ADDRESSING A Multi-Billion Dollar CHALLENGE
Advancing Knowledge of How High-Quality School Environments Can Positively Affect Educational Outcomes
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EXECUTIVE SUMMARY

The built environment matters. There is a small but growing body of knowledge that demonstrates cognitive, social-emotional, and physical development is related to the built environment. In terms of schools, specifically, “researchers have found that school conditions significantly impact learning experiences and student outcomes” (Filardo et al., 2019). Prior to this study, data were not yet sufficient to ensure consistency across schools, or more importantly, to inform large-scale modernization programs. This study addresses this challenge by advancing knowledge on how high-quality school environments can positively affect educational outcomes.

This is an important topic given that over 49.4 million students were enrolled in public elementary and secondary schools in the United States as of the Fall of 2021 (Digest of Education Statistics, 2022). All these students, however, do not have the privilege of attending a school that provides appropriate facilities to support learning. By 2021, the total shortfall in maintenance, operations, and capital expenditures for school facilities in the United States had grown to $85 billion annually (Filardo, 2021). This deficit marked a dramatic increase of more than $25 billion from the findings from a 2016 report (Filardo, 2016)—a concerning trend that has serious negative implications if not reversed. Further, this shortfall is neither economically nor geographically distributed. School districts with high or medium rates of poverty were found to have invested less per school than more affluent districts—not necessarily as a matter of choice but due to factors beyond their direct control. Urban districts also faced higher construction costs than other jurisdictions.

This alarming disinvestment in school facilities over time underscores the value of this research study, which was made possible by the American Institute of Architects College of Fellows Latrobe Prize grant and additional funding from J+J Flooring. The Latrobe Prize is awarded to support a two-year program of research leading to significant advances in the architecture profession. More specifically, the 2019 Latrobe Prize goals were to be “building-centric,” more “human-centric,” enhance decision-making in practice, emphasize immediate application, and “expand the influence of design beyond buildings” such that operations and human behavior, experience, and satisfaction become the desired outcomes of a design project (American Institute of Architects College of Fellows, 2018).

With an interest in asserting, or re-asserting, the pivotal role that schools play in American communities, the research team sought to address the critical need to reinvest in school infrastructure; provide more and better data to inform school planning, design, and construction; and engage the needs of diverse school stakeholders. By developing an understanding of how the modernization of schools in two major cities impacts significant variables in how the success of a primary or secondary education school can be evaluated, the researchers conducted this study to help demonstrate to policymakers and appropriators that addressing the nation’s inadequate school facilities would be an important and necessary step to support equitable educational and community improvement.

This study sought to understand the differences between modernized and non-modernized schools in terms of Indoor Environmental Quality, Educational Adequacy, and Community Connectivity. For this study, modernized schools were defined as facilities that had received within the past decade a major capital reinvestment with the goal of comprehensively updating, realigning, or replacing program spaces, building systems, and furniture, fixtures, and equipment, as well as bringing the facilities into code compliance, to better serve school and community needs. Non-modernized schools were considered environments that did not meet that definition.

Building upon earlier research by Perkins Eastman and others, this study intended to develop new insights into how school
modernization can make a difference in the lives of those who interact with school buildings—i.e., the stakeholders, including school administrators, teachers, staff, students, parents/caregivers of students, and members of the school’s greater community. The research team’s objective was to develop new knowledge that would be of value to both school district leaders and design firms working on modernization plans for new and renovated schools, as well as to provide thoughtful and convincing information for the decision-making around and advocacy for school modernization on a national scale.

This study’s research questions included:

**(1)** Is there a difference in outcomes between modernized and non-modernized schools?

Hypotheses:

- Modernized schools have better Indoor Environmental Quality (IEQ) than non-modernized schools.
- Modernized schools offer greater Educational Adequacy (EA) than non-modernized schools.
- Modernized schools provide more Community Connectivity (CC) than non-modernized schools.
- Teachers, staff/administrators, and students at modernized schools have greater well-being than those in non-modernized schools.

**(2)** If there is a difference, how do the outcomes compare between modernized and non-modernized schools, within the frameworks of IEQ, EA, and CC?

To address these questions, the research team used an explanatory sequential mixed methods design, where quantitative data were collected and analyzed prior to collecting and analyzing qualitative data. Within this framework, the quantitative study followed a causal-comparative research design that sought to describe differences in IEQ, EA, and CC between schools based on the modernization status of the school. The qualitative investigation of the study followed a phenomenological design, allowing the research team to explore stakeholders’ lived experiences in relation to their modernized or non-modernized schools.
Data were collected at 28 schools, from their internal and external stakeholders, and on the neighborhoods surrounding the schools. The schools were selected from a single pool of potential sites within two urban school districts: Baltimore City Public Schools (BCPS) and District of Columbia Public Schools (DCPS), with a mix of modernized and non-modernized buildings within the sample. The modernized buildings included facilities that were renovated and often added onto, as well as several new buildings that had replaced prior facilities. While some of the non-modernized buildings had additions constructed or minor improvements to such things as furniture or interior finishes, plus some capital reinvestment over time, that work had occurred sufficiently long ago or in such minor amounts for the building to be considered non-modernized at the time of the study.

In the same way that most of the world was impacted by the COVID-19 pandemic, this study’s research timeline and process were affected as well. The Latrobe Prize grant was awarded in June 2019, and mandated a two-year timeline for completion of the research. While the research team was able to complete some data collection before most public schools shut down in March 2020 as a result of the pandemic, other data-gathering had not even begun. As a result, while the researchers continued to adapt the methodology and data collection tools to respond to changing circumstances, certain aspects of the research plan had to be abandoned. For instance, questionnaire distribution to community stakeholders was eliminated, plans for interviews had to be scaled back, and the research team found that stakeholder engagement, overall, yielded less data than was hoped for due to reduced participation in the study. Still, the researchers believe this study has yielded important insights and valuable information.

