2 in classrooms with fewer cubic feet (ft^3), may influence student test performance. Research (e.g. Achilles, Prout, Finn & Bobbett, 2004-2005; Prout, 2000) does suggest that class size affects levels of CO_2, and class size as a latent variable was considered only as a matter of context in the present study. The researcher assessed that (a) CO_2 levels fluctuated during scheduled testing times and (b) how such increased fluctuations in CO_2 levels influenced testing outcomes.

Statement of the Problem

The disconnection between obligatory attendance along with students being accountable for performance on standardized tests each year, and the empirical claims that poor IAQ has a negative influence on student performance has been validated. Legal requirements of *No Child Left Behind Act* (PL 107-110, 2001) establish norms that students must meet Adequate Yearly Progress (AYP) and attend school regularly, when at present (2007), there are no IAQ standards in effect specifically for public schools. With *No Child Left Behind Act* (PL 107–110, 2001*)* in full force, the government has been holding schools accountable for AYP, yet there has been no accountability for IAQ in schools. It has simply come down to test scores and ramifications if AYP is not achieved. Bracey (2007) stated, "There is no scientifically based research undergirding the law – there is no research that says choice, supplemental education service (SES), corrective action, or restructuring will actually accomplish what they are supposed to achieve" (p. 476).

School environments, over which students have no control, must not be harmful to student health or safety, and must not hinder or deter students in meeting expected education goals, yet the air that students are breathing may be doing just that. The IAQ of schools is an administratively mutable variable and if administrators know about its effects and its various levels, they can take corrective action.

The IAQ in America's public schools is beginning to gain national interest (Achilles et al., 2004-2005). Prout's findings (2000) indicated that the air samples analyzed were not only unhealthy, but that the IAQ conditions negatively affected teaching and learning. Pending further supporting evidence to Prout's study but shifting the focus to IAQ influence on test performance, specific IAQ guidelines can be developed for public schools, with concentration on recommendations for testing settings.

Purpose of the Study

The purpose of this study was to affirm and extend the consequent of Prout's (2000) findings, with a concentration on IAQ and its influence on student test performance on a high-stakes assessment. Additional empirical evidence may improve conditions in schools by adding support to the need for IAQ and ventilation standards in public schools. Research (e.g., Prout, 2000) has shown that concentrated levels of CO_2 increase as the school day progresses and as students remain in one room for lengths of time with doors and windows closed, as is common at testing times.

With the added evidence and knowledge of (a) how to assess if IAQ influences student test performance and (b) steps to improve IAQ for testing conditions, administrators will have guidelines for assuring student health and for helping students become more successful in an assessment setting. Achilles et al. (2004 – 2005) stated,

> The IAQ of schools is beginning to gain national interest, especially as Americans review the poor quality of many schools, the increase in childhood asthma, episodes of the sick building syndrome and [as shown about concern for air quality in planes and workplaces] the influence of IAQ on health of adults. [Kids, of course, will be last]. (p. 19)

The purpose of this work was to seek definitive information to determine how CO_2 levels may influence high-stakes test performance among four groups of elementary schools students. Two of the four groups of participants were exposed to reduced levels of CO_2 at posttest because they tested in a room with many more ft^3 during the posttest phase.

The influence of IAQ is not immediately obvious without careful analysis of the data. Replication by this study allowed previous findings to be supported and strengthened. These findings may encourage advancements in policy formulation and implementation in public schools. Moreover, the data suggested there are variations that some learning environments with more cubic feet have better conditions, vis-à-vis, more favorable IAQ levels. The Environmental Protection Agency (EPA) (1996) has stated, "Good indoor air quality contributes to a favorable learning environment for students, productivity for teachers and staff, and a sense of comfort, health, and well-being for school occupants. These combine to assist a school in its core mission-educating children."

Research/Guiding Questions

The key research questions that guided this study were developed to identify the influence that IAQ, in particular CO_2, may have on student test performance. The null hypothesis states that there is no difference in testing outcomes based on levels of IAQ and cubic feet per student. Based on empirical evidence, do the data support the hypothesis that increasing levels of CO_2 negatively influence student test performance? Does administering high-stakes testing in rooms with more cubic feet produce more favorable testing outcomes? If another study were to be conducted on a larger scale, would results concur with the findings of this study?

The need for implementation of IAQ standards in public schools is even more acute because students are required to attend school on a daily basis. Relevant IAQ research could contribute to school construction guidelines based on the optimal cubic feet per student to minimize air quality damage on student performance. IAQ is important because it is a manipulative variable: education leaders can do something about improving it, for example, by suggesting classroom sizes based on cubic feet per pupil.

Significance of the Study

The Federal Government should develop and enforce IAQ guidelines so that students may have a better chance at meeting academic goals. The IAQ of public schools should be monitored periodically as per specific guidelines and this research may strengthen the need for these actions. Health care workers, teachers, children, policymakers and community leaders all play important roles in preventing children's exposure to harmful toxicities in their environment (Center for the Future of Children, 1995, p. 22).

The findings in this study may provide suggestions to alleviate or reduce the discrepancy between the empirical and normative claims of students having to meet AYP, but the schools in which they test and learn are not conducive to such. This discrepancy may be remedied by establishing a sense of urgency for administrators to devise policy that implements IAQ standards for all public schools. "Our schools are in worse physical shape than our bridges, our transit system, or our hazardous waste disposal systems" (Ohanian, 2003, p. 741).

Results of this study may provide further empirical support to the administrators of the local schools so that they may be informed of the influence of poor IAQ on student test performance. Administrators, parents, teachers and government officials must be consistently made aware of empirical data that calls attention to the problem of the numbing effects of excess CO_2 in classrooms its relationship to student performance.

By calling attention to this IAQ problem, discussions may be generated which may lead to appropriate remedial action. Suggested actions may include implementation of policy for IAQ standards for all public schools. Federal funding to assist schools with new or improved Heating Ventilation Air Conditioning (HVAC) systems for target schools in need of revamped systems could be included in legislation. Due to inadequate financial resources, if schools are unable to revamp existing HVAC systems where poor IAQ has been detected, federal officials need to be cognizant of the problem when assessing the AYP of students in deteriorating schools. Kozol (2005b) stated:

> There is something deeply hypocritical about a society that holds an eight-year old inner-city child "accountable" for her performance on a high-stakes standardized exam but does not hold the high officials of our government accountable for robbing her of what they gave their own kids six or seven years earlier. (p. 46)

Definitions of Important Terms

Because of the technical nature of this study, terms used in this study are defined and included in Appendix A, as a Glossary of Terms.

Limitations and Delimitations

Experts in the field of education continue to seek out variables that contribute to better performance of students. For example, IAQ levels can be related to class size because smaller class size is indicative of more cubic feet per student, if room size is a constant. Based on Prout's research, more cubic feet per pupil generated better performance both academically and behaviorally.

One limitation of this study is that many variables affect student performance. Poor IAQ in a learning or testing environment is not the only cause for poor test performance. Leach (1997) stated:

> While it is difficult to point directly to statistical data that irrefutably link interior air quality with student performances, we have more than enough indirect evidence, combined with our initiative and plain common sense experience to make this issue well worth pursuing. (p. 32)

Additional variables that affect student achievement are students' poor socio-economic status (SES), learning disabilities, lack of support at home, inadequate teacher training, poor nutrition, emotional state of students, etc. These variables are recognized as substantial but were beyond the purview of the proposed study.

Limitations engendered by the design of this study included student attendance, the small number of classes used in the study, and the collection of data from only two of the six possible grade levels within the school. Knowledge in two different content areas was tested. Therefore, broad generalizations from the data were limited.

Another limitation to this study was the variable of class size. Smaller classes of 13-17 students were not available due to the district's limited space, financial restrictions, and elevated enrollment throughout the district. Class size is not the only answer because that requires more space (Achilles, Prout, Finn, & Bobbett, 2000) and educators may not have the luxury or funding to add more classrooms to existing structures. Present school facilities may not accommodate larger physical cubic feet classroom space, even though they may contain smaller classes. More cubic feet per classroom will allow for more flexibility in assigning different size classes to rooms without the debilitating effects of higher levels of CO_2.

An important limitation of this study was that there was no true experimental group because a predetermined district testing schedule only allowed for an intact group design. The absence of randomization was a limitation.

A further limitation to this study was the norm referencing in the *Northwest Evaluation Association's (NWEA) Measures of Academic Progress (MAP)* (2005) assessment. Standard scores on this assessment were normed using the Rausch Unit (RIT), not a nation-wide norming scale, such as the Normal Curve Equivalent (NCE). In addition, the MAP is primarily a diagnostic tool to help educators engage in data-driven decision-making.

Delimitations in this study included that data collection occurred during previously set district-wide scheduled testing. The specific grade level of participants in the study included two third grades and two fifth grades, with the intent to control for age and physical development of students: that is to the degree possible in pre-existing class assignments. The researcher controlled for student age and size because larger/older students occupy more space, and produce relatively more CO_2 per person. The test normally used was NWEA's MAP (2005) employed to avoid extra testing. No other test than the regularly scheduled MAP was used.

Design & Methods

The study extended Prout's (2000) research, but focused on student test performance outcomes in relation to CO_2 levels in two different testing settings, and was conducted in a suburban school district. During the 2006-2007 school year, the school district was administering NWEA's MAP assessments to all students as part of the district's regular testing program. The researcher took advantage of the Fall/Spring scheduled testing to explore the research questions related to IAQ and student test performance.

To the degree possible with pre-established intact groups (regular classes by grade levels), the researcher conducted an on-site action-research experiment. In the Fall (2006), all k-6 students were tested by class groupings in a single computer room, measuring at 11,750 ft^3 and students used individual computers to take the assessment. After being aggregated to the class level the Fall pretest data was be entered into the district database and served as the pretest or baseline data. The researcher monitored testing to ensure there was proper attention to testing protocols and to collect qualitative data on the testing conditions and student behavior. The IAQ was monitored immediately at the beginning and end of each class' testing session. The regular IAQ-CALC / TSI 8762 TM calibrated for the site recorded IAQ variables and reported CO_2, CO, RH, and T.

Aggregated group data from four classes (two 3rd grade classes and two 5th grade classes) were selected for the pretest or baseline data. Aggregated group data from the same four classes obtained in the regular spring (2007) testing, were compared the posttest assessment. The classes were matched by numbers of students in the class and by grade levels to assure comparability between the groups as much as possible.

At the spring (2007) posttest time, two of the four classes (one 3rd grade control group [3-O] and one 5th grade control group [5-O]) completed the posttest in the same room as the pretest was taken, measuring at 11,750 ft^3. Two of the four classes (one 3rd grade experimental group [3 – X] and one 5th grade experimental group [5-X]) took the posttest in a much larger room, measuring at 70,000 ft^3, using individual computers from the mobile computer lab. Thus, one single variable, cubic feet per student, was manipulated. The IAQ was monitored at the beginning and ending of each testing session. Compared groups tested at the same time of day.

The teachers and test proctors were not informed as to which groups served as the experimental and/or control groups in the data collection. Only group (class) data was used and analyzed; no person was mentioned or discussed individually. All data and analyses were reported anonymously by assignment of a number to each students under the group title of 3 – O, 3 – X, 5 – O, and 5 –X.

Participating classes ranged from 20 – 22 students. The two testing sites used in the study had the same HVAC systems. The pretest classroom measured 11,750 ft^3 in size and the posttest classroom measured 70,000 ft^3 in size.

The IAQ-CALC / TSI 8762, a recently calibrated, scientific instrument took two readings at the beginning and end of each pretest and posttest to report the IAQ of the testing sites. In addition to CO_2, CO, RH, and T were reported. Specific attention was drawn to the varying levels of CO_2 during the 60+ minutes of testing in each session. Each group took both tests in the morning and 3 –O and 3-X tested at the same time of day, but on different days and 5 – O and 5 – X tested at the same time of day, but on different days. The IAQ-CALC / TSI 8762 instrument was placed in the same location each day to collect CO_2 levels at student head height because CO_2 is heavier than oxygen.

Prior to commencement of the pretest, IAQ levels were collected to serve as a baseline against which any changes in levels of CO_2, CO, RH and T were judged.

It was assumed that all groups would perform better on the posttest than on the pretest, as with any pretest / posttest design. However, the effect size for the groups tested in the larger room with more ft^3 at posttest, would be stronger than for the groups tested in the room with 11,750 ft^3 due to lower levels of CO_2 in the bigger room. Data included three domains (a) Descriptive data of IAQ in testing rooms, (b) Quantitative data of whole class test scores on the MAP pretest and posttest and (c) Qualitative data including researcher's observations of testing environment such as student behavior, lighting in the room, and outside weather conditions on testing days.

Organization of the Study

Chapter I contained a statement of the problem, purpose of the study, research and guiding questions, significance of the study, limitations and delimitations, and an outline of the designs and methods used in the study. Definitions of important terms are in a glossary in Appendix A. Chapter II includes review of research and literature and a figure representing the researcher's theoretic framework/ conceptual base for the study. Chapter III describes, in detail, the study design and the methods used to conduct the study. Chapter IV contains the analyses of data for this study pertaining to CO_2 and its influence on student test performance, as well as tables and figures representing those analyses. Chapter V includes a summary, findings, conclusions, discussion and recommendations for policy, practice and research.

Chapter II

REVIEW OF THE RESEARCH, THEORY, AND LITERATURE

Lezotte (2001)emphasized the importance of a "Safe and orderly environment" which make schools effective. "In the effective school there is an orderly, purposeful, businesslike atmosphere which is free from the threat of physical harm. The school climate is not oppressive and is conducive to teaching and learning." Probing the IAQ of schools where children are expected to learn is paramount to maintaining atmospheres that are free from physical harm and are conducive to learning. Accepting the notion that environment influences educational outcomes such as behavior and achievement (Kozol, 1991;2005a) is a critical first step to rehabilitating impeding learning environments.

Education administrators must ensure students' safety while they attend school each day. In addition to reviewing infrastructure of schools to repair damages and remove harmful substances such as asbestos and chemicals, maintenance personnel and administrators of schools must serve as key advocates for children to ensure safety of America's students at school. In the 2001 *Report Card for America's Infrastructure* (as cited in Ohanian, 2003), the American Society of Civil Engineers gave the lowest grade of a D- to public school facilities.

Keeping children safe takes on many facets. Crisis intervention plans are in effect in schools today. Routine practices are carried out each month in schools for fire safety and crisis intervention. Teachers and administrators are trained for emergency situations, but when are teachers and administrators coached and trained on how to help make the air in the learning environment in which they teach safe to breathe? The way to reaching overall "air safety" in classrooms is to implement universal policy enforcing standards for better air quality. A 1995 report from the United States General Accounting Office showed that more than half of our schools have problems that affect IAQ (as cited in "Stink Over IAQ", 1997).

Size Matters

Empirical evidence suggests that students in smaller classes outperform and behave better than their larger class size counterparts behave, even after being taught the same curriculum. One facet of the research conducted in the large-scale, 4 -year [1985-1989] longitudinal experiment Project Tennessee STAR (Student Teacher Achievement Ratio) substantiated that students in small classes (13 – 17 students) in grades K-3, outperformed students in the same grades in regular classes (22-25 students). Fewer discipline problems were evident as well. There was no special teacher training offered and classes were monitored carefully with regard to randomization to ensure consistency within the study (Word, Johnston, Bain, Fulton, Zaharias, Lintz,, Achilles, Folger, and Breda, 1990).

Other research on class size has provided stable, corroborating empirical evidence that demonstrates that classes with under 20 pupils had more positive learning outcomes such as better learning attitudes, varied instructional practices, higher teacher morale and satisfaction and last but not least, higher achievement scores (Bourke, 1986). Review of the research by Garbarino (1980) has demonstrated consistent findings comparing large schools (over 1000 students) with small schools (400 – 500 students) that students in small schools have overall better educational records. Nye's (1995) findings suggested that "Small school size is more important to student achievement in mathematics and the S (small) class type is more important to student achievement in reading" (p. iv). There was more of a sense of community, responsibility, with less behavior offenses such as crime. Fewer episodes of misconduct were reported and large schools have been found to be deficient in character development and socialization, while smaller schools had more opportunities for extra-curricular activities and overall, students had a more positive self-image and personal satisfaction.

Moore (1992) proposed a sense of urgency for those in the educational community who are concerned with the conditions of the nation's school facilities to recommend actions to federal agencies, educational associations, mangers of facilities, and even architects and engineers to alleviate overcrowding problems, which can provide appropriate infrastructure to meet the demanding cubic feet needs of 21st century classrooms. "There is still a crying need for additional studies on the impact of the educational facility design on performance, and for excellent dissemination of the results into the educational, facility management, and architectural communities" (Moore, 1992, p. 2).

Study of IAQ and the number of students and adults per cubic feet may offer added explanations for the Project STAR experiment's findings that small class sizes make a difference in student performance and behavior and help explain the positive effects of small classes. Public school officials face a major problem when attempting to reduce class size: space. The obstacle of making more space within a pre-existing structure is a large feat to overcome. More space costs money. Achilles et al. (2005) suggested,

> If space is not an issue, small classes can be achieved at little or no added cost to the district by reallocation of resources and by careful planning to use the

> approximate 10 pupil difference between a school's pupil-teacher ratio and actual class size. (p.7)

Crowding in the available space may cause student misbehavior and may under certain conditions, change the IAQ of the rooms. Weinstein (1979) stated, "Nowhere else are large groups of individuals packed so closely together for so many hours, yet expected to perform at peak efficiency on different learning tasks and to interact harmoniously" (p. 585).

