INVESTING IN OUR FUTURE

How School Modernization Impacts Indoor Environmental Quality and Occupants

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EXECUTIVE SUMMARY

There are many factors that contribute to a school's ability to educate the future generation—including the physical school building itself. School districts have the opportunity to support the success of a school through buildings that create healthy and safe environments for children to learn and teachers to teach. However, starting with a report released by the U.S. Government Accounting Office in 1995[i] and followed by many subsequent studies, it has been found that many school districts are facing an aging building stock and growing budget cuts, resulting in school buildings with leaky roofs, broken windows, unhealthy air quality, overcrowding, and unsafe drinking water.[ii] While the situation is urgent, it is also an opportunity to evaluate how well-designed school buildings can help improve learning outcomes and the health and well-being of both our students and their teachers.

In early 2018, Perkins Eastman partnered with the District of Columbia Public Schools on a study, co-sponsored by J+J Flooring, to quantify the benefits of the District's school modernization efforts. In order to improve learning environments, staff satisfaction, and student performance, the District of Columbia has invested funds into completing full renovations of many of its non-modernized school buildings to create high-performance, 21st century learning environments.

This paper describes the findings of the study, which looked at the perceived satisfaction of both students and faculty, on-site measurement of Indoor Environmental Quality (IEQ), and archival data collected by the school district. All of these factors are compared between modernized versus non-modernized facilities to assess the success of the modernization efforts in improving the learning environment. It was found that in almost all IEQ factors, modernized schools saw improvements in both measured conditions and occupant's satisfaction over non-modernized schools. It is important to note that this connection was particularly evident in the teachers' reported satisfaction with their classrooms. This paper outlines the specific findings and identifies statistically significant differences between the modernized and non-modernized facilities.

THE RESEARCH QUESTION

Recent research suggests that the Indoor Environmental Quality (IEQ) of a classroom — including daylight,[iii] thermal comfort,[iv] acoustics,[v] and air quality[vi] — can have a significant impact on student and teacher performance. Furthermore, the typical improvements to building mechanical systems, exterior walls and fenestration, and building layout that are often elements of a school modernization effort can greatly change the IEQ of the space. Accordingly, IEQ was a major focus of this design research study.

Our hypotheses were twofold: (1) modernized schools would have better IEQ than their non-modernized counterparts, and (2) faculty and students in modernized schools would have improved well-being, satisfaction, and school performance compared to those in non-modernized school environments. By assessing the IEQ conditions found in recently modernized schools and comparing them to older schools in need of upgrades, this study was able to quantify the value of the improvements from an IEQ perspective, and, ultimately, how this contributes to improvements in school performance.

Definitions

MODERNIZED vs. NON-MODERNIZED

Modernized Schools:

Buildings which have undergone a full renovation including systems, finish, and technology upgrades within the last 10 years.

Non-Modernized Schools:

Buildings which were originally built between the 1930s & 1960s which have only received minor improvements within the past 30 years.

STUDY PARTICIPANTS

To understand the impact of school modernization efforts, this study engaged with the District of Columbia Public Schools — a school district currently in the midst of a modernization effort — to examine the differences between student and teacher well-being, satisfaction, and performance in schools that have been modernized compared to those that have not yet been modernized.

A total of nine public schools were identified across the District, representing a wide range of socio-economic statuses and demographics. Five of the schools selected underwent recent renovations/modernizations and the other four are slated for modernization within the next five years. All of the modernized schools included in the study are full renovations of existing school buildings or renovations with additions, as opposed to new construction projects, thereby representing the typical modernization process pursued in the District of Columbia and reflecting the national concern over an aging school building stock.

In addition to excluding newly constructed schools from the study's sample, the investigation was further focused by only evaluating elementary and middle schools, as these younger students are more vulnerable to environmental impacts due to their continued physical development and elevated respiratory rates, as compared to adults.[vii]

PARTICIPANTS

Elementary Schools

Middle Schools

4 NON-MODERNIZED

- **2** elementary schools
- **1** middle school
- **1** elementary + middle school

5 MODERNIZED

- **3** elementary schools
- **2** middle schools

IMPORTANCE OF THE STUDY

It is estimated that 53% of U.S. public schools need renovations or modernizations to be considered in good overall condition, the cost of which would total around $197 billion.[viii] Knowing that this level of funding is no small ask for school districts and taxpayers across the country, this study aimed to quantify the broader impact school improvements and modernizations can have on student and teacher well-being, satisfaction, and performance in order to create additional justification for the considerable financial expenditure required to upgrade existing school buildings.