**Overall, the results of the study support the researchers’ hypotheses:**

- The modernized schools in general outperformed non-modernized schools around key Indoor Environmental Quality indicators (thermal comfort, air quality, acoustics, and light).
- The modernized schools in general outperformed the non-modernized schools in terms of Educational Adequacy, particularly in regard to school presence, building organization, the sense of community within the building, classroom ambiance, and the perceived safety of the school buildings and campuses.
- The modernized schools provided more Community Connectivity than non-modernized schools. It should be noted, however, the CC findings were based on limited data as this part of the study was the most limited due to the impact of the COVID-19 pandemic.
The study’s findings have significance. When evaluating the impact of the many factors comprising each of the three variables (IEQ, EA, and CC), the study found that school modernization has the biggest impact on (listed from greatest to least statistical effect size): Instructional Space Ambiance; Architectural Presence, Safety and Security, Air Quality, the Main Office, Thermal Comfort, Light, Community Access, and Acoustics.

The study’s researchers also looked for patterns in each district’s archival data and found statistically significant relationships between modernization and school enrollment as well as standardized test scores in mathematics and English language arts over time. Additionally, the research team detected an upward trend in high school graduation rates among students who attended modernized schools, though this finding was not statistically significant.

Looking forward, this report offers several recommendations regarding school modernization for policymakers, school district administrators, and designers. Design recommendations based on this study’s findings include:

- Improve the learning ambiance in instructional spaces
- Enhance civic presence, arrival, and community access
- Control access for safety and security
- Invest in indoor environmental quality for healthier, higher-performing spaces
- Create a “heart” of the community
- Accommodate community partners on-site to magnify their impact
- Consider how the community can engage with a school’s campus/grounds
- Recognize that modernization impacts community members differently
Consistent with the goals of the Latrobe Prize, there are also suggestions for how future researchers can build on this study, including specific guidance in this report’s Appendices for replication (and enhancement) of the work.

Even as the research team proposed this effort to the American Institute of Architects College of Fellows years ago, they articulated this study would only be the beginning of methodically identifying the benefits of modernizing school facilities across the country. Due largely to the COVID-19 pandemic, the researchers were unable to accomplish all that had been hoped for in this study. However, at a minimum, the researchers believe this study provides the groundwork for future researchers to further document how modernized schools can support the health and wellness of school stakeholders, help drive educational success, and solidify a school’s ability to play multiple roles in its community.

The research was supported by Baltimore City Public Schools and District of Columbia Public Schools and was conducted by a multi-disciplinary team of researchers from the global design firm Perkins Eastman and the Drexel University School of Education. The research team also included faculty from Drexel University’s Dornsife School of Public Health and the Architecture program at Drexel University’s Westphal College of Media Arts and Design, along with statistical analysis by Invontics. This work was done under the auspices of the Drexel-based Consortium for Design and Education Outcomes (CDEO), which Perkins Eastman and the Drexel University School of Education co-founded in 2019 to provide informed guidance to schools and school districts that are planning improvements to the health, safety, security, and performance of their learning environments.
Learning environments impact education. Schools also have the potential to positively impact the communities where they are located. The built environment matters.
Research has repeatedly demonstrated that the built environment affects people’s cognitive, social-emotional, and physical development. Of particular note, studies show “school conditions significantly impact learning experiences and student outcomes” (Filardo et al., 2019). Data from research studies to date, however, have not yet been sufficient to inform large-scale modernization programs. This is a significant consideration since an estimated 53% of public schools in the United States need renovations or modernizations to be considered in good overall condition—the cost of which would total around $197 billion (Alexander & Lewis, 2014). Many schools have not been able to address the continued deterioration of their facilities since numerous school districts across the nation have been dealing with capital construction funding shortfalls (Jackson & Johnson, 2021).

Empowering districts to advocate for greater funding, while also enabling them to more effectively spend the limited funds they do have, can help create school facilities that better enhance education. Schools also have the potential to impact the communities where they are located. These impacts can range from providing access to facilities like playgrounds and athletic fields to serving as a gathering place for civic events and, as was amply demonstrated during the height of the COVID-19 pandemic, as distribution points for much-needed items and services.

**The purpose of this study was to understand the differences between modernized and non-modernized primary and secondary education schools in terms of Indoor Environmental Quality (IEQ), Educational Adequacy (EA), and Community Connectivity (CC).** The goal was to understand the multiple impacts of school modernization on various stakeholders to better inform the decision-making about future school-construction projects. This, in turn, would provide specific data about the potential benefits of school modernization to help jurisdictions make a stronger case for the importance and funding of school modernization. In addition, the research team wanted to provide guidance for designers and school district administrators about actionable interventions that have a demonstrably positive impact on educational and community outcomes, such that decision-makers could effectively spend the forecasted billions in modernization dollars to achieve their core mission of educating students for life in the 21st century.

**Addressing a Multi-Billion Dollar Challenge**
This study's research questions included:

(1) Is there a difference in outcomes between modernized and non-modernized schools?

Hypotheses:

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• Modernized schools offer greater Educational Adequacy (EA) than non-modernized schools.
• Modernized schools provide more Community Connectivity (CC) than non-modernized schools.
• Teachers, staff/administrators, and students at modernized schools have greater well-being than those in non-modernized schools.

(2) If there is a difference, how do the outcomes compare between modernized and non-modernized schools, within the frameworks of IEQ, EA, and CC?

Built on precedent research, this study was set to break new ground. The research team (a collaboration of experts in design, sustainability, research, and education, alongside the leadership of two major urban school districts) has created one of the most comprehensive studies linking the built environment to educational outcomes and other community impacts. This report describes the study, its findings, and the implications for school design moving forward.

Study Definitions

Modernized schools were considered facilities that had within the past decade received a major capital reinvestment with the goal of comprehensively updating, realigning, or replacing program spaces, building systems, and furniture, fixtures, and equipment, as well as bringing the facilities into code compliance, to better serve school and community needs. In some cases, but not all, modernized schools are new buildings that replaced existing, obsolescent facilities.

Non-modernized schools were considered environments that did not meet the above definition.

Indoor Environmental Quality (IEQ) considered the following properties of the built environment: thermal comfort, air quality, acoustics, and lighting.

Educational Adequacy (EA) considered how well a school's spaces and design features—inside and outside the classroom as well as inside and outside the building—supported learning and teaching within that environment.