Carbon Dioxide (CO_2)

CO_2 is a colorless, odorless gas that is heavier than air. It is the by-product of human respiration and the burning of fossil fuels. At high concentrations, CO_2 displaces oxygen. Air that is 5% carbon dioxide snuffs candles and car engines. A 10% CO_2 level will cause humans to hyperventilate, grow dizzy, and eventually lapse into a coma. Levels of 30% CO_2 cause humans to gasp and drop dead (Krajick, 2003, pp. 50-51).

CO_2 is so lethal in concentrated doses, that in Ogawa, Japan, chickens are being slaughtered in boxes of CO_2 if the sign of the avian flu is detected ("In Boxes of CO_2", 2005). If livestock is being slaughtered via the use of concentrated levels of CO_2 in small boxes, imagine the repercussions of high doses of CO_2 on the health of America's students, who are forced to attend school in classrooms that have very few cubic feet and are packed with many other kids. To further implicate the potency of CO_2, Eaton – Rob (2005) reported capturing of pigeon-sized parakeets who live in communal nests that are killed with CO_2 by the U.S. Department of Agriculture when their 200 pound nests cause power outages.

Passengers and flight attendants on airplanes complained of headaches and other health ailments linked to the air being circulated on planes. The build-up of CO_2 on airplanes from passengers and poor ventilation was linked to apparent negative health repercussions (Vergano, 2003, pp. 1D-2D).

CO_2 is used in warehouses where plants are stored to slow the aging and maturation process so that plants and produce such as apples can be sold all year. CO_2 can be used in greenhouses to control when fruits and vegetables ripen and enhance productivity. In these cases, CO_2 must be carefully monitored and controlled. High levels of CO_2 can actually stunt plant growth. This is an interesting correlation to high levels of CO_2 negatively stunting learning. Besides CO_2, there are other serious health related issues in schools, in which identification and remediation are critical.

"As the human population increases, its demands on the earth also increase" (Bearer, 1995, p. 11). Bearer notes at present there is a much stronger demand for food, clean air and water, energy, waste disposal, and manufactured goods. With these demands comes an increasing amount of pollutants that are released into the air we breathe, having an adverse effect on humans' health. "Children, because of their unique physical, biological, and social characteristics, are among the most vulnerable members of our population" (Bearer, 1995, p. 11).

In 1970, Auchincloss (as cited in Meacham, 2007) wrote, "The human animal is the most adaptable of creatures, and the challenge of preserving his environment may well be his greatest test (p. 4). Now in the year 2007, humans are confronted with this test more than ever before. Outside environmental factors significantly affect IAQ. With an ever-rising economy comes the need for burning of more fossil fuel. Duval (as cited in Sierra Club, 2007) stated,

> Global warming is probably the biggest threat that has ever faced humanity. That is what is most scary about it – and also what is most exciting. A problem of this scale presents an opportunity for grand solutions: more just and sustainable ways of life that will not only stabilize the climate but also reinvigorate the community, restore environmental and human health, and give us a secure world far more hopeful and fulfilling that the one we live in today. (p. 40)

Carbon emissions are on an upward trend, posing a dangerous influence on global warming. If the outside air is becoming increasingly unhealthy, imagine the ramifications on IAQ in classrooms with poor ventilation. Begley (2007) reported, "Before the Industrial Revolution, the atmosphere held 280 ppm of CO_2. We are now at 380 ppm and climbing" (p. 65). He also noted that molecules of CO_2 linger in the atmosphere for up to 200 years and sometime this century, levels can reach anywhere from 450 - 750 ppm (p. 65). Climatologists have a responsibility to serve as caretakers of the environment and school administrators have a responsibility to serve as stewards of students' safety and well-being. These two responsibilities are symbiotic in nature and the former greatly influences the latter. Begley (2007) reports that Hurricane Katrina happened when CO_2 levels were at 380 ppm. Arctic sea ice is vanishing at 380 ppm (p. 65). "Children are less able than adults to protect themselves, may be more vulnerable to particular toxins, and are not considered responsible for pollution. Children should not be treated as little adults in developing environmental policy" (Bearer, 1995, p.12).

Lewit and Baker (1995) argued that children are being inadequately protected from environmental hazards because of a lack of national research or policy agenda existing to address youngsters' unique vulnerabilities. If there are still no CO_2 standards set in place for schools, how are we protecting our children?

Asthma

"Breathing zones, the places in space where individuals breathe, are closely related to development" (Bearer, 1995, p. 15). Although adults' breathing zone is four to six feet above the floor, children's breathing zones are closer to the floor, where heavier chemicals such as mercury and radon accumulate, as well as heavier gases, such as CO_2 when compared to oxygen. Bearer (1995) argued that children's risk of exposure to an air pollutant may be greater than adults' risk. Children's organs are growing and maturing, and this process can be adversely affected by exposure to harmful chemicals in the environment. The air of the physical environment in which children spend most of their day may contain triggers that may worsen or cause the onset of asthma. Exposure to any environmental agent may be the first step in a sequence of related health effects and different patterns of exposure to a toxin may yield different adverse health effects (Bearer, 1995, p. 13).

Air Quality Sciences (AQS) (2006) reports that asthma, if not managed adequately, can become life-threatening and is the leading cause of absenteeism at a estimated poll of 14 million lost school days for children under the age of 15 (as cited in Aspen Publishers, 2006). "Indoor allergens such as cat and rodent dander, cockroaches, dust mites and fungi/mold have all be implicated in exacerbating asthma symptoms among sensitized individuals and exposure to dust mites also may cause development of asthma among susceptible children" (Tortolero, Bartholomew, Tyrrell, Abramson, Sockrider, Markham, Whitehead, & Parcel, 2002, p. 33). The Institute of Medicine (2000) suggested exposure to other agents such as fungi and cockroaches may also increase the risk of asthma, but evidence is not yet conclusive (as cited in Tortolero et al, 2002). The research of Tortolero et al., (2002) suggests that the presence of high levels of CO_2 could also exacerbate asthma symptoms, be an indicator for more toxins and decrease school performance.

In the State of New Jersey, legislation N.J.S.A 18A40 -12.9 mandates annual asthma education opportunities for the teaching staff and school physician (as cited in Pediatric/Adult Asthma Coalition of New Jersey, 2007). N.J.S.A. 18A:40 – 12.3 mandates that students are allowed to self-administer an inhaler or epipen if approved to do so (as cited in Pediatric/Adult Asthma Coalition of New Jersey, 2007). N.J.S.A. 18A: 40 – 12.7 mandates that public schools maintain a nebulizer in case of an emergency (as cited in Pediatric/Adult Asthma Coalition of New Jersey, 2007).

At the federal level, there is currently legislation under the Americans with Disabilities Act (ADA), which enforces protection for children with asthma.

> This law is written to provide all individuals access to federally funded facilities and programs including public schools. Any child with an "impairment that substantially limits one or more major life activities" is included under this law. For a child, attending school can be regarded as a "major life activity." Asthma may interfere with a child's ability to participate fully in school. Therefore, an environment must be provided where triggers are

> eliminated/minimized and medications are allowed. (as cited in American Lung Association of Colorado, 2003).

Although not a variable for the present study, asthma is identified as a respiratory disorder characterized by wheezing; usually of allergic origin (Webster's Online Dictionary, 2006)). According to the Centers for Disease Control and Prevention (2002), asthma affects nearly five million children under the age of 18 each year, and many of these are in schools. The estimated cost spent in treating asthma is $3.2 billion per year. Cases of childhood asthma have nearly reached epidemic proportions and there is an urgent need to evaluate environmental asthma triggers such as toxins, mold, and overall air quality in the places where children spend most of their day: schools. Students who suffer from asthma miss school more often and nighttime awakenings may affect performance and behavior as well (Taras, 2002). Missing school negatively affects student performance on standardized tests when students are not present for test preparation and learning of the curriculum to be tested. Time on task has been well studied and attendance is linked to student achievement.

Educators can assist in reducing asthma triggers in schools by removing carpeting, keeping classrooms dusted to minimize dust mites and by teaching children in health classes how to recognize their bodies' onset of symptoms in order to act quickly to prevent occurrences. These interventions may reduce episodes and keep children in school more days. At present, there has been no direct link between asthma and IAQ in schools; however the link has not been scientifically ruled out. Yet, progress in reducing asthma triggers in schools may assist educators in meeting AYP because children may attend school more regularly.

There is evidence from the Environmental Protection Agency (as cited in Smolkin, 2003) (EPA) that schools contain high levels of allergens that trigger asthmatic episodes. There is future evidence needed because scientists have not resolved whether it is the allergens in schools that are actually causing the development of asthma, or if the allergens are simply on-setting preexisting symptoms. Continued research and investigation is needed in this area due to the epidemic proportions of asthma cases in children. Scientific studies have not yet established a clear connection between asthma and impaired school performance, although it is apparent that asthma sufferers miss school more often than do their peers (Smolkin, 2003).

The Centers for Disease Control and Prevention's Division on Adolescent and School Health is financing initiatives to establish whether improving poor air quality in schools will limit asthmatic episodes in sufferers. Richardson, Eick, and Jones (2005) reported,

> There is not enough evidence to prove that reducing exposure to indoor allergens and pollutants will reduce respiratory illnesses, apart from reducing exposures to dust mite allergens. There are only encouraging routes and suggestions about how to mitigate the detrimental effects from indoor allergens, especially to sensitized individuals. (p. 336)

Mold

Besides CO_2 and asthma triggers such as dander, dust mites, pests and allergens, additional environmental hazards to which students may be exposed are molds, fungi and mildew. Excessive moisture can contribute to the progression of mold and mildew which can cause IAQ problems. Areas that have high humidity levels are more at risk for growing these harmful bacteria. Poor ventilation is again the culprit for fostering unsafe breathing environments. Proper ventilation through HVAC systems can assist in eliminating or at least improving IAQ. According to the United States EPA (1998), allergic reactions are the most common health problems associated to biological pollutants. The present study measured, but did not analyze RH and T that might relate to molds and fungi.

Because children have a faster respiratory rate than adults do, they tend to be more sensitive to irritating contaminants such as mold. They may be at an increased risk of developing impairment of lung function resulting to exposure to indoor air pollutants (Petronella, Thomas, Stone, Goldblum & Brooks, 2005). There is a deficit of empirical evidence correlating mold to students' specific health issues and this deficit reduces the momentum for governments and local school administration to endorse remediation of toxic mold (Burr, 2001).

To address the issue of poor IAQ in schools, additional research is necessary to inform the public of how the home affects students' health as well. Symptoms of health problems may not begin by a student's being in school and researchers need to be aware of this possibility. The trouble may not only lie in the schools. Areas with high humidity in the home are the kitchen, bathrooms, laundry room and the basement. Mold spores are then dispersed into the air that can trigger problematic health symptoms such as watery eyes, runny noses, sneezing, wheezing and difficulty breathing, nasal congestion, dizziness, fatigue and headaches (US EPA, 1998).

Homes that are being remodeled strike an area of concern for occupants' health. New furniture and carpeting contain harmful preservatives that may induce health ailments. Cabinets, plywood and adhesives all contain formaldehyde, which has been shown to cause cancer in laboratory animals, but has provided limited evidence to cause cancer in humans (US EPA, 1998). Poor housing conditions as well as poverty are closely connected with respiratory illnesses for those children who dwell in such conditions (Krieger, Song, Takaro, & Stout, 2000). “The modern home is “sealed up” and highly thermally insulated to improve energy efficiency, often to the detriment of indoor air quality” (Richardson et al., 2005, p. 329).

Constructing and insulating homes and buildings more tightly than in the past results in reduction in the quantity of fresh air taken into the structure, in turn, retaining less desirable substances such as radon, formaldehyde, mold, and volatile organic compounds (Petronella et al., 2005). However, it is wrong to examine the home in isolation with regard to IAQ problems posing a risk to health, because poor IAQ variables are relative to occupational settings as well, such as school environments and public facilities (Smedje & Norback, 2001).

Sick Building Syndrome (SBS)

Learning in a healthy environment is every child’s right, not a privilege. Unfortunately, not every child has the privilege of attending a “healthy school” due to poor socio-economic status and limited resources. According to the American Association of School Administrators (AASA) (2007), “Urban schools enroll 24 percent of all public school students, 35 percent of all poor students, and 43 percent of all minority students in the nation.” Inner-city schools have higher levels of pollution, more children exposed to second-hand smoke, pest infestations, and high levels of pollution.

All of these variables negatively affect the health of children attending these schools. AASA (2007) declared,

> Maintaining a healthy environment is an essential part of preparing schools for children. A district may have access to quality teachers, beneficial educational programs and state-of-the-art technologies, but if the environment is not properly maintained, this results in an unhealthy learning setting. These resources are of no use to children if they are missing school due to asthma or other respiratory ailment and cannot focus due to poor environmental factors. Smells, headaches, fatigue and allergic reactions are all serious distractions for students in a classroom. (p. 1)

"There is a crisis in American education today, and in American school buildings" (Moore, 1992, p. 1). Much attention has been brought to idea that some environments are "sick", causing employees health ailments and unexplained illnesses that they had not had prior to working at a specific place. Sick Building Syndrome (SBS) is described as a "building whose occupants experience acute health and/or comfort effects that appear to be linked to time spent therein, but where no specific illness or cause can be identified. Complaints may be localized in a particular room or zone, or may spread throughout the building" (Webster's Online Dictionary, 2006).

According to the United States EPA, is has been estimated that 50% of schools in the United States have some kind of IAQ problem (as cited in Aspen Publishers, 2006). Twenty percent of the U.S. population (55 million people) spends a good part of their day in schools and those schools with poor IAQ are putting 27.5 million people (or 10%), at risk for health problems, including six million children in the U.S. who have asthma.

Identifying whether schools are "sick" allows for government and school officials to be proactive in preventing additional illness and health related complications so that students can attend school more by being healthier. Recommendations for improving environmental conditions in sick buildings include routine cleaning of HVAC systems, improving air quality through increased ventilation and education of building management for administrators of schools. Schools are sometimes built on undesirable land near highways with increased automobile emissions and lead, relatively close to power lines with exposure to electromagnetic fields, or on or near former industrial sites, resulting in exposure to arsenic and/or benzene (Bearer, 1995, p. 15).

The nation's schools are aged, frail and failing (Moore, 1992). More than half of the nation's schools were built in the 1960's with a projected life of 35 years (Goldberg & Bee, 1991). It is estimated that by improving facilities the results could range from a 5.5 to 11% increase on standardized tests (Edwards, 1991). Bein (as cited in Ohanian, 2003) stated, "When you've got kids in Kansas City attending class in a former boys' restroom, something is desperately wrong" (p. 742). Nationwide, schools are in desperate need of repairs of roofs, exterior walls, plumbing, windows and lighting (Ohanian, 2003). Children do not have enough textbooks or they are outdated, many classrooms are vermin-infested, overcrowded, and are either sweltering or freezing (Asimov & Williams, 2001).

In addition, the Carnegie Foundation (1988) reported student attitudes about education were a direct reflection of the environment in which they learn. Older schools with deteriorating infrastructures may be doing even more harm than just harboring poor IAQ (as cited in Moore, 1992). Lundt (2004) projected that the U.S. public education system will face an uphill battle for survival and $322 billion will be needed to repair failing facilities, build new facilities, or outfit existing facilities with modern technology (p. 4).

One ailment, which greatly contributes to SBS, is lead, an extremely dangerous and harmful toxin to students' health. It can have deadly effects if exposure is constant over time. Children are most vulnerable to lead's harmful effects. Exposure to lead causes anemia, developmental delays, behavior problems, central nervous damage, and high blood pressure (Hiles & Guevara, 2006). Since children are required to attend school on a regular basis, exposure to deadly toxins such as lead, is even more unfair, unjust and devastating to our children. Parents need to be advocates for their children if they attend an old school facility by demanding that the facility be tested for lead so parents can be aware of the risk posed to children.

Moore and Lackney (1992) posited that there is incontrovertible evidence that learning achievement is influenced by factors such as classroom size, school size, location, and provisions of secluded study areas. These variables, coupled with poor IAQ, may significantly affect student test performance. Weinstein (1979) suggested there has been considerable evidence for decades that classroom environment can influence non-achievement attitudes and behaviors such as decreased social interactions and increased aggressions.

Past empirical studies have shown significant increases in blood pressures of students and teachers if schools were located near noisy urban streets (Moore & Lackney, 1992). Increased blood pressure may result in a series of health related issues. This coupled with poor IAQ would contribute to overall SBS. Indoor air pollutants can escalate five to 1,000 times higher than outdoor air pollutants and can pose serious health risks, affect student learning, and stunt productivity of educators (as cited in "Stink Over IAQ", 1997).

Parents serve as key advocates for ridding the country of "sick schools." "With powerful pull with school boards, parents can have a huge impact on making sure schools are safe" (Gibbs, 2002 as cited in Thomas). Parents, educators and school officials need to be cognizant if the schools their children attend are safe. Their voices can be heard when attempting to implement laws to protect children with regard to indoor air quality in schools. "Parents just are not aware that no laws govern school environments and they believe all schools are safe" (Gibbs as cited in Thomas, 2002, p. D4). Lewit and Baker (1995) stated:

> Much more can be done to protect children from environmental health hazards, and there is reason to be concerned that pending legislation, designed to relax environmental safeguards enacted over the past decade, threatens progress in protecting children, and all age groups from these hazards. (p. 8)

Although safeguards have been put into place by increased legislation and airborne levels of lead have decreased a remarkable 96% since 1975 (Lewit & Baker, 1995), more needs to be done, especially in our schools where children spend most of their day. To prevent any refute to the issue that the conditions of America's schools are not as disadvantaged as they seem and that students are not suffering the health repercussions of SBS, health officials must be audible by voicing the concerns of what they suspect is the demise of their patients' conditions, if they suspect health issues are related to the poor conditions of the schools which their patients attend. "Critics do maintain that the symptoms of poor IAQ are psychosomatic, a position sometimes reinforced by a lack of consensus in the medical profession on the breadth of the health problems caused by poor IAQ" (NEA, 1997, p. 17). Other critics doubt the credibility of studies that attempt to determine if indoor air pollutants such as radon, are actually health threats.