For this study, the District of Columbia Public School system was identified, as their modernization plan gives careful consideration to the distribution of funds and costs associated with modernization, and continues to support the design and construction of high-performance, healthy, and safe learning environments across the entire District. The researchers hope this report will illustrate the benefits of DCPS's investment in high-performance learning environments.

THE DCPS MODERNIZATION PLAN

DCPS is committed to ensuring that all students have access to excellent schools. Since 2007, the District of Columbia Public Schools (DCPS) has invested more than $3 billion in school modernizations and improvements in an effort to provide all students in the District with a 21st-century learning environment. Over the next six years, the District will invest over $1 billion as part of the Capital Improvement Plan to modernize more school facilities. With a focus on equity, student enrollment trends, and building condition, a data-driven approach was developed to prioritize schools in the modernization queue across all eight wards in the District. The typical modernization schedule is a one-year design phase followed by two years of construction.

METHODOLOGY

Building upon a post-occupancy evaluation process initially developed by Perkins Eastman for the Dr. Martin Luther King, Jr. School design research study (see "Measuring Up: Using Pre- and Post-Occupancy Evaluation to Assess High-Performance School Design," published July 2017[ix]), the assessment of each school focused on the classroom, as these spaces represent the core learning environment in which students and teachers are engaged throughout the school day. Data collection involved three different components that were cross-compared between the modernized and non-modernized school samples: an occupant questionnaire, on-site IEQ data collection, and school archival data. This study received an Institutional Review Board exemption determination (according to 45 CFR 46.101(b) – Exempt Categories #2 and #4) due to the anonymity and confidentiality of all data collected, and assurances that the rights and welfare of all individuals involved in the research were protected throughout the process.

Questionnaire

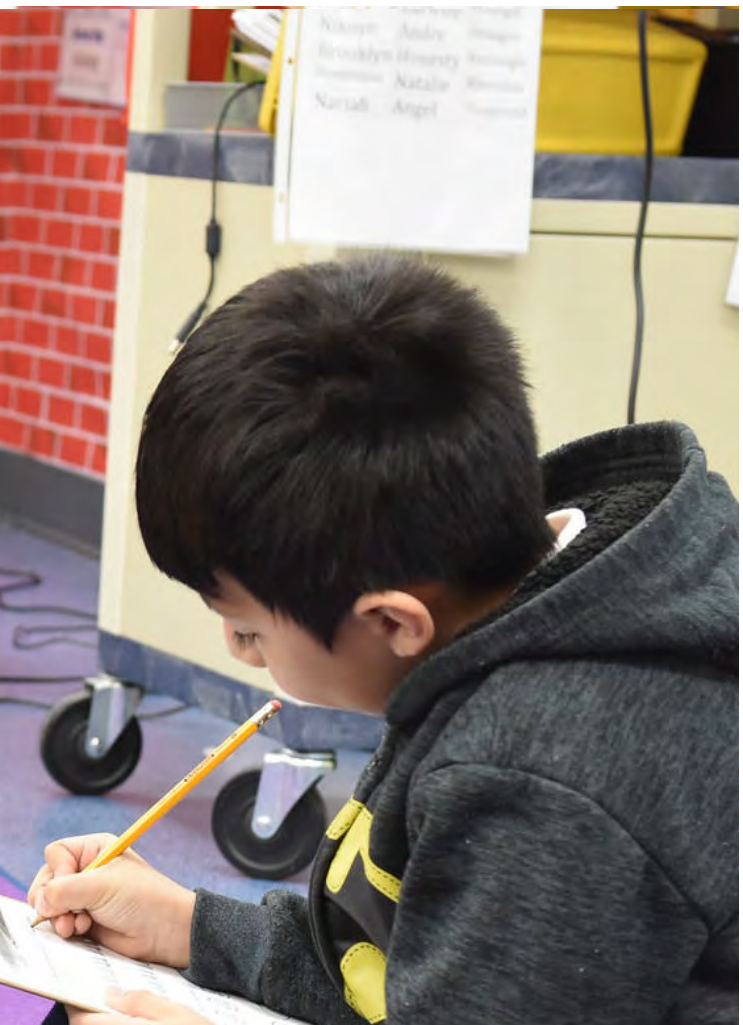
Occupant perception of performance, well-being, and comfort within their classroom was measured using surveys. Due to the wide range of participant ages, four separate versions of the questionnaire were developed: 1) kindergarten through second grade students; 2) third through fifth grade students; 3) sixth through eighth grade students; and 4) teachers. The kindergarten through second grade students engaged in a drawing and writing exercise, while the older students and teachers completed a multiple-choice questionnaire. As the survey was divided into age-appropriate questionnaires, the data analysis and results were also assessed by age group.