Community Connectivity (CC) considered how a school's spaces and design features, both inside and outside the building, supported stakeholders' perceptions about, use of, and engagement with the school, including how well the school enabled interaction between its stakeholders.

Stakeholders included two groups: internal (a school's administrators, teachers, staff, students, and students' parents/caregivers) and external (including but not limited to the residents and businesses in the surrounding neighborhood). Data collection sites included primary and secondary schools (elementary, middle, and high schools).

Well-being considered both health/wellness and quality-of-life indicators by exploring how a school's spaces and design features, both inside and outside the building, contributed to stakeholders' physiological health, psychological health, and cognitive function.

Analysis terminology: In this report, the term “significant” is used to identify a statistical significance, meaning there was a difference between the modernized and non-modernized schools and that the findings were not due to chance. The term “slightly” is used to indicate a noted difference that did not result in a high level of statistical significance. “Effect size” indicates how large a difference there is between the two groups. A large effect size indicates the finding has greater practical application, whereas a small effect size means the real-world applications are limited. For this study, eta-squared values were interpreted such that 0.10 to 0.29 were small effects, 0.30 to 0.49 were moderate effects, and 0.50 or greater were large effects (Cohen, 1988).
WHY THIS STUDY MATTERS

The interest in this study's area of investigation stemmed largely from Perkins Eastman's precedent research study *Investing in Our Future: How School Modernization Impacts Indoor Environmental Quality and Occupants* (Jauregui et al., 2018), which focused on the impact of school modernization on student and teacher well-being, satisfaction, and performance. Indoor Environmental Quality factors (thermal comfort, air quality, acoustics, and lighting) were studied in five modernized schools compared to four non-modernized schools in Washington, DC. The study found that modernized schools showed statistically significant improvements over non-modernized schools, and there was greater occupant satisfaction with IEQ in the modernized facilities. The research team saw these findings as a stepping stone for further inquiry—with a goal of not only expanding the scale of the sample (i.e., the numbers of school districts and schools involved) but also exploring other variables, knowing that factors other than IEQ play a role in school stakeholders’ well-being, satisfaction, and performance.

Another key element that led to this study was the founding of the Consortium for Design and Education Outcomes (CDEO) in 2019 by Perkins Eastman, a global design firm, and Drexel University, an R1 research institution, whose collective goal is to study the impact of environmental design on educational outcomes. With millions of students attending school every day in obsolete and often unhealthy facilities, CDEO’s research is intended to provide informed guidance to schools and school districts planning improvements to health, safety, security, and performance of their learning environments (Perkins Eastman, 2019). Key members of CDEO joined this study's research team to provide design and pedagogical expertise.

As explained in the following sections, additional factors further justified the pursuit of this study, including: the importance of the built environment in education; how recent world events are reshaping schools and communities; the value of schools to their communities; school modernization programs across the country; the principles of high-quality 21st-century learning environments; and precedent research in the areas of Indoor Environmental Quality, Educational Adequacy, and Community Connectivity.
Over the last decade, the concept of “whole child” success has gained momentum and support from educators, neuroscientists, learning scientists, and health professionals. The research-based whole child approach is focused on how a student grows physically, cognitively, psychologically, socially, and emotionally within learning environments (Darling-Hammond & Cook-Harvey, 2018). Hinging on creating a positive school climate for productive learning, the whole child approach recognizes the importance of the environmental conditions of learning. Research around this topic has repeatedly demonstrated the impact that the built environment of schools has on the whole child through social-emotional health, physical health, and learning; teachers’ health, effectiveness, job satisfaction, and retention; and a school’s connectedness to the community at-large.

Growing evidence highlights the effects of the built school environment on students’ social-emotional and physical health (Evans, 2003; Küller et al., 1992; Meklin et al., 2005; Myhrvold et al., 1996; Norbäck et al., 2013). Research also indicates that students’ health is directly correlated with student learning and success (Basch, 2011; Magzamen et al., 2013; Magzamen et al., 2017). For example, improved indoor air quality has been linked to improved respiratory rates (Breysse et al., 2011) and fewer student absences (Free et al., 2010). Studies have also shown clear evidence that the built school environment directly impacts student learning progress in reading, writing, and mathematics (Barrett et al., 2015).

Students are not alone; research has also demonstrated that the built environment and environmental conditions impact teachers as well, which ultimately has implications for whole child well-being. Teachers report higher job performance and satisfaction (Gibson & Levenstein, 2010) and overall better health (Patovirta et al., 2004) within higher-quality school designs and environments. Research has also shown that teacher retention and satisfaction led to increased student success (Berry et al., 2021).

The sphere of influence of the built school environment also impacts the community where the school is located. Historical research has indicated the positive impact school buildings can have on a community’s housing prices and local economies (Bayer et al., 2007; Nathan & Davis, 2018; Neilson & Zimmerman, 2014). Additionally, place-based educational strategies, such as full-service Community Schools, have been supported through federal and local policy as an avenue to increase community wellness, health, and access to food (Dryfoos, 2005; Jacobson, 2020; Medina et al., 2020; United States Department of Education, 2012).

The multiple avenues of impact that the built environment and a building’s environmental conditions have on the whole child and their educational and lifetime success is considerable. Too often, though, the discussion about facilities and infrastructure of schools has not gone beyond architects and professionals in the construction industry or certain other interested parties (Magzamen et al., 2017). This is reflected in the literature, especially education research, and this gap is what this study seeks to address.
Addressing a Multi-Billion Dollar Challenge
World Events Are Reshaping Schools and Communities

Over the last few years, there has been a shift in focus in the United States around the safety and well-being of students and teachers, the vital nature of Community Connectivity for schools, and the requirements of built infrastructure to meet the 21st-century learning demands of primary and secondary education. The year 2020 marked the emergence in the United States of the COVID-19 global pandemic. As of September 2023, there have been over 1.14 million COVID-19-related deaths in the United States alone (Centers for Disease Control and Prevention, 2023).