Theoretical Framework / Conceptual Base for IAQ Study

The theoretic framework / conceptual base for this study is derived from the hypothesis that more cubic feet in classrooms are more optimal as testing environments for students because rooms with more cubic feet have lower levels of CO_2 and of other toxic conditions. After extensive review of the literature, empirical evidence suggests, students perform and behave better in classrooms with better IAQ. In addition to these findings, students' health is not as jeopardized as in rooms with poor IAQ because exposure to air pollutants may be minimal.

Research (Achilles et al., 2004; Prout, 2000) has shown that as the school day progresses, increasing levels of CO_2 make students lethargic and unable to concentrate, in turn negatively influencing student performance. The number of students [ft^3per student], cubic feet of the room, and the time of day are all key variables that can be manipulated to improve IAQ. It is expected that students in both the experimental and control groups will have an increase in their test scores due to the nature of pretest/posttest design of the study. In addition, instruction will between pre and post testing times during the school year. It was hypothesized that students in the experimental groups would perform better on a high-stakes test as a result of post testing in a room with more cubic feet and having been exposed to better IAQ conditions. Figure 1 shows the diagram for the conceptual base for the IAQ study.

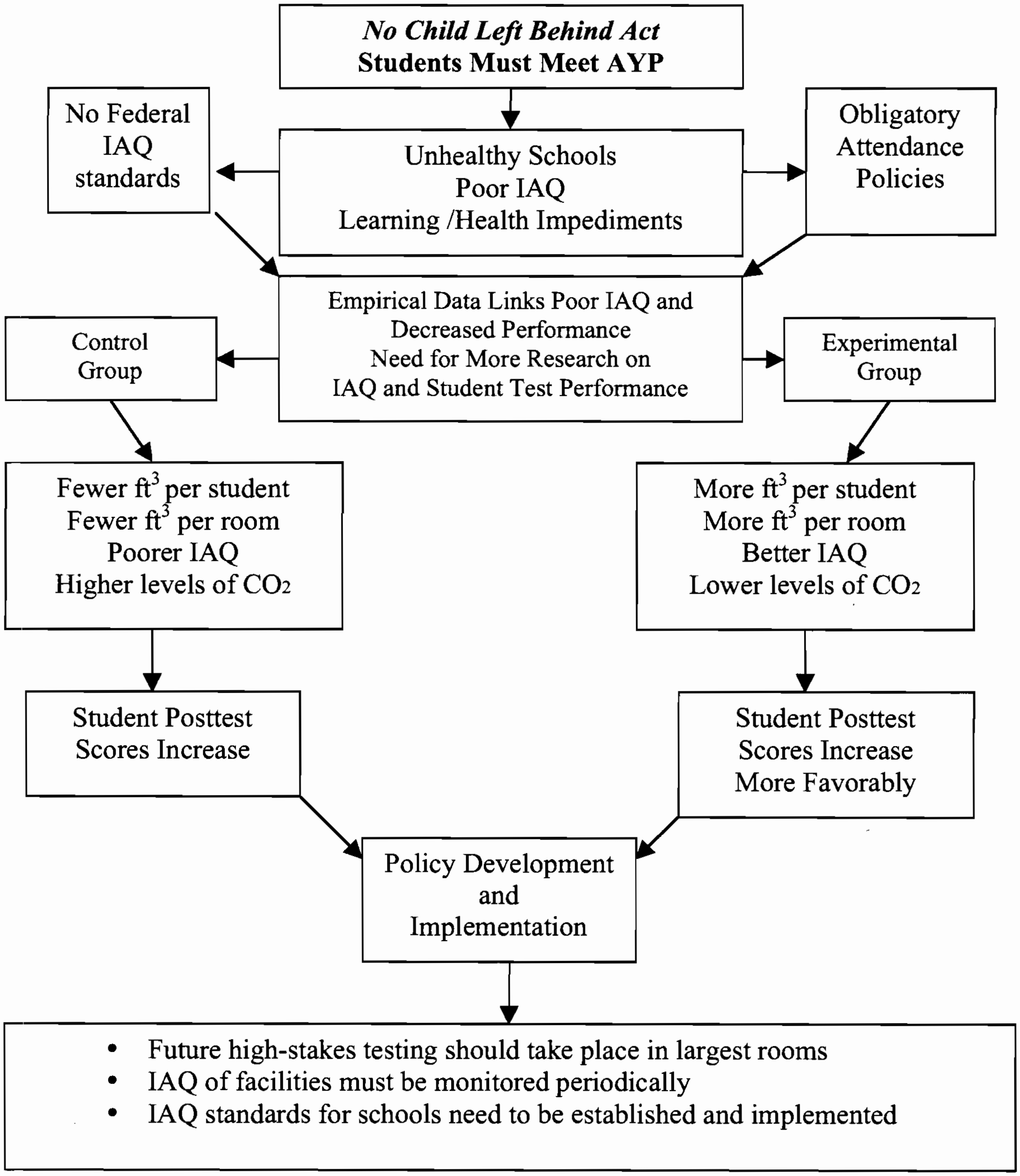

Figure 1. Theoretical framework / conceptual base for indoor air quality (IAQ) study.

Chapter III

DESIGN AND METHODOLOGY

The *No Child Left Behind Act* (PL 107-110, 2001) establishes norms that students must meet AYP and attend school regularly, but presently, there are no IAQ standards in effect for public schools. School environments, over which students have no control, must not hinder or deter students in meeting these goals, yet the air that students breathe may be impeding their learning and possible causing harm to their health.

Design

The purpose of the proposed work was to collect and analyze data to determine how CO_2 levels influence high-stakes test performance among four groups of elementary school students. The research of Prout (2000) suggested that poor IAQ adversely influences student performance both academically and behaviorally. The purpose of this study was to narrow the scope to the influence of CO_2 on children's standardized test scores, using control and experimental groups.

The key research questions that guided this study were stimulated by relevant past empirical evidence. Do the data support the notion that increased levels of CO_2 negatively influence student test performance? Does administering high-stakes testing in rooms with more ft^3 produce more favorable student outcomes? Replication of this study on a much larger scale may add support to the anticipated claim.

Based on Prout's (2000) and other relevant research, the researcher hypothesized that CO_2 levels in classrooms vary based on cubic feet per classroom, thus the IAQ becomes better or worse and the variable of IAQ influences student test performance. Levels of CO_2 are lowest first thing in the morning and increase throughout the day in classrooms with fewer cubic feet. Further, based on Prout's and related works, the research suggests that the increasing CO_2 levels during the school day negatively influence student behavior and performance as the day progresses. Levels of CO_2 vary in schools as a function of such factors as age of the facility, time of the year, number of students in the school, and in each class. In this study, the researcher extended the work of Prout to focus on student test performance with relation to CO_2 levels in two different testing sites. Therefore, this work attempted to contribute findings that suggest the most optimal setting in which high-stakes testing should occur.

Methods

The researcher proposed to include two third grades and two fifth grades under controlled conditions, which strictly monitor CO_2 levels in their classrooms during two separate high-stakes testing events. The CO_2 levels for the two experimental groups (one third grade [3-X, one fifth grade [5 – X]), vis-à-vis the control groups (one third grade [3 – O], one fifth grade [5 – O]), by increasing the cubic footage for the classroom in which the experimental groups will posttest. The control groups were both given the pre and posttests in a classroom with fewer cubic feet.

The posttest occurred 7 months after the pretest. It was anticipated that the time lapse, with attendant changes in learning, would be positive for both experimental and control groups. Other variables that may have influenced student test performance were equated by the use of control groups and analyses of only the general education students' scores. The rationale for using pre and posttest design was to control for the myriad of variables that affect student achievement such as, differences in teacher efficacy, student achievement/learning differences, and SES of students.

"Replication is important in all sciences. It is the way that scientists verify the findings of research" (Frymier, Barber, Gansneder, & Robertson, 1989, p. 229). Thus, the researcher planned in some measure to replicate Prout's (2000) study. The purpose of the proposed work was to be more definitive than was Prout as to how CO_2 levels might influence high-stakes test performance among four groups of elementary schools students. Two of the four groups were exposed to higher volumes of air (70,000 ft^3 vs. 11,750 $ft^{3)}$ and, theoretically, lower CO_2 during the post testing phase.

To ensure that conditions were as constant as possible, teachers were instructed to leave windows and doors closed during the testing session, with exception of normal entry and exiting the testing rooms via the hallway. Testing occurred in the early October and May so that HVAC systems were not in heavy use.

IAQ-CALC / TSI 8762 readings were taken at a range of 44 - 47 inches from the floor, which indicates the average head height of participants randomly selected by classes to be included in the study. Measurements of CO_2 levels were collected at the beginning and end of each testing session. The independent variables were cubic feet of each room and cubic feet per student. The main objective of this study was to suggest optimal settings with regard to cubic feet of rooms for standardized testing. Readings of RH, T, and CO were taken and recorded for all pre and posttests, but were not analyzed in this study and were included.

Data were analyzed using independent and dependent samples *t* tests. As a secondary analysis due to the small sample size, an Analysis of Covariance (ANCOVA) was used to determine if it would provide additional information in answering research questions. The ANCOVA did not provide additional answers to the research questions. ANCOVA results have been included in Appendix C.

Research Design

The design of this research was a pretest/posttest experimental intact group design (Campbell & Stanley, 1963). Data were collected from IAQ-CALC / TSI 8762 outputs to determine the CO_2 levels of the room at the beginning and end of each testing session. Both quantitative and qualitative means were used to collect data. The Mean RIT pretest and posttest scores on NWEA's MAP, along with the IAQ measurements served as quantitative measures. Qualitative measures in this study encompassed the researcher's observation of the testing sessions.

Sampling

A suburban school building was used in the study based on the researcher's accessibility to the school's testing schedule in order to collect data. For identification purposes, classes used in this study were assigned as (a) 3 – O = 3rd grade control group, (b) 3 – X = 3rd grade experimental group, (c) 5 – O = 5th grade control group, and (d) 5 – X = 5th grade experimental group. Then, students within each of the four groups were identified as numerals (1, 2, 3, 4, 5, 6 etc.). Each of the four groups who participated in the study contained 20 to 22 students: totaling 86 student participants. Data were disaggregated to allow for analyses based on cubic feet in both testing sites, and by students' pretest and posttest scores in both the experimental and control groups. All participants' identity remained protected and anonymous throughout data collection, analyses, and reporting.

Because of a very small sample size used in this study (total of four classes, N = 86), effect sizes have been calculated for posttest mean scores for the control and experimental groups. Salkind (2004) explained an effect size as "a measure of the magnitude of a particular outcome" (p. 384). The effect size is the degree to which a phenomenon exists (Cohen, 1977, p. 9) and can be expressed as the standardized difference between two means (Hinkle, Wiersma & Jurs., 2003, p. 309). Effect size was calculated in an equation as:

$$\frac{\left(\text{Mean of X} - \text{Mean of O}\right)}{\text{SD of O}} \tag{1}$$

Instrumentation

The scientific instrument that was used to collect data in this study was the IAQ-CALC / TSI 8762, a calibrated device that measured levels of IAQ readings (CO_2, CO, RH, and T) at the beginning and end of each testing session. The second form of instrumentation that was utilized was NWEA's MAP assessment. Whole class raw and standard mean Rausch Unit (RIT) scores from both the pre and posttests were analyzed and explained in the Results section.

Validity

Threats to the internal validity of the study could have skewed the results. The use of a true control group and experimental design, in all likelihood, reduced or ruled out the contamination of other variables that may influence student test performance. The use of a single school site for both experimental and control groups controlled for school-level variables, such as principal leadership, scheduling, curriculum, and so forth.

Empirical findings in this study add validity to Prout's (2000) prior evidence that classrooms with fewer cubic feet have higher levels of CO_2, in turn, reducing student performance. According to Prout (2000), students and teachers in those disadvantaged rooms became lethargic and unmotivated as the school day progressed as determined by direct observations conducted in the classrooms.

All attempts by the researcher were made to ensure testing conditions remained constant throughout the experiment. Actions such as opening the windows in the testing sites were eliminated by the researcher, with the intent to gauge levels of IAQ accurately in the classrooms where students were performing on a high-stakes test.

The researcher assumed that the IAQ-CALC / TSI 8762 provided valid, reliable data due to recent calibration and provided accurate readings of CO_2 levels of the two classrooms used for testing. NWEA's MAP norm-referenced assessment was administered. Validity of a norm-referenced test is strongest when the test measures what it purports to measure. With regard to the validity of the testing measurement used in the study, NWEA (2007) reported,

> Content validity of NWEA tests is assured by carefully mapping existing content standards from a district or a state into a test blueprint. Test items are selected for a specific test based on their match to the content standards as well as on the difficulty level of the test being created. In addition, every effort is made within a goal area or strand to select items with a uniform distribution of difficulties. Most of the documented validity evidence for NWEA tests comes in the form of *concurrent validity*. This form of validity is expressed in the form of a Pearson correlation coefficient. Two tests are administered to the same students in close temporal proximity, roughly two to three weeks apart. Again, the greater this correspondence, the greater the correlation coefficient will be. A strong

relationship (strong concurrent validity) is indicated when the correlations are in the mid- .80's (Northwest Evaluation Association, 2005).

Reliability

The reliability and validity coefficients that accompany the standardized assessment used were assumed to be meaningful and accurate. Different types of norm-referenced tests are used to assess students for AYP under *NO CHILD LEFT BEHIND ACT (PL 107-110)* yearly throughout school districts and MAP is one version of a norm-referenced test. Reliability across forms is typically referred to as parallel forms reliability. NWEA (2007) reported the MAP assessment's reliability as,

> Reliability is essentially an index, or more precisely, a set of indices of a test's consistency. This consistency typically refers to performance of the test across time, across forms or across its items or parts. Reliability across time is often referred to as test-retest reliability or temporal stability. Two tests are considered to be equivalent in every way except that their items differ. That is, the two tests would have the same number and types of items in the same structure, with the same difficulty levels, measuring the same content within a domain. The question being answered with this type of reliability is, "To what extent do two equivalent forms of the test yield the same results?" Answers to this question are also stated in terms of a Pearson correlation coefficient (r). Test-retest reliability only dipped slightly below .80 twice, both at the grade two level. Most coefficients are in the mid-.80's to the low .90's (Northwest Evaluation Association, 2005).

Data Collection

Pretest and posttest mean RIT scores for each of the four classes of students were evaluated to determine the effects of CO_2 levels on the independent variable, student test performance. In addition, all of the readings of CO_2 levels from the IAQ-CALC / TSI 8762 machine were reported at the beginning and end of each testing session. Students tested at the same time of day each morning, but on different days. The researcher collected qualitative data by observing and reporting conditions of the testing sessions, by having focused on student behavior, weather conditions outside, and lighting in the room.

Data Analysis

Quantitative data (whole class mean RIT scores) were subjected to dependent and independent samples *t*-tests to determine whether the experimental variable of testing in a room with more cubic feet and lower levels of CO_2 favorably influenced student test performance. Data analyses also included two other domains (a) Descriptive data of IAQ in testing rooms, and (b) Qualitative data including researcher's observations of testing environment such as student behavior, lighting in the room, and outside weather conditions on testing days.

The opinion of an outside statistician on experimental design was requested to insure that the data were analyzed appropriately. By consulting an outside analyst, an opportunity for Independence, or a Degree of Separation between the conduct of the study, the collection of data, and the analyses was made certain.

Chapter III has provided a review of the research, theory and literature and included the theoretical framework/conceptual base for the study. Chapter IV contains analyses of the data and findings, descriptive data, inferential statistics, and qualitative patterns.

Chapter IV

ANALYSIS OF THE DATA / FINDINGS

The purpose of this study was to affirm and extend the consequent of Prout's (2000) findings, with a concentration on IAQ and its influence on student test performance on a high-stakes assessment. Four groups of students (two 3rd grade groups and two 5th grade groups) participated in the pretest/posttest design study. One 3rd grade group served as one control group (3 – O) and the other 3rd grade group served as one experimental group (3 – X). One 5th grade group served as one control group (5 – O) and the other 5th grade group served as one experimental group (5 – X). All four groups pre tested in a room with 11,750 ft^3. For the posttest, the two experimental groups, 3- X and 5 – X were moved to a room with 70,000 ft^3. IAQ levels were taken at the beginning and end of each of the testing sessions, and analyses focused mainly on levels of CO_2 as testing took place.

The purpose of the study was to determine if the IAQ in rooms with more ft^3 would be better by having lower levels of CO_2 and in turn, there would be more favorable student testing outcomes, obtained by students in the larger rooms. Students' pretest and posttest Rausch Unit (RIT) scores on NWEA's Measures of Academic Progress (MAP) test were analyzed using dependent and independent samples *t*-tests. Whole group mean RIT scores were included to represent growth from pre to posttest in 3rd grade language and 5th grade mathematics. According to the Northwest Evaluation Association (as cited in NWEA, 2005), a RIT score is a number that indicates a student's instructional level. Students get an overall RIT score at the end of a Measures of Academic Progress (MAP) assessment or Achievement Level Test (ALT). In addition, RIT scores are reported for each goal area of a test. RIT scores show how a student performed on the test on the particular day the student took it. Scores are reported with an associated confidence band, or standard error of measure. If the student were to immediately retake the test under the same conditions, the confidence bands shows the range in which the student would be likely to perform. The first time a student sees the test, they are offered an item at the student's "grade level." RIT ranges vary because the Standard Error of Measure (SEM) may vary from student to student. The SEM speaks to the consistency of a student's answers. If they are very consistent then the SEM is lower, and when students are randomly selecting answers our software detects this and the student ends up with a large SEM. The SEM is applied to either side of the RIT score to help define a "confidence band" or RIT range.