Surveys were distributed to the entire student and faculty populations of the participating schools in order to receive a representative sample from both populations. The student surveys saw a 62% response rate, while the faculty reached a 76% response rate. It should be noted that due to scheduling conflicts, one modernized elementary school and one modernized middle school were unable to participate in the surveying portion of the study, but a balance in responses between modernized and non-modernized schools was still achieved within the dataset. It is also important to note that the faculty were more likely able to comprehend the concepts of the questions being

asked, and therefore able to respond more accurately to their surveys than the student participants, leading to more statistically significant findings during the analysis of survey data.

On-site IEQ Data

The on-site data collection was conducted using sensors that tracked actual IEQ conditions within each school for one week. Four different factors of Indoor Environmental Quality were studied: daylight, thermal comfort, acoustics, and air quality. Three classrooms in each school were selected to study typical conditions — meaning these were standard academic classrooms that represented the average occupancy and use for the majority of the classrooms in the school. Additionally, these classrooms were chosen to represent potentially different daylight, thermal comfort, acoustic, and air quality conditions that may be experienced throughout each school. Whenever possible, classrooms facing different cardinal directions and having differing proximity to nearby roads or other unique external conditions were identified. While thermal comfort, acoustic, and air quality conditions were tracked over the course of one week in each school, due to a limited quantity of sensors, not every school was studied during the same week. However, each of the schools were studied in a similar timeframe to capture comparable weather conditions. Measurements were done across four consecutive weeks in February 2018 during colder weather to capture the season most prevalent during the school year in the Mid-Atlantic region. Daylight measurements were conducted in all schools during a two-day period in March 2018 at the time of the vernal equinox.



Archival Data

The District of Columbia uses a variety of school performance indicators that are tracked across all of their schools on an annual basis. For this study, existing anonymized records were accessed to evaluate student attendance, boundary rates, crime incidents in the surrounding neighborhood, change in enrollment rate, school nurse visits per student, faculty retention rates, and administrator retention rates. These indicators track a broad spectrum of a school's performance, showing much more than what test scores may measure, by looking at everything from the health of students to the impact of the school on the broader community.

Definitions

Enrollment:

Total number of students enrolled in a school

Boundary Rate:

The in-boundary percentage rate is the number of students attending a school who live in the boundary divided by the school's total enrollment[x]

RESULTS

Questionnaire

The drawing exercise given to kindergarten through second grade students allowed the students to select an IEQ factor from a list, describe how it made them feel, and provide a drawing to explain. The exercise was led by their teachers in their classroom setting and incorporated into each class's daily regular activities. While the drawing exercise did not produce statistically significant results, it did lead to some interesting observations.

The drawing exercise revealed that, overall, daylight is the most common quality the students selected to discuss, with 40% of students selecting this factor. Further, daylight was also the one IEQ parameter most often associated with positive emotions, with 94% of responses related to daylight expressing positive emotions. On the other end of the spectrum, comments related to noise/acoustics were most often negative. In fact, in non-modernized schools, 83% of all comments about noise/acoustics were negative, which was an 18% higher dissatisfaction rate than reported by students in the modernized schools. This shows that even from a young age, students are possibly aware of and impacted positively by daylight and negatively by noise.

The third through fifth and sixth through eighth grade students completed a more extensive survey with specific questions addressing various classroom environmental and IEQ factors. There was found to be a statistically significant improvement in responses from students in modernized classrooms regarding feelings of happiness and pride, as well as those students reporting feeling calmer, healthier, and more prepared to learn than those in non-modernized classrooms.