The onset of the COVID-19 pandemic demanded that teaching and learning had to immediately shift to virtual environments (Gedro et al., 2020). Practically overnight, more than 50.8 million students in public schools across the United States had their school buildings shut down (Bailey, 2021). It is estimated that between 2020 and 2021, students lost over a fifth of their traditional annual predicted learning. The impact was even worse among historically marginalized students, including Black and Latino students, English-as-a-second-language learners, students with exceptionalities, and students who attend high-poverty schools and/or whose families have a lower socioeconomic background (Lewis et al., 2021). Researchers conservatively estimated that Caucasian students had seven to eight months of learning loss, while students of color had more than 11 months of loss (Dorn et al., 2020; Sparks, 2020).

At the same time families were coping with the COVID-19 crisis and its attendant economic fallout, with more than 40 million people filing for unemployment. Americans were also witnessing the killing of multiple unarmed Black men and women—unfortunately not a new phenomenon but one that drew heightened attention. These four events—the pandemic, climate change, massive unemployment, and unrest derived from persistent social injustice—concurrently influenced the country (Galea & Abdalla, 2020), impacting not only students’ learning but also their social-emotional well-being. Their families and communities saw increased poverty, violence, and trauma (Zhou et al., 2021). The percentage of students showing social-emotional or behavioral concerns was anticipated to triple due to these traumatic factors (National Association of School Psychologists, 2020). More than 35% of parents in the United States said they were very or extremely concerned for their student’s mental health (Dorn et al., 2021).

Most students, teachers, and staff/administrators started returning to school buildings in Fall 2021. As they returned, a mission to ensure safe, healthy, and supportive environments that promote the whole child’s well-being became—and continues to be—a top priority for school stakeholders (Bailey, 2021).

WHY THIS STUDY MATTERS

Addressing a Multi-Billion Dollar Challenge
Throughout the crises of the last few years, schools have solidified themselves as hubs for community activity, support, and resources. In addition to the traditional delivery of education, schools have provided technology, food services, social-emotional support, and health services. Throughout the COVID-19 pandemic, people gained a greater understanding of the importance of schools and their built environments, beyond the simple schoolhouse concept of only entering a school building for academic purposes. There has been a renewed focus on what schools can be and do for all community stakeholders. This alignment supports the whole child movement, which is linked to the concept of well-being for students, but also teachers, community members, and other stakeholders.

In 2017, the Health Building Teams at the Harvard T. H. Chan School of Public Health reviewed findings of over 250 research articles in their report *Schools for Health: Foundations for Student Success*. This report “synthesizes more than 30 years of research about the impacts of Indoor Environmental Quality in schools, identifies diverse metrics of success beyond standardized test scores, and provides an accessible, evidence-based guide to the daily, acute, and chronic effects school buildings have on students and staff” (Eitland & Allen, 2019). Though these findings currently inform policies for education and infrastructure across the country, researchers have pushed to expand the lens of school health and student achievement to a broader definition that includes assessing the overall health, engagement, and usage of schools for community well-being and, in turn, student success (Cohen & Schuchter, 2013; Eitland & Allen, 2019).

Additional attempts to engage stakeholders and promote the well-being of communities have been gaining momentum in the conversations surrounding school reform, including urban and rural school closures and the full-service Community School movement. When faced with school reform choices that would close urban and rural schools, communities consistently push back, “highlighting their local school’s long-term importance to their neighborhood as an institutional resource—a dimension of value not captured by enrollment-based closure decisions” (Basu, 2007). These cases specifically draw attention to the roles schools have as hubs of “community relational networks” (Bondi, 1987; Oncescu & Giles 2014) and engines for creating social capital development (Brinig et al., 2010; Fischel, 2006; Witten et al., 2007). An article about schools as a nexus for community development states, “schools [are] social hubs and sources of social support, as neighborhood organizations, as supporters of local business and anchors of economic development” (Good, 2022, p. 605).

Even within the understanding of the importance of the built environment for learning and stakeholder well-being, research has highlighted the demand for additional cross-disciplinary evidence of this connection (Eitland et al., 2017). This study directly addresses this request by exploring the impact of the built environment and the well-being of school stakeholders, and ultimately on student success. It is only through studies like this, which take a multi-disciplinary approach, that policymakers will have a fuller understanding of their decisions surrounding school infrastructure and modernization on students and the communities where the schools are located.
Half of all public schools in the United States are said to need major facility repair (Alexander & Lewis, 2014). However, it was estimated in 2021 that the United States under-invests in the maintenance, operations, and capital expenditures for maintaining public school facilities by $85 billion a year (Filardo, 2021), leaving millions of students in buildings that are outdated. This is a dramatic increase of more than $25 billion compared to the findings from a 2016 report (Filardo, 2016)—a concerning trend that has serious negative implications if not reversed. Further, this shortfall is neither economically nor geographically distributed. School districts with high or medium rates of poverty were found to have invested up to 12.4% less in per-student expenditures than districts with low rates of poverty (Allegretto et al., 2022)—not necessarily as a matter of choice but due to factors beyond their direct control. Further, urban districts typically face higher construction costs than other jurisdictions.

Though school districts across the nation are attempting to modernize their facilities as funding allows, when schools become outdated, students and teachers may be exposed to poor air quality, mold, inconsistent air temperatures, insufficient lighting, overcrowding, disorganized layouts, and other facility issues—all of which may be tied to an increased probability of lower academic success. In 2011, the United States Environmental Protection Agency reported an estimated 46% of public schools have poor environmental conditions (United States Environmental Protection Agency, 2011). Research has also demonstrated that schools with infrastructure that is neglected, in disrepair, or relies on temporary buildings suffer from lower student attendance rates and higher drop-out rates (Branham, 2004; Kelling & Wilson, 1982).

Educational success requires school facilities that promote learning through the provision of a healthy and safe environment (Wargocki, 2015). This study set out to understand what impact modernization may have on stakeholders, and accordingly, what recommendations can be made to those investing in the modernization of school infrastructure.
As the nation modernizes schools for the 21st century, several factors need to be considered when designing these new or renovated facilities, including the increasing urbanization of the nation’s population, changing climates, standardized health performance indicators, and continued national school infrastructure assessment (Etland et al., 2017). Researchers have noted that successful school structures in the 21st century must fit four main categories: flexibility, sustainability and resiliency, community engagement, and small schools (Hanover Research, 2011). Specifically, in terms of design, 21st-century classrooms must include collaborative spaces, flexible furnishing, natural lighting, bright colors, integration of technology, and hands-on learning environments (Krueger, 2018).