Descriptive Data

Participants in Group 3 - O were tested in language. Table 1 indicates that four special education students were included in the class. Of the 20 students, three general education students received free lunch. There was a wide range of scores from the lowest to highest pretest mean RIT score (161 -214, or a difference of 53), as well as a wide range of scores for the posttest mean RIT score (166-219, or a difference of 53). The pretest mean RIT for the whole control group (191.3) was significantly lower than the posttest mean RIT (199.1), exhibiting a positive difference in growth of 7.8 mean units. Of the four special education students, none received free lunch. The special education population within this group composed nearly one-fifth of the control group. Special education students were instructed all year with two teachers in the room, modifications to assessments and assignments were administered, study guides were given and some of the students were pulled out of the classroom and received small group resource room instruction. Although Table 1 reports mean RIT scores for special education students, only general education students' scores were used in the analysis for the purpose of controlling for the variable of student learning differences. Special education students' scores were included for reporting purposes only.

Table 2 reports only scores of the general education students included in Group 3 – O who were tested in language. Of the 16 general education students, three received free lunch. There was a wide range of scores from the lowest to highest pretest mean RIT score (173 – 200, or a difference of 27), and an even wider range of scores for the posttest mean RIT score (184 – 217, or a difference of 33). The pretest mean RIT for the general education students in the control group (194.2) was significantly lower than the posttest mean RIT (202.4), exhibiting a positive difference in growth of 8.2 mean units. The researcher analyzed only general education students' scores to control for special education student learning differences.

Table 1

Whole Class RIT Scores for Language Arts 3rd Grade Control Group from Pre to Post in Indoor Air Quality (IAQ) Study

Student	Gender	Pre	Post	Difference
1***	M	161	166	+5
2	M	173	184	+11
3	M	175	186	+11
4***	M	177	186	+9
5	M	184	195	+11
6	M	186	200	+14
7***	F	189	195	+6
8***	M	191	196	+5
9	F	193	206	+13
10	M	193	204	+11
11	M	194	200	+6
12*	F	194	195	+1
13	F	196	202	+6
14*	F	197	209	+12
15	M	198	208	+10
16	F	199	196	-3
17*	M	200	217	+17
18	F	205	207	+2
19	F	206	211	+5
20	M	214	219	+5

Note. (*) indicates a student receiving free lunch. (***) indicates a special education student. Testing site cubic feet held constant at 11,750 from pre to post.
Males (n=12) Females (n=8). Average Pretest RIT = 191.3.
Average Posttest RIT = 199.1. Difference of 7.8 from Pre to Post.

Table 2

General Education RIT Scores for Language Arts 3rd Grade Control Group from Pre to Post in Indoor Air Quality (IAQ) Study

Student	Gender	Pre	Post	Difference
2	M	173	184	+11
3	M	175	186	+11
5	M	184	195	+11
6	M	186	200	+14
9	F	193	206	+13
10	M	193	204	+11
11	M	194	200	+6
12*	F	194	195	+1
13	F	196	202	+6
14*	F	197	209	+12
15	M	198	208	+10
16	F	199	196	+3
17*	M	200	217	+17
18	F	205	207	+2
19	F	206	211	+5
20	M	214	219	+5

Note. (*) indicates a student receiving free lunch. Testing site cubic feet held constant at 11,750 from pre to post. Males (n=9) Females (n=7). Average Pretest RIT = 194.2. Average Posttest RIT = 202.4. Difference of 8.2.

Participants in Group 3 - X were tested in language. Table 3 indicates there were no special education students included in the experimental group. Of the 22 students, two received free lunch. There was a wide range of scores from the lowest to highest pretest mean RIT score (184 – 218, or a difference of 34), as well as a wide range of scores for the posttest mean RIT score (192 – 230, or a difference of 38). The pretest mean RIT for the whole experimental group (201.7) was moderately lower than the posttest mean RIT (206.9), exhibiting a positive difference in growth of 5.2 mean units.

Compared to Group 3 - O, Group 3 - X scored higher on both the pre and posttests, but had significantly higher mean RIT scores on the pretest (X = 201.7, O = 194.2), an overall difference of 7.5 mean units. Overall growth in mean RIT may be less for the experimental group than for the control group from pre to post (X = 5.2, O = 8.2) but there was less room for experimental-group growth due to higher pretest mean scores and adjustments made because of RIT process. This could be referred to as a ceiling effect.

Although there was significant growth from pre to posttest for both 3rd grade experimental and control groups, the overall mean posttest RIT for the general education students in the control group (202.4) is lower than the mean RIT for the experimental group (206.9), a mean difference of 4.5 RIT points.

Table 3

Whole Class RIT Scores for Language Arts 3rd Grade Experimental Group from Pre to Post in Indoor Air Quality (IAQ) Study

Student	Gender	Pre at 11,750 ft^3	Post 70,000 ft^3	Difference
1*	M	184	192	+8
2	M	190	213	+13
3	M	193	194	+1
4	M	194	186	-8
5	M	196	199	+3
6	F	196	204	+8
7	M	196	194	-2
8	F	201	205	+4
9	F	201	215	+14
10	F	202	211	+9
11	M	202	200	+2
12	F	203	207	+4
13*	M	203	217	+14
14	F	204	205	+1
15	F	205	211	+6
16	F	206	208	+2
17	M	206	198	-8
18	M	207	216	+9
19	M	207	199	-8
20	F	212	223	+11
21	M	212	224	+12
22	M	218	230	+12

Note. (*) indicates a student receiving free lunch. Males (n=13) Females (n=9). Average Pretest RIT = 201.7. Average Posttest RIT = 206.9. Difference of 5.2.

Participants in the Group 5 - X were tested in mathematics. Table 4 shows one special education student was in the control group. Of the 22 students, one general education student received free lunch. There was a wide range of scores on the pretest (201 – 232, or a difference of 31) as well as a wide range of scores for the posttest (207 – 243, or a difference of 36). The pretest mean RIT for the whole control group (216.5) was significantly lower than the posttest mean RIT (222.4), exhibiting a positive difference in growth of 5.9 mean RIT units.

The one special education student within this group composed only a mere fraction of the control group. However, this student had instruction all year with small-group instruction in mathematics, modifications to assessments and assignments were administered, study guides were provided and there was a teacher's assistant when the student received small-group resource-room instruction. Although Table 4 reports mean RIT scores including the special education students' scores, only general education students' scores were used in the analyses.

Table 5 displays only the scores of the general education students included in Group 5 - O. Of the 21 students, one received free lunch. There was a wide range of pretest scores (201 – 232, or a difference of 31), and an even wider range of posttest scores (207 – 243, or a difference of 36). The pretest mean RIT for the general education students in the control group (216.9) was moderately lower than the posttest mean RIT (223.0), exhibiting a positive difference in growth of 6.1 mean points. The researcher analyzed only general education students' scores to control for the variable of student learning differences.

Table 4

Whole Class RIT Scores for Mathematics 5th Grade Control Group from Pre to Post in Indoor Air Quality (IAQ) Study

Student	Gender	Pre	Post	Difference
1	F	201	207	+6
2	M	207	214	+7
3	M	209	214	+5
4***	M	210	202	-8
5	F	211	219	+8
6	F	211	227	+16
7	M	212	231	+19
8*	M	213	219	+6
9	M	214	217	+3
10	F	215	229	+14
11	F	216	225	+9
12	F	218	220	+2
13	M	218	218	+0
14	F	218	221	+3
15	M	219	219	+0
16	F	219	234	+15
17	M	220	225	+5
18	M	220	225	+5
19	M	225	229	+4
20	M	227	220	-7
21	F	229	226	-3
22	F	232	243	+11

Note. (*) indicates a student receiving free lunch. (***) indicates a special education student. Males (n=12). Females (n=10). Average Pretest RIT = 216.5. Average Posttest RIT = 222.4. Difference 5.9.

Table 5

General Education RIT Scores for Mathematics 5th Grade Control Group from Pre to Post in Indoor Air Quality (IAQ) Study

Student	Gender	Pre	Post	Difference
1	F	201	207	+6
2	M	207	214	+7
3	M	209	214	+5
5	F	211	219	+8
6	F	211	227	+16
7	M	212	231	+19
8*	M	213	219	+6
9	M	214	217	+3
10	F	215	229	+14
11	F	216	225	+9
12	F	218	220	+2
13	M	218	218	+0
14	F	218	221	+3
15	M	219	219	+0
16	F	219	234	+15
17	M	220	225	+5
18	M	220	225	+5
19	M	225	229	+4
20	M	227	220	-7
21	F	229	226	-3
22	F	232	243	+11

Note. (*) indicates a student receiving free lunch. Testing site cubic feet held constant at 11,750 from pre to post. Males (n=11) Females (n=10). Average Pretest RIT = 216.9. Average Posttest RIT = 223.0. Difference of 6.1.

Participants in Group 5 - X were tested in mathematics. Table 6 shows that eight special education students were included in the experimental group. Of the 22 students, none received free lunch. There was a wide range of scores on the pretest (188 – 225, or a difference of 37), as well as a wide range of scores for the posttest (194 – 229, or a difference of 35). The pretest mean RIT for the whole experimental group (214.3) was moderately lower than the posttest mean RIT (218.3), exhibiting a positive difference in growth of 4 mean points.

Of the eight special education students, none received free lunch; six were female, and two were male. The special education population within this group is substantial and composed nearly one-third of the experimental group. Special education students were instructed in mathematics all year with two teachers in the room, Individualized Education Program (IEP) modifications to assessments and assignments were administered, study guides were provided and some students were pulled out of the classroom and received small group resource room instruction. Although Table 6 shows mean RIT scores for special education students, only general education students' scores were used in the primary analysis to control for the variable of special education student learning differences.

Table 6

Whole Class RIT Scores for Mathematics 5th Grade Experimental Group from Pre to Post in Indoor Air Quality (IAQ) Study

Student	Gender	Pre at 11,750 ft^3	Post 70,000 ft^3	Difference
1*	F	188	194	+6
2*	F	197	196	-1
3*	F	202	212	+10
4*	F	203	208	+5
5*	F	204	202	-2
6*	M	207	203	-4
7*	F	208	212	+4
8*	M	210	202	-8
9	M	214	217	+3
10	F	215	229	+14
11	F	216	225	+9
12	F	218	220	+2
13	M	218	218	+0
14	F	218	221	+3
15	M	219	219	+0
16	F	219	234	+15
17	M	220	225	+5
18	M	220	225	+5
19	M	225	229	+4
20	M	227	220	-7
21	F	229	226	-3
22	F	232	243	+11

Note. (*) indicates a special education student. Males (n=9) Females (n=13). Average Pretest RIT = 214.3. Average Posttest RIT = 218.3. Difference of 4.

Table 7 shows only the scores of the general education students included in Group 5 - X. Of the 14 general education students, none received free lunch. There was a wide range of scores for the pretest (214 – 232, or a difference of 18), as well as a wide range of scores for the posttest (217 – 243, of a difference of 26). The pretest mean RIT for the experimental group (220.7) was moderately lower than the posttest mean RIT (225.1), exhibiting a positive difference in growth of 4.4 mean units.

Compared to the general education students in the control group, the general education students in the experimental group scored higher on both the pre and posttests, but had begun with significantly higher mean RIT scores on the pretest (X = 220.7, O = 216.9), an overall difference of 3.8 mean points. Overall growth in mean RIT is less for the experimental group from pre to post (X = 4.4, O = 6.1) than for the control group, but there was less room for growth in the experimental group due to higher pretest mean scores. This could be referred to as a ceiling effect, and/or related to the RIT scoring format.

Although there was positive growth from pre to posttest for both 5th grade experimental and control groups in mathematics, the overall mean posttest RIT for the general education students in the control group (223.0) is lower than the mean RIT for the experimental group (225.1), a mean difference of 2.1 RIT points.

Table 7

General Education RIT Scores for Mathematics 5th Grade Experimental Group from Pre to Post in Indoor Air Quality (IAQ) Study

Student	Gender	Pre at 11,750 ft^3	Post 70,000 ft^3	Difference
9	M	214	217	+3
10	F	215	229	+14
11	F	216	225	+9
12	F	218	220	+2
13	M	218	218	+0
14	F	218	221	+3
15	M	219	219	+0
16	F	219	234	+15
17	M	220	225	+5
18	M	220	225	+5
19	M	225	229	+4
20	M	227	220	-7
21	F	229	226	-3
22	F	232	243	+11

Note. (*) indicates a student receiving free lunch. Males (n=7) Females (n=7). Average Pretest RIT = 220.7. Average Posttest RIT = 225.1. Difference of 4.4.

Table 8 shows IAQ readings for the beginning and end of each pre and post testing session. Table 8 displays CO_2 levels and cubic feet of each testing site in addition to the number of students and adults in the room. The CO_2 levels in the pretest room consistently escalated as testing time progressed (the highest level recorded was 1338 ppm) and some have reported that desirable, even maximum levels of CO_2 in a classroom are 800 ppm (Pike-Paris, 2005). For the 3rd grade control group (3-O), the pretest took place in a room of 11,750 ft^3 and CO_2 levels gained 270 ppm by the end of the pretest (1018 – 1288 ppm). For the 3rd grade experimental group (3-X), the pretest took place in the same room as the control group and CO_2 levels gained 262 ppm by the end of the test (1076 – 1338 ppm). The 8 ppm difference of CO_2 between pre and post testing was minimal.

The 5th grade control group (5-O) also took the pretest in the room with 11,750 ft^3 and CO_2 levels gained 194 ppm as the test progressed (860 – 1054 ppm). There was an increase of 109 ppm of CO_2 during the 5th grade experimental (5-X) pretest (1032 – 1141 ppm). Of all four groups, 3 - O had the most gain in ppm of CO_2 and had the fewest number of students in the room. The group that had the lowest gain in CO_2 was 5 – X (109 ppm). This group had one more adult than all the other groups in addition to 22 students, and had 11,750 ft^3.

When analyzing the levels of CO_2 during the posttest, note that the room for groups 3-X and 5-X had significantly lower levels of CO_2. This was a function of the size of the room in which these two groups took the posttest (70,000 ft^3). During the posttest for 3 – O, CO_2 levels increased 1135 ppm from the beginning to the end of the test (546 – 1681 ppm). CO_2 levels for 3 – X only increased 44 ppm (586 – 630 ppm) and posttest occurred in a room with 70,000 ft^3. The 5th grade control group (5-O) took the posttest in the room with 11,750 ft^3 and CO_2 levels gained 358 ppm as the test progressed (1355 - 1713 ppm). The CO_2 levels for 5 -O began at the highest reading of all the other starting CO_2 levels. Group 5 – X had the one of the lowest CO_2 readings for the groups' pretests and posttests, (565 – 506 ppm) and actually dropped 59 ppm as testing occurred. Group 5 – X post tested in the room with 70,000 ft^3 (see Table 8).

Table 8

Group Composition and CO_2 Levels in Parts per Million (ppm) in the Testing Facilities in Indoor Air Quality (IAQ) Study

			Pretest (11, 750 ft^3)			Posttest		
Group	Adults	Students	Begin CO_2 ppm	End CO_2 ppm	Gain	Begin CO_2 ppm	End CO_2 ppm	Gain
3 – O	3	20	1018	1288	270	546	1681	1135
3 – X	3	22	1076	1338	262	586	630	44
5 – O	3	22	860	1054	194	1355	1713	358
5 – X	4	22	1032	1141	109	565	506	-59

Note. Desirable CO_2 levels = < 800 ppm (Pike-Paris, 2005). Pretest room held constant at 11, 750 ft^3. Posttest room = 11, 750 ft^3 for 3 – O and 5 – O. Posttest room = 70,000 ft^3 for 3 – X and 5 – X.

Tables 9 and 10 display control and experimental IAQ conditions in ppm for each pretest and posttest session. Tables include other variables of IAQ such as relative humidity (RH), temperature (T) and carbon monoxide (CO). The PEL for CO is 50 ppm (OSHA, 2007), based on adults during an 8-hour period and does not indicate levels for children. The PEL for CO_2 is 5,000 ppm.

Table 9

Control Group IAQ Readings for RH, CO, and T from Pre to Post in Indoor Air Quality (IAQ) Study

			Pre			Post	
Grade	Reading	RH	CO ppm	T (°F)	RH	CO ppm	T (°F)
3 - O	Initial	30.7	0	74.5°	35.4	0	68.9°
	Final	27.2	0	75.3°	30.4	0	76.9°
5 - O	Initial	25.7	0	72.9°	29.6	0	73.2°
	Final	25.1	0	73.8°	40.7	0	77.0°

Table 10

Experimental Group IAQ Readings from Pre to Post RH, CO, and T from Pre to Post in Indoor Air Quality (IAQ) Study

			Pre			Post	
Grade	Reading	RH	CO ppm	T (°F)	RH	CO ppm	T (°F)
3 - X	Initial	44.0	0	71.6°	26.9	0	73.8°
	Final	38.8	0	73.9°	26.6	0	73.6°
5 - X	Initial	36.7	0	73.1°	31.9	0	74.3°
	Final	35.1	0	74.8°	42.5	0	73.8°

Table 11 summarizes CO_2 levels for each testing session in addition to group mean RIT scores. The CO_2 levels decreased in the room with 70,000 ft^3 as group 5 – X post tested. The data show there was a considerable difference in CO_2 levels between groups 3 – O and 3 – X (a difference of 1051 ppm) at the posttest. An even greater difference in CO_2 levels was displayed between groups 5 – O and 5 – X (a difference of 1207 ppm). The data show that the students in the larger room had better IAQ conditions in addition to higher mean RIT scores on the posttest.