Additionally, there is increased satisfaction with all facets of the Indoor Environmental Quality within modernized schools. Students in modernized schools were more likely to be satisfied with the temperature, air quality, noise levels, and daylight in their classrooms compared to students in non-modernized classrooms. This statistically significant increase in satisfaction with the IEQ factors and health and happiness in modernized classrooms supports existing research that shows these factors are indeed related.

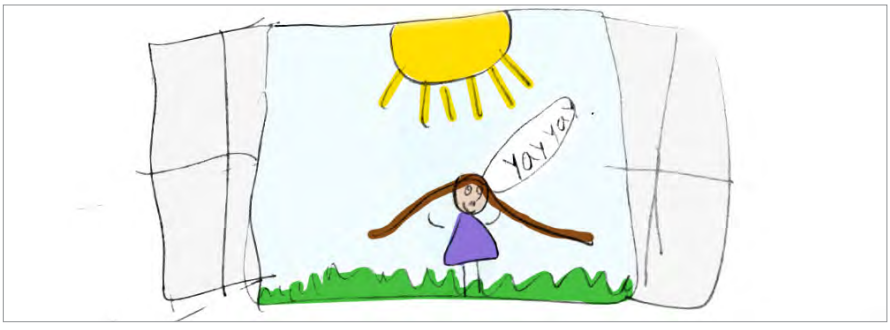
STUDENT DRAWING EXERCISE**

BAD NOISE LEVELS

I can not pay attention.

GOOD DAYLIGHTING

The daylight in my classroom makes me feel ready to learn because I fell active seeing light.



***Drawings from pilot testing, not DCPS participants*

The faculty responded to additional questions about their perceptions of their classrooms. This survey resulted in the most statistically significant data points in the study, indicating a strong correlation between teacher's satisfaction with their classrooms and the school's modernization status. Similar to students, faculty generally demonstrated higher satisfaction rates with daylight than for any other IEQ parameter, regardless of modernization status. Overall, the highest IEQ satisfaction in the survey was reported for daylight quality, with 49% of respondents being satisfied across all the schools. This is notably better than thermal comfort, acoustics, or air quality, each of which only received 31% satisfaction.

Looking specifically into the differences seen between modernized and non-modernized schools, faculty in modernized schools reported statistically significant higher levels of satisfaction with every aspect of Indoor Environmental Quality. This indicates that in terms of faculty perception, modernized schools have notably better Indoor Environmental Quality than non-modernized schools.

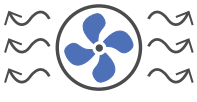
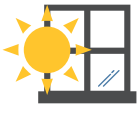
STUDENTS ARE...

25% more proud to go to school in a modernized building

AND

16% happier,
18% calmer,
17% healthier, and
16% more ready to learn
in modernized school classrooms

IN MODERNIZED SCHOOLS

STUDENTS ARE...		FACULTY ARE...
9% more satisfied with thermal comfort		**40% more** satisfied with thermal comfort
14% more satisfied with air quality		**45% more** satisfied with air quality
18% more satisfied with acoustics		**30% more** satisfied with acoustics
13% more satisfied with daylight		**45% more** satisfied with daylight

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On-Site IEQ Data

DAYLIGHT

To study daylight within the classroom environments, two measures of daylight quality were examined in each room in both the morning and the afternoon. First, how well the daylight gets distributed throughout the entire classroom was studied using a light meter and, second, the presence of glare or over lit conditions within classrooms were studied using calibrated cameras. The distribution of daylight quantifies what percentage of the floor area could feasibly be lit without using electric lighting, while also identifying what areas are receiving too much or too little light to be visually comfortable. Under lit conditions indicate that additional electric lighting is required to create an appropriate lighting level for learning. On the other hand, glare indicates conditions where occupants would be visually uncomfortable due to over lit conditions and also areas where solar heat gain may cause thermal comfort issues.