Components of 21st-century learning, being a product of the problem-based learning approach, incorporate the need for flexible classroom spaces and learning environments, and are in more demand than ever (Pearlman, 2010). Further, researchers have linked the importance of learning environments directly to 21st-century learning by noting that design translates directly into facilities’ pedagogical designs (Washor, 2003). Twenty-first century learning environments also extend beyond student learning to teacher engagement and collaboration (Sigurdardottir & Hjartarson, 2011). School design is no longer simply about the classroom; it is moving beyond these traditional spaces to incubator spaces, home base, specialized focus labs, project spaces, outdoor spaces, breakout spaces, presentation spaces, libraries, classrooms, and many others (Fisher, 2005; Li et al., 2005).

As the Organisation for Economic Co-operation and Development (OECD) stated in 2006, “The principles of lifelong learning, inclusion, integration, sustainability, connectivity, and quality have become catchphrases of educational policy... and those responsible for designing educational facilities are responding in new and exciting ways.” While the OECD points to varied and diverse settings that support these principles, for purposes of this study, the research team focused on the environmental design response associated with the design of contemporary public schools in the United States.

Building upon the principles defined by each of the study’s participating school districts in their Educational Specifications and the literature review performed for this study, the principles defining 21st-century schools could be expressed as:

- Honor the value that the community places on education through an appropriate and ennobling presence in the school’s context.
- Engage the community by providing services and resources that sustain not only children but enhance the resilience of families and neighbors.
- Strive to become an oasis of safety, enhancing each user’s ability to focus on teaching and learning.
- Respond to the social, emotional, cognitive, and other developmental needs of the children being served.
- Welcome all learners through supportive and adaptive learning environments.
- Provide sufficient flexibility to enable diversity of activity on a daily basis and to allow the pedagogy, technology, and curriculum to evolve over time.
- Foster the development of a strong professional community among teachers.
- Leverage every square foot as educational space, inside and out.
- Enhance health and well-being through the provision of appropriate indoor environmental quality.
- Connect learning to the real world, through sustainable design, to address issues of climate change and social and environmental justice.
Indoor Environmental Quality (IEQ) consists of a complex relationship of several factors that impact the well-being of occupants within a building. While there is ongoing research into which physical, psychological, or social indicators best reflect how occupants respond to these factors, there are also several techniques for measuring the IEQ indicators themselves, such as thermal comfort, air quality, acoustics, and lighting (Bluyssen et al., 2011). Researchers also note that, to have a truly comprehensive model of IEQ, data must be gathered through objective measurement as well as “occupants’ perception of their indoor building environment” (Nimlyat, 2018, p. 598).

Over the years, research has established direct correlations between building design and the well-being of students and teachers. IEQ has specifically been shown to have an impact on human health and academic performance (Al Horr et al., 2016; Redlich et al., 1997; Seppänen & Fisk, 2006). For example, a study found that students in daylit classrooms progressed 20% faster on mathematics tests and 26% faster on reading tests than students in windowless classrooms (Heschong Mahone Group, 1999). IEQ-focused renovations have also been connected to long-term academic performance (Stafford, 2015). Some researchers also suggest learning disorders may develop as a result of insufficient acoustic conditions (Bottalico & Astolfi, 2012).

Research on environmental factors such as lighting, school location, classroom design, room size, and ventilation rates have shown how a school can impact children’s learning and behavior (Killeen et al., 2003; Knez & Kers, 2000; Kuo & Sullivan, 2001; Ulrich, 2004). For instance, lighting has been shown through experimental studies to “significantly alter the positive and negative mood of the participants, in addition to impairing or enhancing cognitive performance in memory and problem-solving tasks” (Kumar et al., 2008, p. 457).

Research has also demonstrated that IEQ varies from building to building, and that air quality is correlated with the socioeconomic status of the community in which the school is located, because the proximity to industrial sites and neighborhoods with less greenery affect outdoor air conditions (Hänninen & Haverinen-Shaugnessy, 2015). Modernization, however, can dramatically improve indoor air quality. Unfortunately, school districts of lower socioeconomic status have not historically invested in modernization at the same level or at similar rates as districts in more affluent communities. Thus, the combination of external air quality conditions in urban neighborhoods and minimally modernized school environments should be considered an equity issue when thinking about air quality in schools. “The school environment must be homogeneously clean, safe, and comfortable in order to reduce exposure to chemical and biological agents, prevent diseases, facilitate cognitive development, and avoid unequal educational outcomes” (Alonso et al., 2021, p. 1). As the country strives to provide a more equitable educational system and facilities designed around the well-being of the whole child, examining how IEQ differs from building to building is vital.

Of further interest on a national scale, Indoor Air Quality (IAQ) and ventilation in schools were of particular focus during the COVID-19 pandemic, as many looked for ways students could return to school buildings as safely as possible (Jones et al., 2020). The potential effects of IAQ on students’ health and academic performance has been well-researched (Alonso et al., 2021). Additionally, studies have confirmed that the transmission of COVID-19 increases in indoor environments with high occupancy, including classrooms (Africa, 2020; Noorimotlagh et al., 2021). Specifically examining the ventilation rate of occupied spaces can indicate the risk of indoor pollutants on the health and well-being of students and teachers (Fisk, 2017; Lipinski et al., 2020). Researchers have demonstrated that IAQ in schools is associated with lung function, respiratory systems, respiratory infections, and absenteeism (Madureira et al., 2015). Through cross-sectional studies, researchers found associations in IAQ and educational outcomes specifically for carbon dioxide (CO$_2$) and temperature. “Approximately one third of surveyed school administrators who have implemented IAQ programs have reported fewer asthma attacks, fewer visits to the school nurse, and lower absenteeism” (Magzamen et al., 2017, p. 378).