Table 11

Summary Table of CO_2 Levels with Pre and Posttest MAP Scores for Indoor Air Quality (IAQ) Study

				Pretest			Posttest	
Group	Adults	Students	ft^3	Mean RIT	Highest CO_2 ppm	ft^3	Mean RIT	Highest CO_2 ppm
3 – O	3	20	11,750	194.2	1288 (+ 270)	11,750	202.4	1681 (+ 1135)
3 – X	3	22	11,750	201.7	1338 (+ 262)	70,000	206.9	630 (+ 44)
5 – O	3	22	11,750	216.9	1054 (+ 194)	11,750	223.0	1713 (+ 358)
5 – X	4	22	11,750	220.7	1141 (+ 109)	70,000	225.1	506 (- 59)

Note. Desirable CO_2 levels = < 800 ppm (Pike-Paris, 2005). Numbers in parentheses below CO_2 ppm show how much CO_2 level increased/decreased in ppm during testing.

Inferential Statistics

A dependent samples *t*-test was conducted for Group 3 – O based on scores from pre to posttest in language. At pretest, there were 20 students and 3 adults present, with CO_2 levels beginning at 1018 ppm and ending at 1288 ppm. At posttest, there were 20 students and 3 adults present, with CO_2 levels beginning at 546 ppm and ending at 1681 ppm. Room size was held constant from pre to post at 11,750 ft^3. Pre scores ($M = 194.2$, $SD = 10.72$) were lower than post scores ($M = 202.4$, $SD = 9.81$), $t(15) = -6.171$, $p < .001$. Scores improved significantly from pre to post, a condition that was expected.

A dependent samples *t*-test was conducted for Group 3 – X based on scores from pre to posttest in language. At pretest, there were 22 students and 3 adults present, with CO_2 levels beginning at 1076 ppm and ending at 1338 ppm, (an increase of 262 ppm). At posttest, there were 22 students and 3 adults present, with CO_2 levels beginning at 586 ppm and ending at 630 ppm, (an increase of 44 ppm). Pre testing took place in a room which measured 11,750 ft^3 and post testing took place in a room which contained 70,000 ft^3. Pre scores ($M = 201.7$, $SD = 7.79$) were lower than post scores ($M = 206.9$, $SD = 11.27$), $t(21) = -3.036$, $p = .006$. That is, there was a significant increase in test scores from pre to post. Figure 2 displays 3rd Grade Fluency scores from pre to post for both the experimental and control groups.

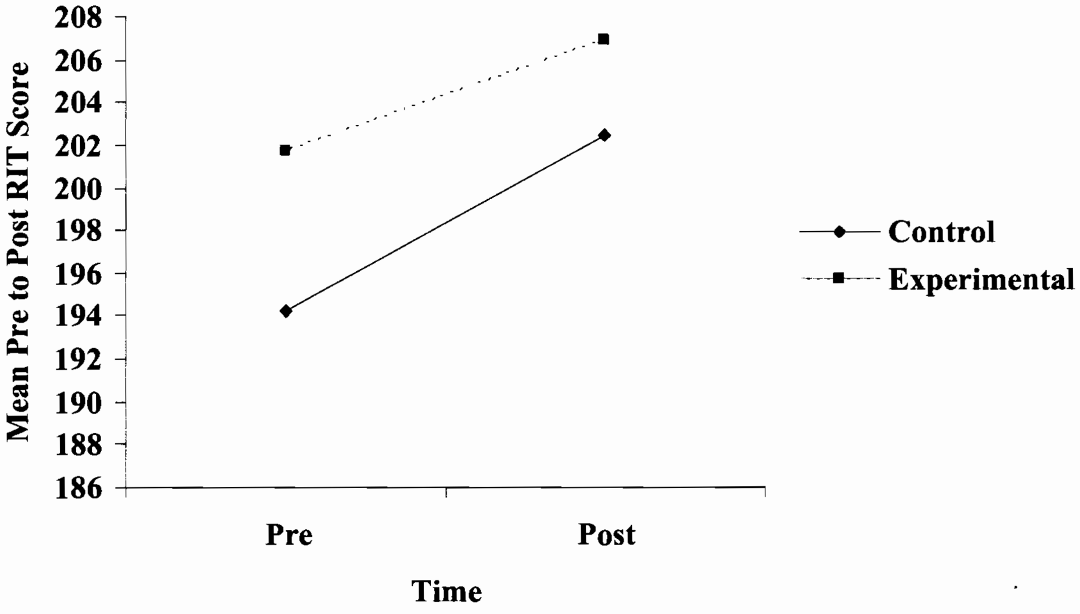

Figure 2. Graph comparing control and experimental 3rd grade *Measures of Academic Progress* (MAP) fluency scores from pre to posttest in indoor air quality (IAQ) study. *Note*. Differences in scores for each group from pretest to posttest (O = + 8.2, X = + 5.2).

An independent samples *t*-test was conducted on 3rd grade pre scores by Group (control vs. experimental). Experimental pre scores (*M* = 201.7, *SD* = 7.79) were significantly higher than control pre scores (*M* = 194.2, *SD* = 10.72), *t*(36) = 2.515 , *p* = .017 (Figure 3). The experimental group scored statistically significantly higher (p = < .05) than the control group initially. The effect size (ES) for the differences in pretest scores of control and experimental groups in the study was .69, a very strong ES between the two groups' pretest averages.

An independent samples *t*-test was conducted on 3rd grade posttest scores by Group (control vs. experimental). Experimental post scores (*M* = 206.9, *SD* = 11.27) were not significantly different from control post scores (*M* = 202.4, *SD* = 9.81), *t*(36) = 1.261, *p* = .216 (Figure 4). The ES for the differences between posttest scores of control and experimental groups in the study was .45, a moderately strong ES between the two groups' posttest averages.

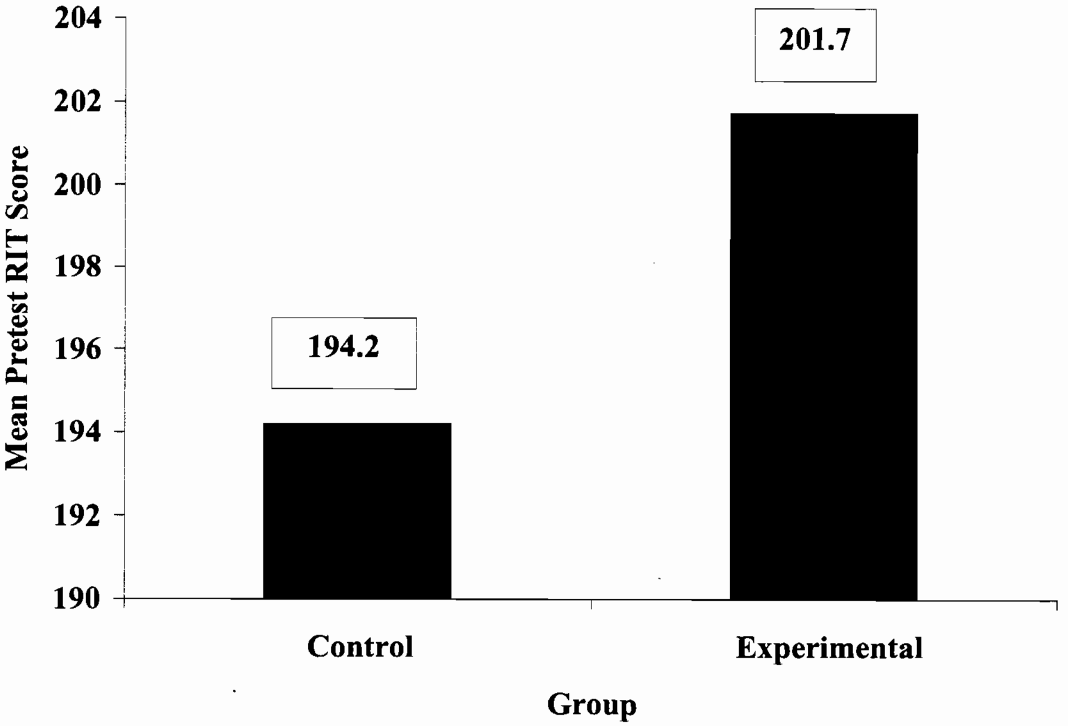

Figure 3. Graph comparing 3rd grade *Measures of Academic Progress* (MAP) pretest fluency scores in indoor air quality (IAQ) study.
Note. t(36) = 2.515 , $p = .017$, (sig. $p < .05$). ES = .69, very strong.

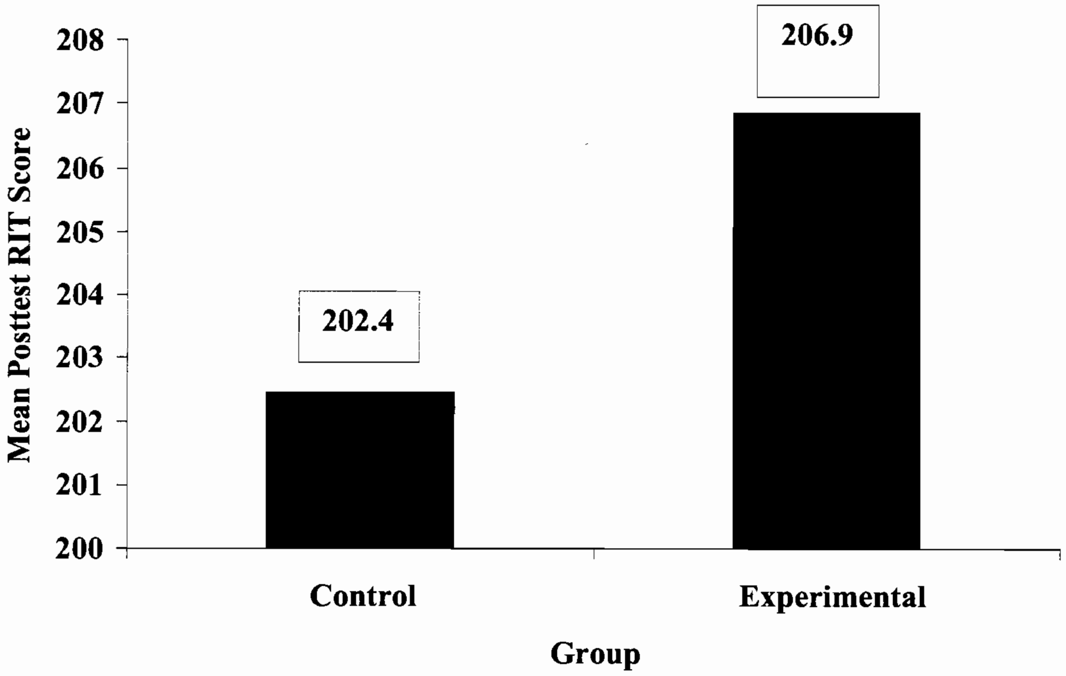

Figure 4. Graph comparing 3rd grade *Measures of Academic Progress* (MAP) posttest fluency scores in indoor air quality (IAQ) study.
Note. t(36) = 1.261 , p = .216, (ns). Effect size = .45, moderately strong.

A dependent samples *t*-test was conducted for Group 5 – O based on scores from pre to post in mathematics. At pretest, there were 22 students and 3 adults present, with CO_2 levels beginning at 860 ppm and ending at 1054 ppm (a gain of +194 ppm). At posttest, there were 22 students and 3 adults present, with CO_2 beginning at 1355 ppm and ending at 1681 ppm (a gain of + 326 ppm). Room size was held constant from pre to post at 11,750 cubic feet. Pre scores ($M = 216.9$, $SD = 7.44$) were statistically significantly lower than post scores ($M = 223.0$, $SD = 7.88$), $t\ (20) = -4.373$, $p < .001$, a condition that could be expected.

A dependent samples *t*-test was conducted for Group 5 – X based on scores from pre to post in mathematics. At pretest, there were 22 students and 4 adults present, with CO_2 levels beginning at 1032 ppm and ending at 1141 ppm (a gain of +109 ppm). At posttest, there were 22 students and 4 adults present, with CO_2 levels beginning at 565 ppm and ending at 506 ppm (a difference of -59 ppm). Note that pre testing took place in a room of 11,750 ft^3 and post testing took place in a room of 70,000 ft^3. Pre scores ($M = 220.7$, $SD = 5.43$) were significantly lower than post scores ($M = 225.1$, $SD = 7.09$), $t\ (13) = -2.620$, $p = .021$. Figure 5 displays 5th Grade Fluency scores from pre to post for both the experimental and control groups.

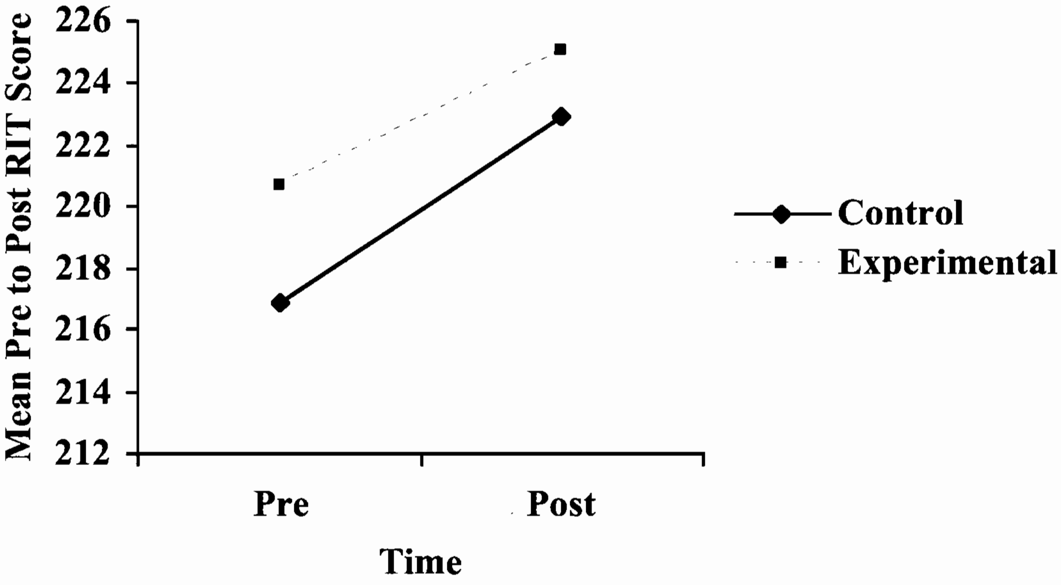

Figure 5. Graph comparing control and experimental 5th grade fluency scores from pre to posttest in indoor air quality (IAQ) study.
Note. Differences in scores for each group from pretest to posttest (O = + 6.1, X = + 4.4).

An independent samples *t*-test was conducted on 5th grade pre scores by Group (control vs. experimental). Experimental pre scores (*M* = 220.7, *SD* = 5.43) were not significantly different from control pre scores (*M* = 216.9, *SD* = 7.44), *t* (33) = 1.663, *p* = .106 (Figure 6). The effect size for the differences between pretest scores of control and experimental groups in the study was .51, a moderately strong ES between the two groups' pretest averages.

An independent samples *t*-test was conducted on 5th grade post scores by Group (control vs. experimental). Experimental post scores (*M* = 225.1, *SD* = 7.09) were not significantly different from control post scores (*M* = 223.0, *SD* = 7.88), *t*(33) = .810, *p* = .424 (Figure 7). The ES for the posttest scores of control and experimental groups in the study was .26, a minimally strong ES between the two groups' posttest averages.

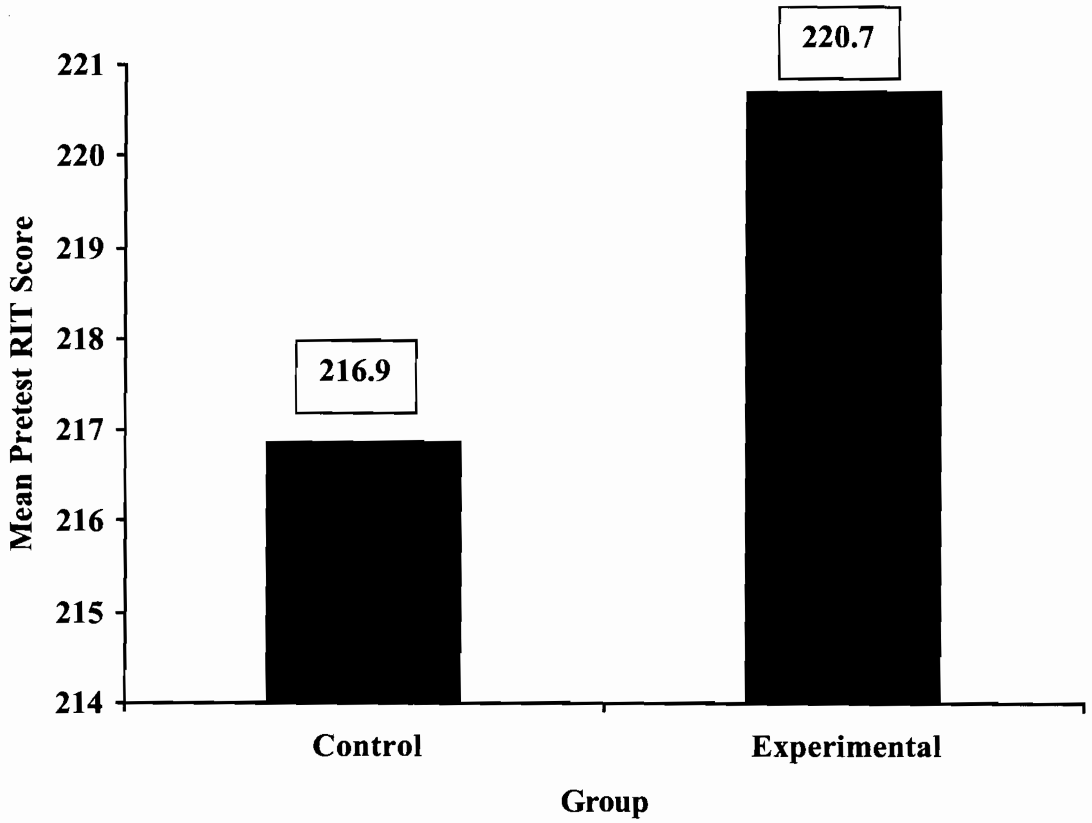

Figure 6. Graph comparing 5th grade *Measures of Academic Progress* (MAP) pretest fluency scores in indoor air quality (IAQ) study.
Note. t(33) = 1.663, p = .106. ES = .51, moderately strong.