DAYLIGHT AND WELLBEING

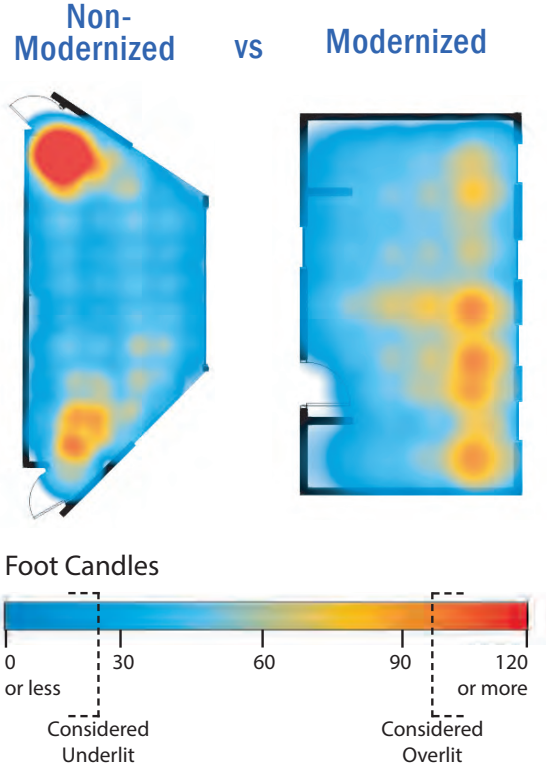
Daylight affects student's concentration and general wellbeing.[xi, xii] Students in classrooms with windows perform 20% faster on math tests and 26% faster on reading tests than students in windowless classroom.[xiii]

GLARE IMAGING

Non-Modernized

Modernized

DAYLIGHT DISTRIBUTION



* white areas in diagrams read as above 120 footcandles*

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The results show that the evaluated schools were generally more likely to be under lit than over lit. However, in agreement with the results of the questionnaire, which showed higher satisfaction in regards to daylight, schools across the study were well lit on average, with about 60% of the studied floor area meeting but not exceeding the LEED requirements for daylight autonomy and glare.* Even with the restrictions associated with altering daylight quality in renovation projects, the evaluated modernized schools were found to have more well lit areas than in the non-modernized schools, by around 7%. Although this is not a large difference, the statistically significant increase in satisfaction from the questionnaire data may indicate that even small improvements in classroom daylight can have a marked impact.

Concerning glare, the study found that the modernized schools experience a lower amount of glare on desks and floor surfaces during school hours. This is a positive finding considering glare can negatively impact students' and teachers' abilities to see and their general visual comfort. Combined with the daylight distribution results, this shows that not only do the modernized schools have more well-lit areas, they also experience lower glare, showing that modernization efforts are improving daylight quality without over-lighting the classroom environments.

FOOTNOTE: *Illuminance levels between 300 lux and 3,000 lux

DESIGN ALTERATIONS

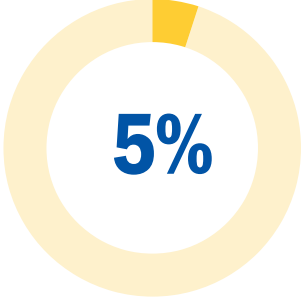
As all the modernizations evaluated in this research study were largely renovations of existing facilities, design interventions altering the daylight quality within the classrooms were limited. For instance, altering a classroom's orientation to be more appropriate or changing window area is often infeasible. However, design alterations such as replacing existing windows, adding exterior shading, and/or altering the reflectance values of the materials within each classroom are commonly used in renovations to improve daylight distribution and glare. It is also important to note that two of the non-modernized schools had undergone recent window replacements before this study.

DAYLIGHTING IN MODERNIZED SCHOOLS

UNDER LIT

WELL LIT

OVER LIT



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ACOUSTICS

There are many factors that may contribute to sound levels and appropriate acoustics within a classroom. The focus for this study was on measured ambient noise levels within a classroom, which may be representative of mechanical background noise and other exterior noise sources, and also on occupied noise levels, which may indicate issues with acoustically reflective surfaces and reverberation times that cause amplification of normal classroom noise. A decibel meter was used to track sound levels over time. Nighttime readings were studied to assess ambient noise levels, while school hour readings (8 AM - 3 PM) were studied for occupied noise levels to determine both average and peak levels.

Definitions

Ambient Noise:

Ambient noise, also known as background noise, includes regular noise conditions from mechanical systems and the exterior environment that establish a baseline level of noise within a space.

Occupied Noise:

Occupied noise measures the decibel levels within a space due to occupied conditions, combining background noise levels with live activity levels to get a total decibel reading.

dBA:

dBA stands for A-weighted decibels, which measures the relative loudness of sounds as perceived by the human ear.

NRC:

NRC stands for Noise Reduction Coefficient, which is an average rating of how much sound a surface can absorb.