By studying IEQ, including IAQ, in schools, this study aimed to understand the impact of IEQ-focused modernization efforts on occupants’ well-being, satisfaction, and performance—requirements that need to be considered for an equitably designed educational facility.
There is a considerable and growing body of peer-reviewed literature focusing on how the quality of a school facility impacts student achievement as well as teacher effectiveness and retention (Filardo et al., 2018). It is important that schools be considered safe, healthy, and attractive places where students feel they can thrive (Castaldi, 1994). Educational Adequacy (EA), in terms of school facilities, is an assessment of how well a school’s spaces and design features (inside and outside the classroom, as well as inside and outside the school building) support learning and teaching within that environment. For example, a study of more than two dozen schools found that well-designed primary schools enhance children’s academic performance in reading, writing, and mathematics (Barrett et al., 2015). They found that differences in the physical characteristics of classrooms explained 16% of the variation in learning progress over a year. Others have “advocated that the classroom should be an extension of the home and neighborhood, a place to encourage spatial freedom so that children might explore, work with manipulatives, and complete creative activities” (Tanner, 2015, p. 11).

Studies have also shown how the construction of new schools with flexible spaces and design features can directly impact student test scores, school enrollment, and neighborhood housing prices (Neilson & Zimmerman, 2014; Lafortune & Schönholzer, 2017). Another study found that schools in better physical condition and that had taken steps toward modernization had higher teacher retention rates compared to buildings that were non-modernized and/or had poor physical conditions (Buckley et al., 2004). Low EA has also been recognized as a barrier for teaching and the implementation of specialized curricula—a key component for 21st-century learning environments and meeting 21st-century learning goals (Filardo et al., 2018).

Researchers have noted that the impact of EA on students’ education can be “conceptualized as an additional ‘teacher’ in which children learn from interactions with the physical environment” (Magzamen et al., 2017, p. 379). In this vein, research has also highlighted the importance of movement and circulation within schools as part of the process of learning, noting that students and teachers are an integral part of the environment, not separate entities (Tanner, 2015).

Additional design patterns of successful 21st-century schools have been identified through a meta-analysis of architectural design in schools, including: safety and security, display spaces and places for student artifacts, safe spaces for personal belongings, quiet places within spaces, green spaces, outdoor rooms, instructional neighborhoods, technology for students and teachers, public areas, color configurations, the roof system, and one’s overall impression of the school (Tanner, 2015). The notion of EA gets to the way teachers, students, and families view their school’s design. The concept of instructional neighborhoods has been linked, through decades of research, as a strong influence on student achievement (Earthman, 1995; Tanner, 2015).

By investigating EA in schools, this study aimed to contribute to the knowledge base by identifying spaces and design features within schools that impact the way students and teachers interact with the educational environment.
Schools have traditionally served as anchors for their communities. Primarily, schools offer the physical space where young people learn. However, they also serve as connecting points for people in the surrounding neighborhoods who engage with the school. Researchers have found this concept of Community Connectivity (CC) to be critical to sustaining a vibrant town or city (Cohen & Schuchter, 2013; Jourdan et al., 2021).

One facet of CC is the connectedness that students may feel with their school, which helps establish positive behavior patterns and life choices for their current and future health. In fact, “school connectedness was found to be the strongest protective factor for both boys and girls to decrease substance use, school absenteeism, early sexual initiation, violence, and risk of unintentional injury (e.g., drinking and driving, not wearing seat belts) … and as a protective factor against emotional distress, disordered eating, and suicidal ideation and attempts” (Centers for Disease Control and Prevention, 2009, p. 5). Teachers’ health and performance is also related to their feelings of connectedness to their place of work and their school building.

Beyond impacting “student and teacher health and performance, [schools] are vital community assets” (Filardo et al., 2018, p. 4). Research has demonstrated that school closures have negative social, institutional, economic, and physical implications on neighborhoods (Foster & Brooks-Gunn, 2013). Additionally, residents of neighborhoods in the process of perceived gentrification have voiced feelings of exclusion when schools are built for the influx of new populations into their communities (Danley & Weaver, 2018).

From a more positive perspective, schools can and do play important roles that transcend their core mission of educating children. The COVID-19 pandemic shined a light on this fact. For example, during this time of crisis, schools served as distribution points for food.

Since the founding of the first public school in the United States in 1635 (National Geographic Society, 2023), schools have demonstrated an important civic value by serving as voting venues, a gathering place for community events, a home for cultural and other entertainment offerings, and a location for adult education classes, among other activities. The United Nations has also recognized schools as an important mitigating factor in disaster response (Takahashi et al., 2015). In times of community-wide upheaval, schools become “sites and sources of community resilience in five distinct ways: they distribute social welfare services, promote human development, care for children, provide stable employment, and strengthen democratic solidarity” (Fay et al., 2020, p. 2).

In recent years, the Community School strategy in the United States has increased in popularity as a means of, among other things, developing neighborhood connectiveness through “building trust, establishing norms, and linking people to networks and services” (Diamond & Freudenberg, 2016)—especially in areas facing cycles of poverty, crime, and disengagement. Full-service Community Schools have been shown to help residents by “navigating fragility and building resilience” (Herrenkohl et al., 2019, p. 121). These schools generally are based on several pillars, or critical practices, including “(1) integrated systems of support, (2) powerful student and family engagement, (3) collaborative leadership with shared power and voice, (4) expanded and enriched learning opportunities, (5) rigorous, community-connected classroom instruction, and (6) a culture of belonging, safety, and care” (Learning
Policy Institute, n.d.). At this point in time, only a relatively small percentage of public schools in the United States can be considered full-service Community Schools. However, a larger number of schools throughout the nation incorporate into their operations “integrated student supports” or “wraparound services” that help to accomplish many of the outcomes pursued by the full-service Community Schools.

While not all schools actively strive to create and maintain strong connections to their communities, research has shown that building relationships with the stakeholders surrounding the physical school environment can increase area property values, civic engagement, and residents’ overall safety and health (Cohen & Schuchter, 2013; Sampson et al., 2002). Building these relationships can also serve the school and its district well by solidifying the public’s view of the school as a positive presence in the community (Neilson & Zimmerman, 2014). In turn, this can lead to increased stakeholders’ involvement inside the school building as well as their support for school funding. Among stakeholders ranging from policymakers to researchers to teachers, however, there is still a persistent gap between their understanding of and appreciation for great school design and its ability to enhance community connectedness (Foster & Brooks-Gunn, 2013).