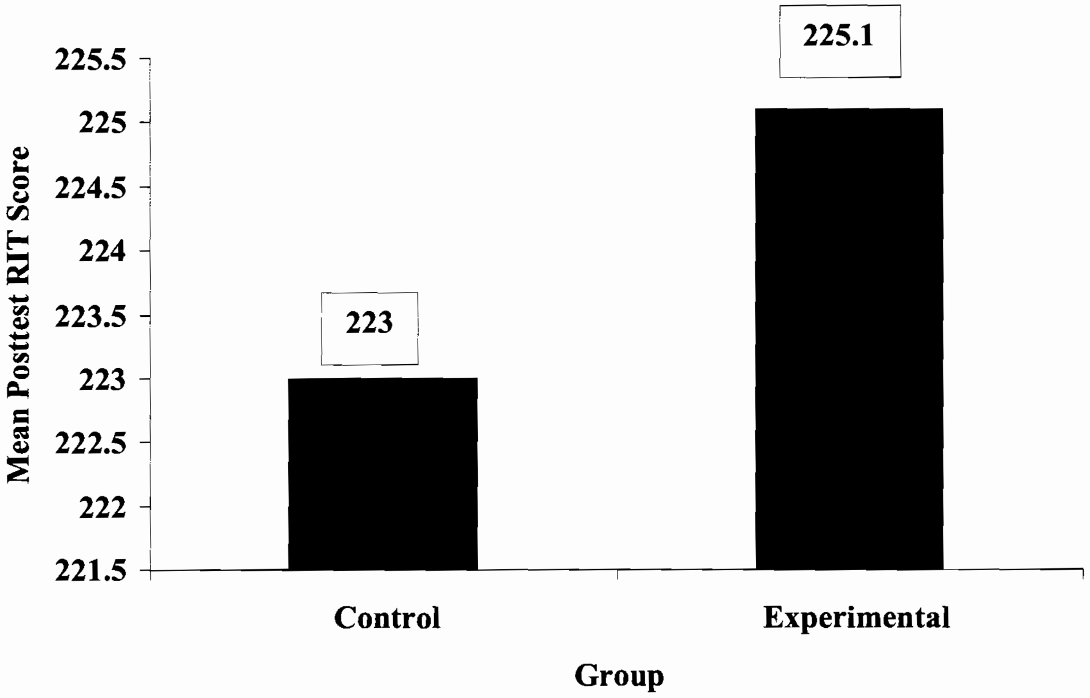

Figure 7. Graph comparing 5th grade *Measures of Academic Progress* (MAP) posttest fluency scores in indoor air quality (IAQ) study.
Note. t(33) = .810 , p = .424 (ns). Effect size = .26, mildly strong.

Figure 8 compares pretest and posttest scores for both 3rd grade and 5th grade experimental and control groups. Figure 8 clearly shows that both 3 - X and 5 – X clearly started out with higher pretest RIT mean scores (3 – X, M = 201.7) (3 – O, M = 194.2). (5 – X, M = 220.7) (5 – O, M = 216.9).Although growth was demonstrated for each of the four groups from pre to posttests, control groups did exhibit more growth (3 – O = 8.2 points, 3 – X = 5.2 points) (5 – O = 6.1 points, 5 – X = 4.4 points) due to having more room for growth from beginning at a lower RIT mean (ceiling effect), and/or because of Rausch Unit (RIT) process.

Figures 9 and 10 exhibit CO_2 levels for each group's pretest and posttest. Levels of CO_2 for all testing sessions increased as testing progressed, with the exception of group 5 – X at posttest, when CO_2 levels decreased. All four classes of children tested in the morning. Groups 3 – O and 3 – X pre tested at (10:20 a.m.) post tested at (8:20 a.m.). Groups 5 – O and 5 – X pre tested at (10:20 a.m.) and post tested at (11:00 a.m.). All four classes pre tested in the room that measured 11,750 ft^3. At posttest, groups 3 – X and 5 – X were moved to a room that measured 70,000 ft^3 .The CO_2 levels decreased in the room with 70,000 ft^3 as group 5 – X post tested. The data show there was a considerable difference in CO_2 levels between groups 3 – O and 3 – X (a difference of 1051 ppm) at the posttest. An even greater difference in CO_2 levels was displayed between groups 5 – O and 5 – X (a gain of + 1207 ppm for 5 - O). (see Figure 10).

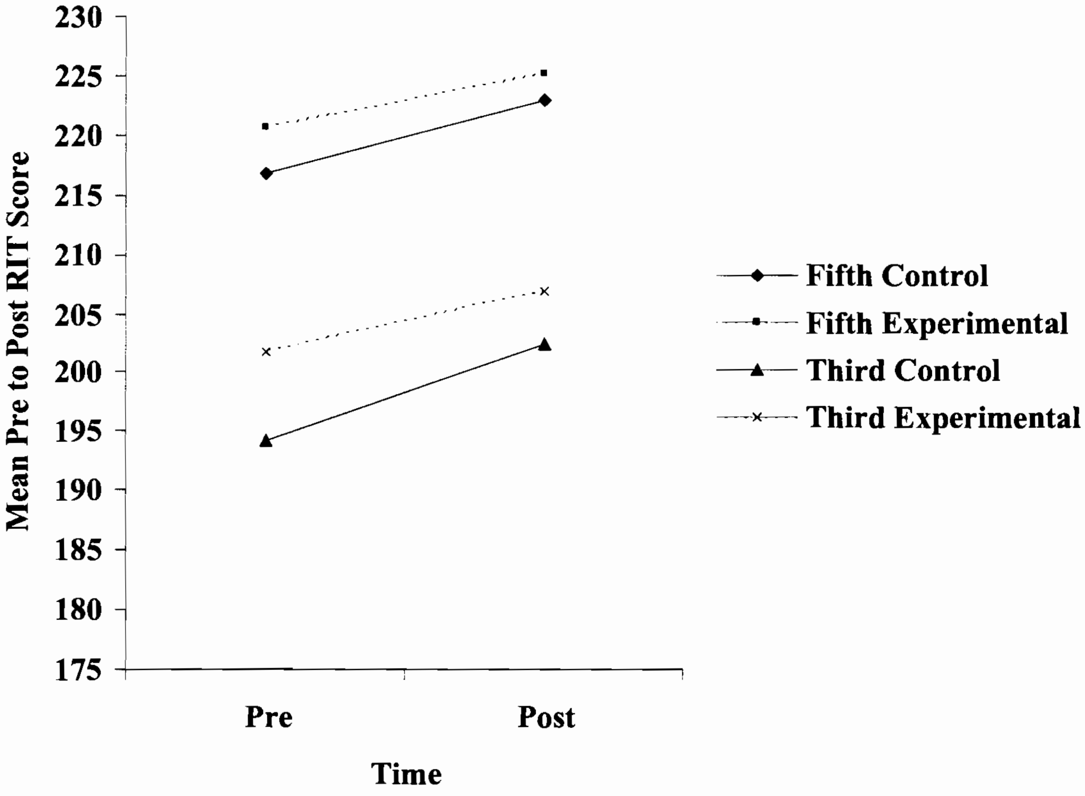

Figure 8. Graph comparing 5th and 3rd grade *Measures of Academic Progress* (MAP) fluency scores from pretest to posttest in indoor air quality (IAQ) study.

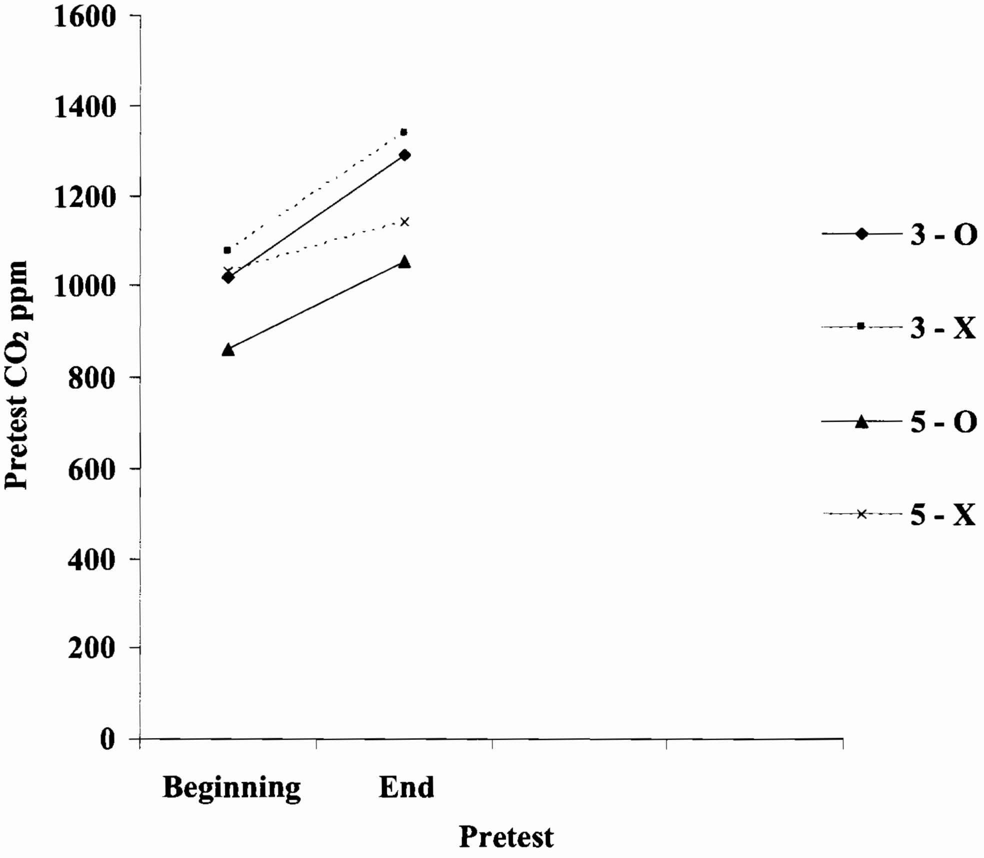

Figure 9. Graph of pretest CO2 levels in indoor air quality (IAQ) study
Note. Testing site held constant at 11,750 ft^3. Groups tested at the same time of day. IAQ measurements were taken at the beginning and end of each testing session.

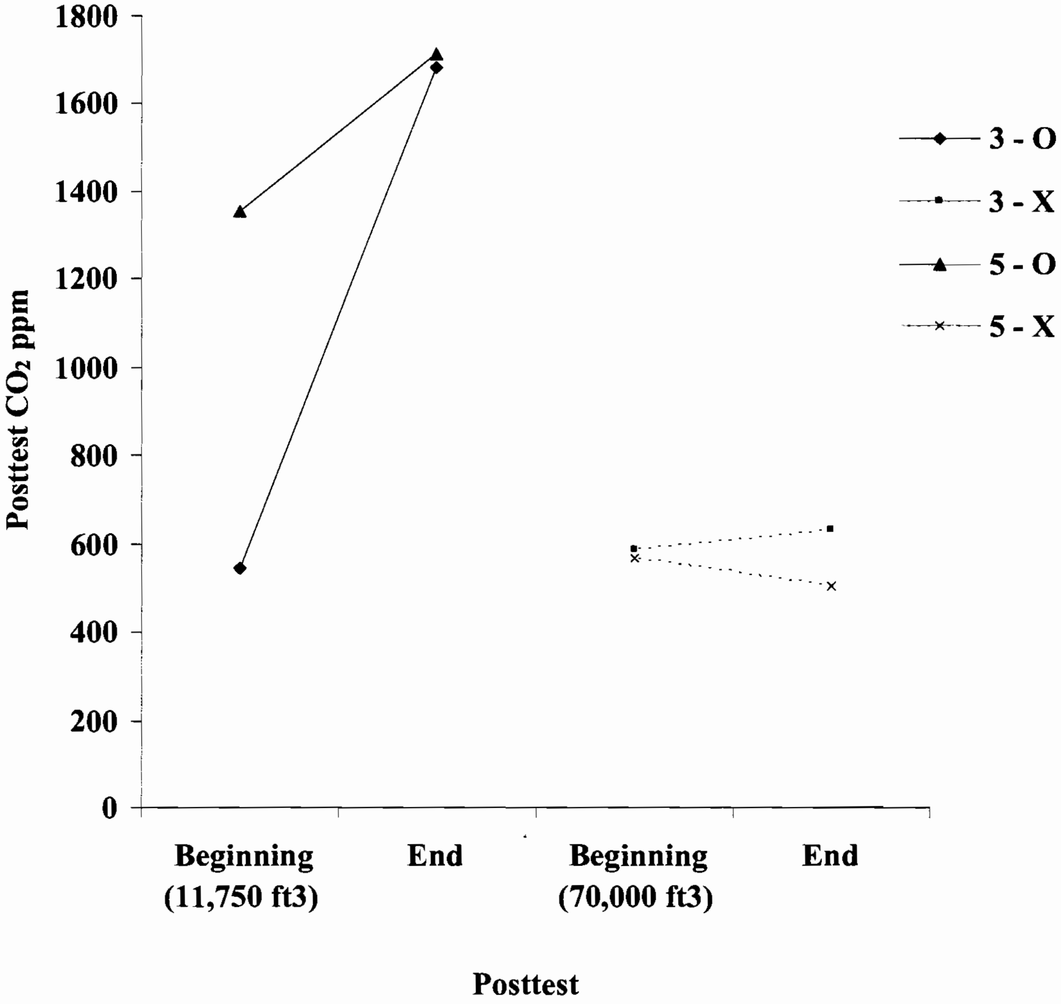

Figure 10. Graph of posttest CO2 levels in indoor air quality (IAQ) study.
Note. Testing site was manipulated for groups 3 – X and 5 – X and measured 70,000 ft^3. Groups tested at the same time of day. IAQ measurements were taken at the beginning and end of each testing session.

Qualitative and Descriptive Patterns

During pretest sessions, the researcher observed participant behavior for the entire duration of each test, as IAQ readings were recorded. IAQ readings were taken at the beginning and ending of each testing session. All four groups of students pre tested in the same room, measuring 11, 750 ft^3 and used a personal computer to take the test.

The students (*n* = 20) in the 3rd grade control group were on task and alert at the commencement of the session (10:20 a.m.). Toward the end of the session, many students were slouching and resting their chins on their hands as they finished the test (11:00 a.m.). The outside temperature was 47° F and it was sunny, dry and cool. The room was fairly dark, due to the sunny day and light shining through the windows. The proctor turned the classroom lights off so students did not have a glare on the computer screens. Average student head height from the floor was 44 inches. CO_2 levels began at 1018 ppm and ended at 1288 ppm (a gain of 270 ppm). The RH began at 30.7 and ended at 27.2, (a difference of -3.5).

Students in the 3rd grade experimental group took the test the following day, in the same location at the same time of day. The student (*n* = 22) behavior was similar to that of the control group. Students were on task for the beginning half of the testing session, but became slightly lethargic and slouchy near the end. The outside temperature was 54° F and it was damp, cool and cloudy outdoors. The room was well-lit this time, due to all of the lights being on because of the cloudy weather outside. Average student head height was also 44 inches. CO_2 levels began at 1076 ppm and ended at 1338 ppm (a gain of +262 ppm). The RH began at 44.0 and ended at 38.8, (a difference of -5.2). The RH was higher during the experimental group's pretest session compared to control group's pretest session (a difference of +16.8).

Students (*n* = 22) in the 5th grade control group tested on a sunny, cool day with temperature of 52° F. The room was well-lit and average head height was 46 inches. Students remained on task the entire testing session and seemed less slouchy than the two previous groups of students. Testing began at 10:20 a.m. and ended at 11:40 a.m. CO_2 levels began at 860 ppm and ended at 1054 ppm (a gain of +194 ppm).

Students (*n* = 22) in the 5th grade experimental group started the pretest alert. By the end of the testing session, several students were yawning and leaning. The lighting was bright. It was a sunny, cool and breezy day, with outside temperature of 53° F. Testing began at 10:20 a.m. and ended at 11:40 a.m. Average student head height was 45 inches. CO_2 levels began at 1032 ppm and ended at 1141 ppm, (a gain of +109 ppm). The RH in the classroom was higher for the experimental group (36.7) than for the control group (25.1), a difference of +11.6.

For the posttests, the same procedures to collect data occurred as for the pretest. Students (*n* = 86) tested at the same time of day. The manipulated variable was the location of the posttest, in a room with much greater cubic feet of space for the two experimental groups. The 3rd grade and 5th grade experimental groups were moved to a room measuring at 70,000 ft^3 for the posttest. The 3rd grade control group and the 5th grade control group took the posttest in the same room as the pretest, measuring 11,750 ft^3.

Students (*n* = 20) in the 3rd grade control group were observed as having been on task and attentive, but began showing signs of fatigue near the end of the test. The outside temperature was 50° F and it was sunny, breezy and cool. The room was bright and well-lit. Student head height was 45 inches. CO_2 levels began at 546 ppm and ended at 1681 ppm, (a gain of +1135 ppm).