Ambient noise readings showed that sound levels were 11% lower in modernized schools than in non-modernized. These readings likely indicate that modernizations lead to lower background noise levels due to improvements made to the mechanical systems – both in noise level and locations of components relative to the learning environment – and in building envelope to prevent infiltration of exterior noise.

However, when studying noise levels in occupied classrooms, the results showed high levels in all schools in the study, regardless of whether they were recently modernized or not. Averaging around 52 dBA during school hours and peaking at over 80 dBA in many schools, this data reflects the large dissatisfaction that was found across the board with acoustics in the questionnaire responses, and might indicate an issue that needs to be better addressed in modernization projects. Perhaps pursuing enhanced acoustics design strategies to further reduce reverberation times and increase high NRC surfaces within the classroom environment could help address this issue within modernizations moving forward.

CLASSROOM
ACOUSTICS MATTER

Poor acoustics can cause teachers to strain their voices in order to be heard by their students, causing teachers fatigue. It can also have negative effects on a student's ability to learn, as was demonstrated by a study examining students at a school under the regular flight path of a nearby airport. These students performed 20% lower on a reading test than students in a nearby school outside the flight path.[xiv] Additionally, non-native language speakers are found to have an additional 28% reduction in comprehension at higher noise levels,[xv] signaling that poor acoustics disproportionally affect the performance of non-native speakers and should be addressed, especially in diverse urban areas.

AIR QUALITY

Like acoustics, there are many different factors that influence air quality within a classroom. For the purposes of this study, the focus was on the effectiveness of ventilation, as indicated by CO2 levels within the classroom over time. A CO2 sensor was used to measure CO2 levels over the course of one week in each classroom, and data was analyzed during typical occupied conditions (i.e., between 8 AM - 3 PM).

In the modernized schools, the results indicate that the median CO2 levels during occupied conditions were 25% lower than in the non-modernized schools. Although the non-modernized schools' CO2 levels were on average falling within the range of ASHRAE Standard 62.1 requirements for ventilation (around 1,000 ppm), the modernized schools were functioning with lower CO2 levels (around 750 ppm). This suggests that improvements made to the mechanical systems during modernization efforts produce major improvements in ventilation rates and more effective reduction of CO2 levels within the classroom environment.

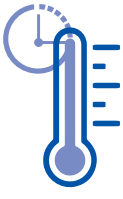
In addition to looking at the average CO2 levels during occupied conditions, peak CO2 levels were also studied. Continuous occupancy with inadequate ventilation can cause CO2 levels to spike, particularly in afternoon hours when the classroom has been in use all day. The data showed that the modernized schools, on average, hit peak CO2 levels that were 41% lower than peak CO2 levels found in the non-modernized schools. This finding further reinforces the fact that modernized schools have improvements in ventilation effectiveness within classrooms, leading to better air quality for both students and teachers.

This photo not taken in a DCPS facility.

HEALTH
IS IN THE AIR

Healthy air quality can positively impact students' instances of respiratory illness,[xvi] attendance,[xvii] task completion speed,[xviii] and grades. Studies have found that students in classrooms with higher air ventilation rates scored 14-15% higher on standardized tests.[xix]

Definitions

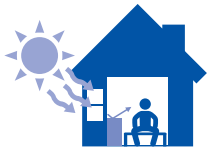


Time Outside the Comfort Zone:

The ASHRAE defined comfort zone ranges from 68°F - 75°F, and the percentage of time that a classroom is outside of this range is considered the time outside of the comfort zone.

Thermal Bridging:

An area of an envelope which has a higher thermal conductivity than surrounding materials, creating a path for heat transfer.



Radiant Surface Temperature:

The temperature of a nearby surface that, through radiant heat transfer, can impact occupant comfort within a space.

THERMAL COMFORT

Performance of the mechanical system, the building facade, and glazing can all affect occupants' satisfaction with the temperature of a space. This study looked at two aspects impacting thermal comfort: temperature of the classroom environments and thermal bridging of the building envelope. Temperature was tracked using temperature and relative humidity sensors that logged data over the course of one week, and thermal bridging potential was assessed using a thermal imaging camera to look at heat transfer at a single point in time.