As whole child well-being in a 21st-century learning environment becomes a critical priority for schools across the nation, we must focus our attention on how existing school buildings, plus new or renovated ones in the future, can encourage Community Connectivity (CNN, 2016; Cohen & Schuchter, 2013).
This study employs a five-part, multi-method approach plus a literature review to address the research questions (Table 1). Data were collected at participating schools, from their internal and external stakeholders, and on the neighborhoods surrounding the schools. The following sections of this report describe each of the methodologies used in the study. For information about replicating the study (i.e., specific tools and procedural guidelines), refer to the Appendices.

Of note, the originally planned methodology had to be adjusted given the challenges of conducting the study during the COVID-19 pandemic—either due to health and safety precautions, changes in the participating schools’ occupancy loads or policies, and/or other factors complicating the completion of the data collection phase. Included in each description of the methodologies herein is a summary of what the research team originally intended alongside how the study had to be modified due to the pandemic and related unforeseen circumstances.

Given the challenges of conducting the study during the COVID-19 pandemic, the originally planned methodology had to be modified. Details are explained herein.

### Methodological Approach

**HYPOTHESES**

- Modernized schools have better Indoor Environmental Quality than non-modernized schools
- Modernized schools offer greater Educational Adequacy than non-modernized schools
- Modernized schools provide more Community Connectivity than non-modernized schools
- Teachers, staff/administrators, and students at modernized schools have more positive well-being outcomes than those in non-modernized schools
- Teachers, staff/administrators, and students at modernized schools have more positive well-being outcomes than those in non-modernized schools

**TABLE 1. The Study’s Research Questions and Data Collection Processes**

<table>
<thead>
<tr>
<th>RESEARCH QUESTION #1</th>
<th>Is there a difference in outcomes between modernized and non-modernized schools?</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESEARCH QUESTION #2</td>
<td>If there is a difference, how do the outcomes compare between modernized and non-modernized schools, within the frameworks of IEQ, EA, and CC?</td>
</tr>
</tbody>
</table>

- Literature Review
- IEQ Data Logging with Live Measurements
- Visual Assessments with Floor Plan Analysis and Photography
- Stakeholder Questionnaires
- Stakeholder Interviews/Focus Groups
- Archival Data
This study used an explanatory sequential mixed methods design (Creswell & Creswell, 2017), such that quantitative data were collected and analyzed prior to collecting and analyzing qualitative data (Figure 1). In such a design, the robust sources of quantitative data are collected to better understand the general research problem. Then, qualitative data are collected to further explain or elaborate on the findings of the quantitative results. The use of both quantitative and qualitative data allowed the researchers to thoroughly answer the research questions using various data sources.

Within the explanatory sequential design, the quantitative study followed a causal-comparative research design that sought to describe differences in IEQ, EA, and CC between schools based on the modernization status of the school (i.e., modernized or non-modernized). Such a design did not involve the manipulation of any independent variable, but instead aimed to identify any observable differences across the sample based on the presence of a previously occurred difference (i.e., modernization status).

The qualitative investigation of the study followed a phenomenological design, in which the “primary purpose of phenomenology as a research methodology stemming from its philosophical roots is to study what it is like as we find-ourselves-being-in-relation-with others ... and [in relation to] other things” (Vagle, 2018, p. 20). The use of phenomenology allowed the research team to understand stakeholders’ lived experiences in relation to their modernized or non-modernized schools.

Since this study used a causal-comparative design, the research team cannot directly make an argument for causality (as such an argument is only appropriate with the use of an experimental design). Instead, the purpose of this study was to more deeply describe potential differences present within the naturally occurring groups (i.e., modernized versus non-modernized schools). Additionally, through the mixed methods design, any observed differences discovered during the quantitative analysis were more thoroughly explored through the qualitative analysis. Therefore, while other existing studies have identified differences between modernized and non-modernized schools (e.g., the Clever Classrooms study by Barrett et al., 2015), this study sought to obtain a deeper and more holistic understanding of the existence of these differences and the potential reasons for those differences.
This research study began in June 2019, when the American Institute of Architects College of Fellows (AIACOF) and J+J Flooring (J+J) provided generous grants to perform the work. When first proposed, the study had a two-year timeline, as shown at right.

In March 2020, however, when the research team was in the midst of collecting data in the field, the study was interrupted by the onset of the COVID-19 pandemic. At first, all work on the study ceased due to both health and safety concerns as well as the fact that the spaces being studied suddenly became unoccupied. The researchers assumed on-site measurements would resume within just a matter of weeks. Unfortunately, the study went on hold as concerns for people’s well-being continued and remote learning became the norm through the rest of the 2019-2020 academic year.

When the study was halted, the completed data collection up to that time included:

- IEQ on-site metrics (data logging and live measurements) had been collected at 21 schools (65% of the original sample);
- Visual Assessment Tool data had been collected at 17 schools (50% of the original sample);
- Questionnaires had been developed for five different user groups in two different school systems, with rollout dates coordinated for each district, but distribution had not yet begun; and
- Interview guides had been developed, but data collection had yet to be scheduled.

By September 2020, the researchers had a better understanding of how the participating school districts would reopen for the 2020-2021 academic year. Accordingly, the research team began strategizing how to continue the study in a meaningful way and discussed with the school districts how and when to restart data collection. The researchers decided on two key approaches for restarting the study: First, the study’s research design, research questions, and hypotheses would largely remain the same. Slight modifications were necessary, however, to reflect changes in perceptions about what constitutes a “high performance” school in light of mid-pandemic thinking. For instance, in the definition and associated evaluation of “modernized” schools, the research team now took into consideration such things as the role of a school as a community center when it is not performing its primary academic function. The second key decision the researchers made was related to how data could be collected with schools remaining unoccupied or only partially...
occupied during the academic year, and how that ultimately would impact the study’s sample. (Refer to the Sample and Sampling Methods section for information on how the study’s sample changed due to the COVID-19 pandemic.)

In Fall 2020, the study resumed with the following changes. Details around these modifications to the study are provided in upcoming report sections.