Students (n = 22) in the 3rd grade experimental group were observed as very focused and alert. The room was also well-lit and bright. The outside temperature was 55° F and very sunny. Average student head height was also 45 inches. The RH was lower for the experimental group (26.6) compared to control group (35.4), a difference of – 8.8. CO_2 levels were significantly lower in the experimental group than the control group's testing site. CO_2 levels began at 586 ppm and ended at 630 ppm (a gain of +44 ppm).

Students (n = 22) in the 5th grade control group were observed as on task for most of the test, but near the end of the test, some students were yawning and stretching and appeared to be lethargic and tired. The room was well-lit. It was a sunny, cool day, and the outside temperature was 53° F. Testing took place from 11:00 a.m. – 12:00 p.m. Average student head height was 47 inches. CO_2 levels began at 1355 ppm and ended at 1713 ppm (a gain of +358 ppm). The RH began at 29.6 and ended at 40.7, (a difference of 11.1).

Students (n = 22) in the 5th grade experimental group tested on a bright, sunny, breezy day. Outside temperature reached 58° F and the room was well-lit. Testing took place from 11:00 a.m. – 12:00 p.m. The average student head height was 47 inches as well. Student behavior appeared as focused for most of the test. Some students slouched near the end and seemed to take more time to respond to questions. CO_2 levels began at 565 ppm and ended at 506 ppm, (a difference of -59 ppm), a considerable difference from levels of CO_2 in 5th grade control group's posttest room. These CO_2 measurements were significantly lower than the 5th grade control group. The RH began at 31.9 and ended at 42.5, (a gain of +10.6). Final RH readings did not vary much between the two settings, but both sessions had gains in RH readings as testing progressed. Table 8 shows ft^3 and CO_2 levels of testing sessions for each group.

Summary

Many variables affect student achievement. Teacher efficacy, student socio-economic status, learning disabilities, morale of the learning environment, IAQ of the learning environment and emotional state of students are only some. In order to ensure that the dynamics of each group of participants were similar to one another, only the test scores of general education students' scores were analyzed to adjust for any special education IEP requirements.

The descriptive test data show that students in all four groups exhibited improvement from pre to posttest scores, two groups in language and two groups in mathematics. The 3rd grade control group was initially performing lower than the 3rd grade experimental group on the pretest. Although the control group exhibited more growth when comparing mean RIT scores, the experimental group had more favorable posttest performance.

The 5th grade students in both the control (O) and experimental (X) groups exhibited similar outcomes with regard to pre and posttests. There was significant growth from pre to posttest, and the experimental group, which started higher, produced more favorable posttest results. The narrower range of growth was exhibited from the (X) group, probably due to less room for growth as a result of starting at a much higher pretest mean RIT than the (O) group.

With regard to inferential statistics of this study, attainment of statistical significance was likely affected by the limited sample size of only four groups of participants. Dependent samples *t*-tests provided statistical significance of growth from pretest to posttest, but independent samples *t*-tests showed that the posttest differences (X ,O) were not statistically significant.

Students in each of the four groups who participated in the study remained on task for most of the testing sessions. Toward the end of the testing, some participants seemed fatigued and slouchy. The room with fewer ft^3 had higher CO_2 levels during both the pre and posttests. Outside weather conditions mildly affected indoor RH levels.

Chapter IV has provided analyses of the data and findings, descriptive data, inferential statistics, and qualitative and descriptive patterns in the study. Chapter V will provide a summary, findings, conclusions discussion and recommendations for policy, practice and implications for future research.

Chapter V

SUMMARY, FINDINGS, CONCLUSIONS, DISCUSSION, AND RECOMMENDATIONS

Summary

The problem investigated in this study focused on the influence of IAQ on student test performance. Four classes of students were used in the study (two 3rd grades and two 5th grades). Groups 3 – O and 5 – O served as the control groups and 3 – X and 5 – X served as the experimental groups for the study. The standardized, norm-referenced instrument Northwest Evaluation Association (NWEA) *Measures of Academic Progress* (MAP) was used in the pretest/posttest experimental design. Students' mean Rausch Unit (RIT) scores were reported in the fall and spring were analyzed via the use of independent and dependent samples *t*-tests. IAQ readings were taken at the beginning and end of each testing session. Students tested in the morning and at approximately the same time of day on consecutive days at both pre and posttest sessions. All four classes pre tested in a room that measured 11,750 ft^3 , all four groups having used the same stationary computers. Using mobile computer laptops for the posttest, groups 3 – X and 5 – X were moved to a room that measured 70,000 $ft^{3.}$ It was determined that IAQ levels were better in the larger testing room, in particular, CO_2 levels were substantially lower. General education students in both experimental groups (3 –X and 5 – X) performed better on the posttest than did students in groups 3 – O and 5 – O.

Findings

The research findings in this study showed that students who tested in the classroom with more cubic feet produced higher posttest scores in language and mathematics than the control students who tested in a room with fewer cubic feet per student. Although all four groups of participants exhibited growth from pre to posttest, the two control groups (3 –O and 5 – O) who pre tested and post tested in a smaller room (11,750 ft^3) had lower posttest scores than the experimental groups (3 - X and 5 – X) who post tested in the larger room (70,000 ft^3). The CO_2 levels were significantly higher in the smaller room during all pre and post testing times. In the testing room with more cubic feet, students had significantly low CO_2 levels, making the IAQ of that testing environment desirable. This subsequent research to Prout (2000) reinforced findings that classrooms with fewer cubic feet have higher CO_2 levels and in accordance with theories on CO_2 levels, these higher levels impeded the concentration, stamina and overall test performance of youngsters who participated in the study. Although the researcher omitted special education students' scores from the data analyses, those students were a part of the class, were present in the room during pre and post testing times, and contributed to the overall number of students in the class and generation of CO_2.

The highest recorded level of CO_2 during the pretest was 1338 ppm and the lowest level was 860 ppm. During the posttest, the highest level of CO_2 was 1713 ppm and the lowest level was 506 ppm. Although the highest levels are not near the PEL of 5,000 ppm, they are above the indoor limits that establish healthy IAQ. These findings are similar to what Prout (2000) reported,

> An indoor level of CO_2 less than 600 ppm is necessary to avoid health complaints by building occupants, and at greater levels is associated with increased occupant discomfort and complaints of stuffiness, drowsiness, tiredness, eye irritations, stale air, and lack of oxygen. (p. 35)

The CO_2 measurements in this study were higher for every pretest session (highest reading = 1713 ppm), but were lower for some of the experimental group's posttest sessions (lowest reading = 506 ppm). Pike-Paris (2005) reported acceptable levels of CO2 are $\leq$ 800 ppm.

The null hypothesis states that there is no difference in testing outcomes based on levels of IAQ and cubic feet per student. Based on the data, the null hypothesis is not accepted. The key research questions that guided this study were developed to identify the influence that IAQ, mainly CO_2, had on student test performance. Based on empirical evidence, the data do support the hypothesis that lower levels of CO_2 positively influence student test performance. Administering high-stakes testing in rooms with more cubic feet does produce more favorable testing outcomes and CO_2 levels are lower than in rooms with fewer cubic feet. If another study were to be conducted on a large scale, it is assumed that results would further support the present findings and statistical significance between groups would be attained. The effect size (ES) of .69, indicated a very strong effect when comparing pretest scores of 3 – O and 3 – X: The ES of .45, indicated a moderately strong effect when comparing posttest scores of 3 – O and 3 – X. The ES of .51 indicated a moderately strong effect when comparing pretest scores of 5 – O and 5 – X. The ES of .26 indicated a minimally strong effect when comparing posttest scores of 5 – O and 5 – X.

Conclusions

Findings in this study are similar to and corroborate findings from analyses of research conducted by AQS (as cited in Aspen Publishers, 2006) that student test scores improved as the physical conditions of school buildings improved. In this particular study, posttest IAQ conditions improved in the room with more cubic feet and student test performance was more favorable for the participants who took the posttest in that room. The U.S. EPA (1995) findings testified that symptoms of being exposed to poor IAQ, especially CO_2 levels, can result in reduced ability to concentrate which impairs teaching and learning experiences overall (as cited in Petronella et al., 2005).

Qualitative patterns in this study portrayed students becoming tired, lethargic and slouchy as testing sessions progressed and CO_2 levels increased, particularly in the smaller testing room when CO_2 levels reached 1713 ppm. Indeed, however the 11,750 ft^3 of the smaller room is much larger (13 – 15 times) than the average classroom in U.S. schools (often 770 – 880 ft^3) and 70,000 ft^3 us approximately 80 – 91 times larger than the average classroom. These students also scored lower on the posttest compared to the experimental group. Schmidt (1994) had suggested that "Excess CO2 levels in occupied classrooms and offices can cause headaches, lethargy, and reduced mental activity" (p. 2). "At high levels, CO_2 causes drowsiness and lethargy and could be detrimental to teaching and learning" (Achilles, 2004, p.12). According to a report on the scores of the 2006 Scholastic Aptitude Test (SAT), the new version of the test was lengthened by 45 minutes and added a writing component, forcing students to test for five hours in the same location and some observers pointed out that fatigue played a factor in lower test scores. If IAQ measurements had been taken during these testing sessions, what would CO_2 measurements be?

This observation was rebutted the College Board (2006) that was "quick to dispel the notion that fatigue could play a factor in the lower scores (p. 5). "A College Board analysis of the performance of more than 70,000 test-takers on the critical reading in mathematics section during the spring and fall 2005 SAT administrations showed no difference in student performance" (p. 5).

The sample size of this study was small, which influenced statistical significance, but an immediate benefit of this research was the collection and analyses of data that suggest there is a positive relationship between IAQ and student achievement and student test performance.

As Leach (1997) stated:

> While it is difficult to point directly to statistical data that irrefutably link interior air quality with student performances, we have more than enough indirect evidence, combined with our intuitive and plain common sense experience to make this issue well worth pursuing. (p. 32)

Findings from this study coupled with the thorough review of the research, theory and literature suggest a positive connection between IAQ and student achievement and student test performance. The theoretical framework/conceptual base for this study was supported based on the empirical data that show IAQ influences student test performance. Federal mandates of *NO CHILD LEFT BEHIND ACT (PL 107-110)* require students to meet AYP and attend school regularly, yet the schools in which students learn may be impeding their learning and harming their health, raising absenteeism. IAQ standards are lacking in public schools. If students are to meet AYP, they need to learn in environments that foster learning. Results of this study demonstrated that students performed better on a high-stakes test when they tested in a large, well-ventilated room with lower levels of CO_2. The data support the observations and conclusion of Prout (2000) that IAQ influences student performance.

One branch of the theoretical framework to this study suggested that rooms with more cubic feet and with higher cubic feet per student have better IAQ and lower levels of CO_2. The data analyzed in this study support this theory, as the students in this study participated in regular classes (20 - 28 students). When moved to posttest room measuring 70,000 ft^3 in contrast to the pretest room measuring 11,750 ft^3 (70,000 ft^3 is about 6 times that in ft^3), room size allowed for more cubic feet per child. Each of the classes used in the study had 20 – 22 students and the total school population was <500 students. Data from Nye (1995) suggest small school size (< 470 students) is important to student achievement in mathematics as opposed to large school size (>670). It was concluded that if the population of students used in this study were to be compared to students from large schools, they may still perform better because there was more cubic feet per student in this study. Although CO_2 levels were over desired levels according to Pike-Paris (2005), the levels were not an immediate threat to students' health. Students in larger schools may have higher levels of CO_2, and poorer IAQ, negatively influencing student test performance. Note that HVAC differences will influence IAQ, but HVAC was controlled in the present study as all groups were tested in the same building.

The theoretical framework/ conceptual base that inspired this study has been suggested in statements from (Kozol, 1991; 2005b) accepting the notion that environment influences educational outcomes such as behavior and achievement is a critical first step to rehabilitating impeding learning environments. Students are required by law to attend school and are tested yearly on how they perform in school; yet the need for attention to facilities remains fundamental to students' daily success and success on high-stakes tests that are not departing from schools' accountability arena any time soon.

Policy

Problems must first be found preceding solutions and decision-making (Achilles, Reynolds, & Achilles, 1997). After extensive review of the literature, it is apparent that there is an epidemic of poor IAQ in our nation's schools. This research, coupled with other studies providing empirical evidence on the effects of poor IAQ on students, serves as the problem finding referenced by Achilles. There is no time like the present to use the problems that have been found to begin solving them.

Findings in this study provide suggestions to alleviate or reduce the discrepancy between the empirical and normative claims of students having to meet AYP, but the rooms in which they test and learn may not be equally supportive for student outcomes. This discrepancy may be addressed by establishing a sense of urgency for administrators to devise policy for implementing IAQ standards for all public schools. "Our schools are in worse physical shape than our bridges, our transit system, or our hazardous waste disposal systems" (Ohanian, 2003, p. 741).

Results of this study provide empirical support to the administrators of the local schools so that they may be informed of the influence of poor IAQ on student test performance. Administrators, parents, teachers and government officials must be consistently made aware of empirical data that calls attention to the problem of the numbing effects of excess CO_2 in classrooms its relationship to student performance.

Specific IAQ guidelines for schools are still in great need and are crucial to ensuring good health of students and teachers. School facilities must be regularly checked for poor IAQ and air pollutants such as mold, dust and toxins such as lead and asbestos. Culminating research must drive the initiative to develop policy for improving or maintaining good IAQ in schools. Maintaining small class sizes needs to be a predominant national policy to ensure students are reaping the benefits the empirical evidence has suggested about keeping class sizes small (15 – 17 students). More students produce more CO_2. In smaller rooms, crowding them with more than 25 students may make IAQ levels very poor. Research suggests that the poorer the IAQ, the fewer optimal student learning and behavior outcomes occur (Prout, 2000).

School facilities and their conditions need to be included in the mission of a district. "Risk characterization often ignores children. Then, when regulations or other policy steps are taken to control risk, children's interests are left out of the process" (Landrigan et al., 1995, p. 40).Unhealthy children have a difficult time focusing and attendance rates can be greatly influenced which can impede student achievement. Unhealthy staff members cannot teach effectively and may, like their students, have high absenteeism rate. Federal mandates should mirror those enforced in N.J.A.C. 12:100.13 which covers IAQ in existing buildings occupied by public employees including schools. Districts are to provide preventative maintenance, to improve ventilation, reduce microbial contamination and issue advance notice of renovations or remodeling (as cited in Pediatric/Adult Asthma Coalition of New Jersey, 2007).

Parents of children who have health issues such as asthma or allergies to mold, must act as advocates for their children by having IAQ in schools regularly checked and remediate if necessary. Parents of these vulnerable children are stakeholders in developing policy that research strongly suggests is needed nationwide to protect America's youth in an institution which is a right, not a privilege. Districts also need to implement no smoking, no pets, minimal carpeting and no idol vehicles around students.

It is critical that policy makers understand the direct link between students' health and their academic success in order to minimize liabilities.

Students must become involved in exposing their failing facilities by writing to government officials and politicians and by capturing and sending images of unhealthy learning environments in pictures. Borbely stated, "When confronted by children, politicians can no longer make excuses" (as cited in Moses, 2006, p. 41).

Practice

This research suggests that high-stakes testing be conducted in larger classrooms if school facilities can accommodate such a change. Windows and doors being ajar for the duration of testing session may assist with improving IAQ, by lowering levels of CO_2 and temperature. Testing students in smaller groups may also help CO_2 levels remain lower which may result in students being more alert and less lethargic during testing and learning. In the State of New Jersey, students with asthma are protected by the annual asthma education code N.J.A.C 18:40 – 12.9, which mandates annual asthma education opportunities for school teaching staff and physician (as cited in Pediatric/Adult Asthma Coalition of New Jersey, 2007). This mandate needs to be adopted and enforced on a federal level, so that all children in the United States are protected. Utilization of the EPA's Tools for Schools (1995) serves as a catalyst for improving IAQ in schools. Financially, districts can apply for grants or bonds to help fund IAQ initiatives if problems are detected.

Implications for Future Research

This study should be replicated on a much larger scale to identify if testing environments with better IAQ continue to produce more favorable student test performance. There is a continuous need for further research on how IAQ affects students' health, behavior and test performance, especially since schools are held accountable for AYP according to *NO CHILD LEFT BEHIND ACT (PL 107-110)*. This small study was conducted in a relatively affluent suburban school district, where school facilities are in very reasonable condition with regard to IAQ, so these results may not reflect conditions that may occur in other geographical locations. Future research would be beneficial if it focused on the IAQ of schools that have not met AYP according to the *NO CHILD LEFT BEHIND ACT (PL 107-110)*. After reviewing the literature there is a need for research to determine the effects of mold and air pollutants and their relationship to asthma, being that cases of childhood asthma have reached epidemic proportions. Research to determine if high CO_2 levels are a marker for the presence of other toxins in schools would certainly paint a clearer picture of the overall influence of IAQ on students' achievement and health.

It may be beneficial for future researchers to add a qualitative aspect to control for some variables in the study that were beyond the scope of this study. For example, students can be polled to determine if they had breakfast before testing or what time they went to bed to indicate if they had a substantial amount of sleep the night before testing. Future research in the field of IAQ and its influence on student test performance may focus on the variable of teacher efficacy by surveying teachers to learn how long they have been teaching, and determining the level of degree/specialization they hold. These implications may assist researchers in controlling for the multitude of variable that influence student achievement. Finally, testing students across various grade levels in the same subject may add strength to the outcome of a future study because the results may be more generalized.

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Appendix A

Glossary of Terms

Terms used in this study are defined here for clarity and precision.

Analysis of Covariance (ANCOVA) – A test used to equalize initial differences between groups (Salkind, 2004).

Carbon dioxide (CO_2) - A heavy, odorless, colorless gas formed during respiration and by the decomposition of organic substances; absorbed from the air by plants in photosynthesis (Webster's Online Dictionary, 2006).