The results indicate that modernized schools are more comfortable from a temperature perspective than non-modernized schools. Temperatures within the evaluated modernized schools fell within the ASHRAE-defined comfort zone (68°F - 75°F) 84% of the time, while the non-modernized schools were only within the comfort zone 42% of the time on average — half of the time of modernized schools.

THERMAL DISCOMFORT

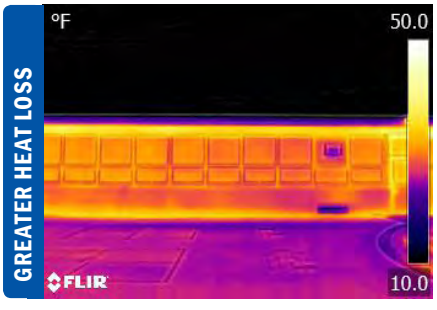
Thermal discomfort can cause feelings of fatigue, irritability, and depression. Studies have shown that for every decrease of 1.8°F between 77°F and 68°F, student's speed performance on tests was improved from 2-4% in all tasks.[xx]

While none of the evaluated schools were ever below the comfort zone during occupied hours, the peak temperatures found in the modernized schools were over 4°F lower than those found in the non-modernized schools, which were overheated during this winter study, peaking around 81°F on average. This indicates that, while the mechanical systems are working during the cooler winter months by providing heat, the non-modernized buildings may have less ability to control or deliver the appropriate amount of heat to an individual classroom space, resulting in overheating during the winter.

Thermal comfort is also affected by other parameters beyond air temperature, such as radiant surface temperatures and air speeds. Heat loss through the building envelope caused by thermal bridging and infiltration can create cooler exterior surfaces within the classroom environment in winter, leading to discomfort. A thermal imaging camera was used to assess the effectiveness of the building envelope at minimizing thermal bridging and infiltration. The results found that the modernized schools generally had fewer instances of visible heat loss through the envelope than the non-modernized schools, especially at critical areas like window and door openings, floor plates, and roof and foundation conditions. These results, combined with the improved air temperatures within the classroom spaces, show that not only are the modernized schools doing a better job at delivering a thermally comfortable space, but they also are likely saving energy in the process because of the reduction of heat loss through the envelope.

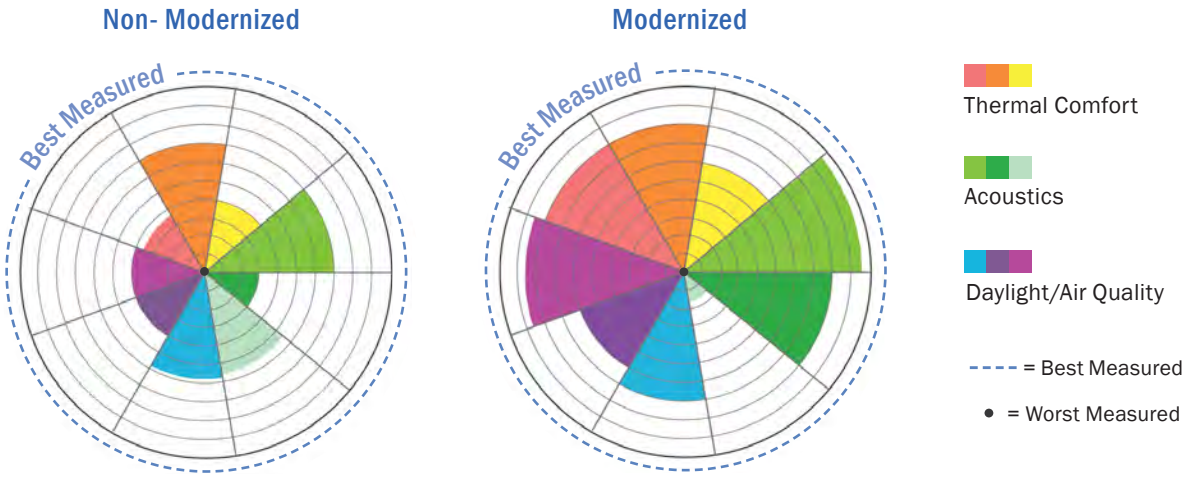
THERMAL IMAGING

Non- Modernized



Modernized

OVERALL ENVIRONMENTAL QUALITY



With the outside circle of these graphs representing the best measured on-site IEQ data collected in the study, and the center of the graph representing the worst measurement, these visuals show how, by almost every metric studied, the modernized schools were performing significantly better on average than non-modernized schools.