Control group - The group in a research study that is treated "as usual" (Fraenkel & Wallen, 2000, p. 662).

Cubic feet (ft^3) - Is a non-metric unit of volume, used in the United States. It is defined as the volume of a cube with edges one foot in length (Webster's Online Dictionary, 2006).

Dependent variable - The variable that is, or is presumed to be, the result of the manipulation of the independent variable (Hinkle, Wiersma & Jurs, 2003, p. 735). For this study the dependent variable will be student performance on *NWEA's MAP* assessment.

Experimental group - The group in a research study that receives the treatment or method of special interest in the study (Fraenkel & Wallen, 2000, p. 664).

Experimental research - Research in which at least one independent variable is manipulated, other relevant variables are controlled, and the effect on one or more dependent variables is observed (Fraenkel & Wallen, 2000, p. 664).

Heating-Ventilation/Air-Conditioning System (HVAC) - Is an acronym that stands for "heating, ventilation, and air-conditioning." These three functions are closely interrelated, as they all change the temperature, pressure and humidity of the air within a building. In modern building designs, the design, installation and control systems of these functions are integrated into a single "HVAC" system (Webster's Online Dictionary, 2006).

Independent variable - A variable that is controlled or manipulated by the researcher. A categorical variable used to form the grouping of observations (Hinkle, et al., 2003, p. 736). For this study the independent variables will be ft^3 per classroom and ft^3 per student.

Indoor Air Quality (IAQ) - Deals with the healthiness of air inside of buildings. Its scope includes mold, bacteria, chemicals, allergens, and anything that can exist in the air and affect people's or animal's health. Some people are trained in testing the quality of indoor air and certified by organizations such as the American Industrial Hygiene Association, American Indoor Air Quality Council, and the Indoor Environmental Standards Organization (Webster's Online Dictionary, 2006).

IAQ-CALC / TSI 8762 - a calibrated instrument that measures indoor air quality components such as carbon dioxide, carbon monoxide, relative humidity and temperature. This instrument will be used in the present study to assess IAQ of testing sites.

Measures of Academic Progress (MAP)- Achievement tests in mathematics, reading, language usage and science that are taken on a computer devised by the Northwest Evaluation Association (NWEA) (Northwest Evaluation Association, 2005).

Parts per million (ppm) - Is a standardized measure of concentration used to show the amount of a substance, often a fluid or gas, as a function of a norm of quantity (parts of X per million). The ppm value is equivalent to the absolute fractional amount multiplied by one million (10^6) (Webster's Online Dictionary, 2006).

Permissible Exposure Limits (PEL) - the legally enforceable standards for the uppermost levels of a hazard or toxic exposure, based on a worker of an 8 hour day (adult, not child standards) (US EPA, 2000).

Policy - The outputs of a political system, usually in the form of rules, regulations, laws, ordinances, court decisions, administrative decisions, and other forms. Public policy may be perceived as a pattern of activity applied consistently and repetitively (Kruschke & Jackson, 1987, p. 35).

Sick Building Syndrome (SBS) - Building whose occupants experience acute health and/or comfort effects that appear to be linked to time spent therein, but where no specific illness or cause can be identified. Complaints may be localized in a particular room or zone, or may spread throughout the building (Webster's Online Dictionary, 2006).

Standardized assessment - One that compares the performance of every individual subject with a norm. The norm may be established independently, or by statistical analysis of a large number of subjects (Webster's Online Dictionary, 2006). Standardized assessments in the field of education include the *Measures of Academic Progress*, *Miller Analogies Test, Terra Nova,* and the *High School Proficiency Assessment.*

Appendix B

SPSS Outputs

T-Test

condition = experimental

Paired Samples Statistics(a)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Third pre	201.7273	22	7.78999	1.66083
	Third post	206.8636	22	11.26856	2.40247

a condition = experimental

Paired Samples Correlations(a)

		N	Correlation	Sig.
Pair 1	Third pre & Third post	22	.710	.000

a condition = experimental

Paired Samples Test(a)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Third pre Third post	-5.13636	7.93603	1.69197	-8.65500	-1.61773	-3.036	21	.006

a condition = experimental

condition = control

Paired Samples Statistics(a)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Third pre -	194.1875	16	10.71584	2.67896
	Third post	202.4375	16	9.81135	2.45284

a condition = control

Paired Samples Correlations(a)

		N	Correlation	Sig.
Pair 1	Third pre & third post	16	.868	.000

a condition = control

Paired Samples Test(a)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Third pre-Third post	-8.25000	5.34790	1.33697	-11.09969	-5.40031	-6.171	15	.000

a condition = control

T-Test
condition = experimental

Paired Samples Statistics(a)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Fifth pre	220.7143	14	5.42684	1.45038
	Fifth post	225.0714	14	7.08698	1.89407

a condition = experimental

Paired Samples Correlations(a)

		N	Correlation	Sig.
Pair 1	Fifth pre & fifth post	14	.533	.050

a condition = experimental

Paired Samples Test(a)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Fifth pre-Fifth post	-4.35714	6.22164	1.66280	-7.94941	-.76488	-2.620	13	.021

a condition = experimental

condition = control

Paired Samples Statistics(a)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Fifth pre	216.8571	21	7.44504	1.62464
	Fifth post	222.9524	21	7.88338	1.72029

a condition = control

Paired Samples Correlations(a)

		N	Correlation	Sig.
Pair 1	Fifth pre & fifth post	21	.654	.001

a condition = control

Paired Samples Test(a)

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Fifth pre – fifth post	-6.09524	6.38674	1.39370	-9.00245	-3.18803	-4.373	20	.000

a condition = control

T-Test

Group Statistics

	condition	N	Mean	Std. Deviation	Std. Error Mean
Third pre	experimental	22	201.7273	7.78999	1.66083
	control	16	194.1875	10.71584	2.67896
Third post	experimental	22	206.8636	11.26856	2.40247
	control	16	202.4375	9.81135	2.45284
Fifth pre	experimental	14	220.7143	5.42684	1.45038
	control	21	216.8571	7.44504	1.62464
Fifth post	experimental	14	225.0714	7.08698	1.89407
	control	21	222.9524	7.88338	1.72029

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Third pre	Equal variances assumed	.854	.362	2.515	36	.017	7.53977	2.99777	1.46002	13.61953
	Equal variances not assumed			2.392	26.002	.024	7.53977	3.15201	1.06075	14.01880
Third post	Equal variances assumed	.451	.506	1.261	36	.216	4.42614	3.51090	-2.69429	11.54656
	Equal variances not assumed			1.289	34.745	.206	4.42614	3.43340	-2.54587	11.39814
Fifth pre	Equal variances assumed	.932	.341	1.663	33	.106	3.85714	2.31955	-.86203	8.57631
	Equal variances not assumed			1.771	32.664	.086	3.85714	2.17786	-.57548	8.28976
Fifth post	Equal variances assumed	.411	.526	.810	33	.424	2.11905	2.61522	-3.20167	7.43976
	Equal variances not assumed			.828	30.017	.414	2.11905	2.55870	-3.10638	7.34448

Appendix C

ANCOVA Results

An ANCOVA was conducted on 5th Grade Posttest Scores by group (Control vs. Experimental) after controlling for Pretest Scores. The assumption of homogeneity of regression slopes was met confirming that the factor Group and covariate Pretest Scores do not interact. The assumption of homogeneity of variances was also met. Results indicate that after controlling for the differences on Pretest Scores, there is not a significant difference between the Control and Experimental group in Posttest Scores, $F(1,32) = .07, p = .80$. Means and standard deviations for the Control and Experimental group on Posttest scores are shown, before and after controlling for Pretest Scores.

An ANCOVA was conducted on 3rd Grade Posttest Scores by group (Control vs. Experimental) after controlling for Pretest Scores. The assumption of homogeneity of regression slopes was met confirming that the factor Group and covariate Pretest Scores do not interact. The assumption of homogeneity of variances was also met. Results indicate that after controlling for the differences on Pretest Scores, there is not a significant difference between the Control and Experimental group in Posttest Scores, $F(1,35) = .86, p = .36$. The means and standard deviations for the Control and Experimental group on Posttest scores are shown, before and after controlling for Pretest Scores.

Analysis of Covariance for 5th Grade Posttest Scores as a Function of Group, Using Pretest Scores as a Covariate

Source	*df*	*F*	Sig.	2	p
Pretest Scores	1	19.47	.001	.38	.99
Group	1	.07	.80	.002	.06
Error	32	(36.84)			

Note. Number in parentheses represents mean square error.

Adjusted and Unadjusted Group Means and Variability for 5th Grade Posttest Scores Using Pretest Scores as a Covariate

		Unadjusted		Adjusted	
Group	*N*	*M*	*SD*	*M*	*SE*
Experimental	14	225.07	7.09	223.47	1.66
Control	21	222.95	7.88	224.02	1.35

Analysis of Covariance for 3rd Grade Posttest Scores as a Function of Group, Using Pretest Scores as a Covariate

Source	*df*	*F*	Sig.	2	p
Pretest Scores	1	48.76	.001	.58	.99
Group	1	.86	.36	.02	.15
Error	35	(49.08)			

Note. Number in parentheses represents mean square error.

Adjusted and Unadjusted Group Means and Variability for 3rd Grade Posttest Scores Using Pretest Scores as a Covariate

		Unadjusted		Adjusted	
Group	*N*	*M*	*SD*	*M*	*SE*
Experimental	22	206.86	11.27	204.03	1.55
Control	16	202.44	9.81	206.34	1.84

Appendix D

Special Education RIT Scores for 3 – O and 5 - X

Table 12 and 13 display the mean RIT scores of only the special education students in the control and experimental groups (3 – O and 5 – X) that were excluded from the data analyses. These tables are included for reporting purposes only. It should be noted that all of the students in 3 – O exhibited growth from pre to posttest. Only four out of eight special education students exhibited growth from pre to posttest in group 5 – X.

Table 12

Special Education RIT Scores for Language Arts 3rd Grade Control Group from Pre to Post

Student	Gender	Pre	Post	Difference
1	M	161	166	+5
4	M	177	186	+11
7	F	189	195	+6
8	M	191	196	+5

Note. Testing site cubic feet held constant at 11,750 from pre to post. Males (n=3) Females (n=1). Average Pretest RIT = 179.5. Average Posttest RIT = 185.8.

Table 13

Special Education RIT Scores for Mathematics 5th Grade Experimental Group from Pre to Post

Student	Gender	Pre at 11,750 ft^3	Post 70,000 ft^3	Difference
1	F	188	194	+6
2	F	197	196	-1
3	F	202	212	+10
4	F	203	208	+5
5	F	204	202	-2
6	M	207	203	-4
7	F	208	212	+4
8	M	210	202	-8

Note. Males (n=1) Females (n=6). Average Pretest RIT = 202.4. Average Posttest RIT = 203.6

Appendix E

Permission to Conduct Study

POST OFFICE BOX 579
ADMINISTRATION BUILDING
200 SQUANKUM-YELLOWBROOK RD.
HOWELL, N.J. 07731

HOWELL TOWNSHIP PUBLIC SCHOOLS

PROUD OF OUR SCHOOLS - CONCERNED FOR OUR CHILDREN

ENID GOLDEN, Ed.D
SUPERINTENDENT OF SCHOOLS

(732) 751-2480
FAX (732) 919-1060

October 10, 2006

To Whom This May Concern:

I grant permission for Denise Hreha, doctoral student at Seton Hall University, to collect data in order to complete her dissertation. She will use two testing areas within Ramtown School for the administration of the Measures of Academic Progress (MAP) test in the fall of 2006.

Two third grade classes and two fifth grade classes will be used in the study. A calibrated machine (IAQ-CALC / TSI 8762) will be placed at each testing site to establish baseline readings of four components relating to Indoor Air Quality (IAQ): temperature, carbon dioxide, carbon monoxide, and relative humidity. The pretest and posttest cites vary greatly in size. All four classes will pretest in the smaller classroom. For the posttest (spring of 2007) one 3rd grade and one 5th grade class will test again in the smaller classroom and will serve as the control group. The other 3rd and 5th grade classes will posttest in the much larger classroom serving as the experimental group.

The purpose of this study is to collect and analyze data that suggest that larger testing areas have better IAQ, which positively affects student test performance. All data collected in this study is anonymous, especially students' and teachers' identity. This study poses no threats or distractions to students due to the fact that MAP testing was to occur in the district anyway and the two experimental groups post-testing in the larger area may be being moved to more favorable conditions. In addition, the IAQ-CALC / TSI 8762 machine poses no distraction to the students as they test, due to its small size and soundless operation.

Sincerely,

Enid Golden

Enid Golden

Appendix F

IAQ Instrument Certificate of Calibration and Testing

TSI CERTIFICATE OF CALIBRATION AND TESTING

TSI Model 8762 TSI Serial No. 01100280

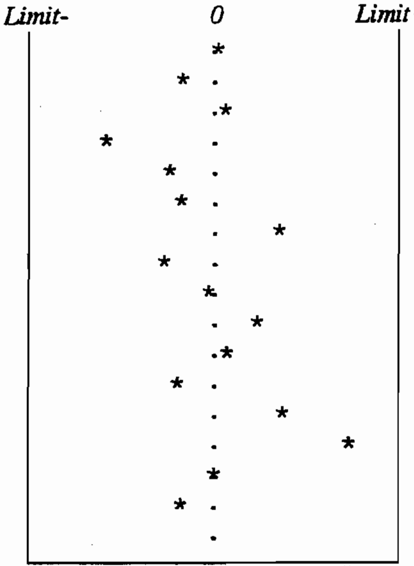
Description IAQ Meter with CO2 and CO

Calibration Standard Multi-Gas Calibration Bench #127

CALIBRATION VERIFICATION RESULTS

Calibration Standard	Instrument Output	Difference
5133 PPM	5135 PPM	0.0 %
3000 PPM	2984 PPM	-0.5 %
1000 PPM	1003 PPM	3 PPM
500 PPM	471 PPM	-29 PPM
0 PPM	-12 PPM	-12 PPM
140.0°F	139.8°F	-0.2°F
41.0°F	41.4°F	0.4°F
15.0 %rh	14.2 %rh	-0.8 %rh
30.0 %rh	29.9 %rh	-0.1 %rh
50.1 %rh	50.8 %rh	0.7 %rh
70.0 %rh	70.2 %rh	0.2 %rh
89.8 %rh	89.2 %rh	-0.6 %rh
0.0 PPM	1.1 PPM	1.1 PPM
50.0 PPM	52.2 PPM	2.2 PPM
100.0 PPM	100.0 PPM	0.0 %
201.0 PPM	199.9 PPM	-0.5 %

Error Compared to Tolerance



Tolerance Limits:

CO2: 50PPM or 3% of reading
rh: ± 3%rh
Temp: ± 1°F
CO: 3PPM or 3% of reading

TSI Incorporated does hereby certify that the above described instrument conforms to the original manufacturers specifications (not applicable to As Found data) and has been calibrated using standards whose accuracies are traceable to the National Institute of Standards and Technology within the limitations of NISTs calibration services or have been derived from accepted values of natural physical constants or have been derived by the ratio type of self calibration techniques. The calibration ratio for this instrument is at least 6.7:1 for barometric pressure and 3:1 for differential pressure. TSIs calibration system meets ISO-9001:2000 and complies with ISO 10012:2003, Quality Assurance Requirements for Measuring Equipment. This report may not be reproduced, except in full, unless permission for the publication of an approved abstract is obtained in writing from the calibration organization issuing this report.

Applicable Test Report	Report Number	Date Last Verified
DC Voltage	E002463	04-07-06
Barometric Pressure	E001329	05-01-06
Pure Nitrogen	N134380	01-13-06
CO2 1000 PPM in N2	cc73638	04-15-04
CO2 5000 PPM in N2	cc183828	03-28-06
Temperature 0 C	E000822	04-04-06
Temperature 60 C	E001806	04-04-06
Humidity	E002008	04-05-06
CO 200 PPM in N2	CC152777	11-21-2005

Calibrated by

☑ Final Function Check

Aug 1, 2006
Calibration Date

TSI Incorporated, 500 Cardigan Road, Shoreview, MN 55126 USA
Tel: 800-874-2811 651-490-2874 FAX: 651-490-2121 www.tsi.com

Appendix G

Institutional Review Board Non-Review Certification

IRB non Review certification

STUDENT : Denise Hrcha

Title of Dissertation: Influence of Indoor Air Quality

I certify, by my signature below, that the above indicated study does not require IRB review as a result of a lack of involvement with human subjects (see OHRP flow chart) and as indicated by any or all of the following (check all that apply).

1. Historical research ______
2. Public data base ______
3. *Proprietary data base ______
4. Freedom of Information ______
5. Right to know – sunshine law ✓

Student signature: Denise M. Hrcha

Advisor approval: C M Achilles

Reviewed by : ______________________
Marty Finklestein – Higher Ed

Daniel Gutmore
Daniel Gutmore – K – 12 3/31/07

- Proprietary data that does not identify individuals

Appendix H

Human Participants Protections Education for Research Completion Certificate

National Cancer Institute

U.S. National Institutes of Health | www.cancer.gov

Se

NCI Home | Cancer Topics | Clinical Trials | Cancer Statistics | Research & Funding | News

Human Participant Protections Education for Research T

Completion Certificate

This is to certify that

Denise Hreha

has completed the **Human Participants Protection Education for Research Teams** online course, sponsored by the National Institutes of Health (NIH), on 10/10/2006.

This course included the following:

- key historical events and current issues that impact guidelines and legislation on human participant protection in research.
- ethical principles and guidelines that should assist in resolving the ethical issues inherent in the conduct of research with human participants.
- the use of key ethical principles and federal regulations to protect human participants at various stages in the research process.

[redacted]