Archival Data

An analysis of the District's archival data showed that, on average, the modernized schools were outperforming the non-modernized schools around student attendance, boundary rate, enrollment rate of change, school nurse visits per student, and faculty retention rates. However, none of these factors was deemed statistically significant. In other words, a recent modernization effort could not be pinpointed as the cause for the improved student performance indicators. However, it is still possible that these results could be seen over time. Of the modernized schools studied, one was completed in 2015, one in 2016, and two in 2017. It is likely that the modernized schools have not been in operation long enough to see statistically significant performance improvements. Existing research shows that a change in satisfaction is not likely to lead to visible performance improvements until three to five years down the road.[xxi,xxii,xxiii]

Correlations

Based on the existing bodies of academic research on Indoor Environmental Quality, the researchers originally hypothesized that the modernized schools would see improved Indoor Environmental Quality conditions. These improvements in IEQ would then lead to both improved student and faculty satisfaction and well-being, and improved school performance. Although each of these conditions was assessed individually as detailed above, they were also analyzed against each other for correlations. In the on-site data and the questionnaire responses from the faculty (which were the most statistically significant), significant correlations were identified between the on-site measurements collected for thermal comfort, air quality, and daylight and faculty satisfaction rates. This shows that improvements in Indoor Environmental Quality conditions do, in fact, lead to improvements in satisfaction and that occupants are able to perceive these improvements.

Finally, at the core of the study, correlations between the on-site IEQ measurements and the school performance indicators were assessed. Overall, thermal comfort measurements showed the highest correlations with school performance indicators, indicating that thermal comfort has a positive effect on student attendance, enrollment, and school nurse visits per student. Daylight has the second highest correlations with school performance indicators, showing a positive effect on boundary rate, crime,** and enrollment rates. On the other hand, neither acoustics nor air quality seem to have a strong relationship to any of the proposed school performance indicators.

FOOTNOTE = ** It is possible that the relationship between daylight and crime could be related to clearer exterior views associated with improved daylighting that creates a feeling of more "eyes on the street."

This photo not taken in a DCPS facility.

CONCLUSION AND IMPACTS

Aligned with our hypotheses, the results of this study indicate that from an Indoor Environmental Quality satisfaction perspective, modernized schools showed statistically significant improvements over non-modernized schools. Faculty and students alike are more satisfied with IEQ in their classrooms and measured IEQ improvements support this increase in satisfaction.

This study also revealed the importance of daylight within a classroom. Across all age ranges, daylight is more noticed, evokes more positive feelings, and is more closely correlated to satisfaction than any other IEQ parameter. Although most of the DCPS school building stock that was evaluated is considered well lit, classrooms are more likely to be under lit, and this is something that should be focused on and addressed in future modernization projects.

Additionally, this study revealed a challenge present across all the DCPS school buildings studied, which can be addressed moving forward. During occupied conditions, classrooms across the evaluated schools have high noise levels, leading to high levels of dissatisfaction among both faculty and students. The researchers suggest that this issue should be a topic of focus in all future modernization projects. Although all renovations in the District must meet LEED Gold and, therefore, must satisfy the LEED prerequisite for Minimum Acoustic Performance,[xxiv] it is clear that this may not be enough. Alternative methods and thresholds for acoustic control in occupied classrooms should be considered.

Even though school performance indicators did not reveal statistically significant findings at this stage, the study does set the groundwork for continuing this research to determine how modernizations that improve Indoor Environmental Quality correlate to school performance in the future. The research team hopes to continue to study this sample of schools over the next five years, and to potentially expand the study to a larger sample within the district, as next steps.

Other ideas for expanding this study include adding new construction modernization projects to the sample or studying specific design strategies used in each modernization and how successful they were at improving Indoor Environmental Quality. Additionally, expanding the study into other school districts could be useful, as each district approaches school modernization differently. Further, engaging high schools (and high school students) would provide a more robust data set, particularly since the survey data from high school students may be as reliable as the faculty survey data, or at least more reliable than the perceptual data collected from younger students.

Overall, this study supports the continued funding of modernizations of the existing school building stock, using high-performance design criteria in order to protect the health, well-being, safety, and satisfaction of those that teach and learn in our school buildings.

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