- A modified sample
- Revised methodological approach where necessary (e.g., virtual engagements rather than in-person activities)
- Updated data collection tools, as appropriate (e.g., removal of content in the questionnaires that may be skewed by recent events, such as questions about the building’s effect on one’s well-being)
- An updated timeline

One of the biggest changes to the revised study was its timeline. Where the research team had originally planned for a two-year long exploration, the pandemic-induced delays—plus general difficulties coordinating with schools that were mired in their own challenges during this time—resulted in a considerable extension of the study’s schedule. As such, the study’s actual timeline is as follows. Included therein are the interactions with the study’s Advisory Committee (experts in the field who were engaged by the research team to guide the study).

### ORIGINAL (PRE-PANDEMIC) TIMELINE

<table>
<thead>
<tr>
<th>Phase 1: Study Initiation and Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>June 2019 – September 2019</strong></td>
</tr>
<tr>
<td><strong>Objectives:</strong> exploratory and feasibility planning; precedent research and literature review; development of the comprehensive plan (scope, methods, schedule, budget); establishment of the Advisory Committee</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phase 2: Methodology Development</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>October 2019 – December 2019</strong></td>
</tr>
<tr>
<td><strong>Objectives:</strong> sample identification; tool procurement/development; data collection prep and site coordination; creation of training materials for data collectors; selection and training of data collectors; obtain school clearances for data collectors; begin IRB approval process</td>
</tr>
</tbody>
</table>

- Milestone: Deliverable 1 (progress report) to be submitted to AIACOF and J+J in December 2019

<table>
<thead>
<tr>
<th>Phase 3: Data Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>January 2020 – May 2020</strong></td>
</tr>
<tr>
<td><strong>Objectives:</strong> floor plan analysis; on-site IEQ metrics (data logging and live measurements) and data download; on-site visual assessments, with photography; questionnaires; interviews and transcriptions; archival data collection; creation of community profiles</td>
</tr>
</tbody>
</table>

- Milestone: Deliverable 2 (progress report and presentation at the 2020 AIA National Convention) to be submitted to AIACOF and J+J in May 2020

<table>
<thead>
<tr>
<th>Phase 4: Data Analysis and Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>June 2020 – December 2020</strong></td>
</tr>
<tr>
<td><strong>Objectives:</strong> quantitative analyses; qualitative analyses; reviewing outcomes and development of recommendations; data visualization</td>
</tr>
</tbody>
</table>

- Milestone: Deliverable 3 (draft of the final report) to be submitted to AIACOF and J+J in December 2020

<table>
<thead>
<tr>
<th>Phase 5: Reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>January 2021 – June 2021</strong></td>
</tr>
<tr>
<td><strong>Objectives:</strong> content creation and graphic design for final deliverable</td>
</tr>
</tbody>
</table>

- Milestone: Deliverable 4 (final report and presentation at the 2021 AIA National Convention) to be submitted to AIACOF and J+J in June 2021
June 2019–September 2019  
**Phase 1: Study Initiation and Planning**  
Exploratory and feasibility planning; precedent research and literature review; development of the comprehensive plan (scope, methods, schedule, budget); establishment of the Advisory Committee

| October 2019–December 2019  
**Phase 2: Methodology Development**  
Sample identification; tool procurement/development; data collection prep and site coordination; creation of training materials for data collectors; selection and training of data collectors; obtain school clearances for data collectors; begin IRB approval process |
|--------------------------|---------------------------------|
| October 2, 2019  
Advisory Committee  
Meeting to review the study’s intent and get feedback on the comprehensive plan |
| December 12, 2019  
Milestone  
Deliverable 1 (progress report) submitted to AIACOF and J+J (and shared with the Advisory Committee) |

| January 2020–February 2020  
**Phase 3: Data Collection (pre-pandemic original methodologies)**  
Floor-plan analysis; on-site IEQ metrics (data logging and live measurements) and data download; on-site visual assessments, with photography; creation of community profiles. Not yet begun before the onset of the COVID-19 pandemic: questionnaires; interviews and transcriptions; archival data collection |
|--------------------------|---------------------------------|
| January 15, 2020  
Advisory Committee  
Meeting to get feedback on Deliverable 1 and updates on the study’s progress |

| February 2021–February 2023  
**Phase 3: Data Collection (Post-pandemic modified methodologies)**  
Revised sample finalized; data collection resumes: on-site visual assessments (February 2021–June 2021); questionnaires (October 2021–November 2021); interviews and focus groups (March 2022–November 2022); archival data (December 2022–February 2023) |
|--------------------------|---------------------------------|
| June 8, 2022  
Advisory Committee  
Correspondence outlining the progress to-date |
| July 28, 2022  
Advisory Committee  
Meeting to discuss how to proceed with analysis and reporting given the complications with data collection |

| May 2022–April 2023  
**Phase 4: Data Analysis and Findings**  
Quantitative analyses; qualitative analyses; reviewing outcomes and development of recommendations; data visualization |

| June 7, 2023  
Milestone  
Final Presentation at the 2023 AIA National Convention |
|--------------------------|---------------------------------|
| July 27, 2023  
Milestone  
Final Presentation to J+J and participating school districts |

| December 2023  
Final report completed; submitted to AIACOF and J+J |
|--------------------------|---------------------------------|
March 25-31, 2020
Correspondence to AIACOF, J+J, Advisory Committee, and participating school districts outlining the progress to date, changes to the study due to COVID-19, and plans for moving forward with the study in Fall 2020

May 15, 2020
Milestone
Deliverable 2 (progress report) submitted to AIACOF and J+J (and shared with the Advisory Committee)

October 2020–January 2021
Modifications to the data collection processes/tools; resubmission to IRBs based on changes to the study; coordination with participating schools to restart data collection

October 6, 2020
Advisory Committee
Correspondence to get feedback on the study’s revised comprehensive plan

November 17, 2020
Correspondence to AIACOF, J+J, Advisory Committee, and participating school districts outlining the revised comprehensive plan

October 2022–December 2023
Phase 5: Reporting
Content creation and graphic design for final deliverable, including draft reviews by AIACOF, J+J, Advisory Committee, and participating school districts

June 7, 2023
Milestone
Final Presentation at the 2023 AIA National Convention

July 27, 2023
Milestone
Final Presentation to J+J and participating school districts

December 2023
Final report completed; submitted to AIACOF and J+J

MARCH 2020
Onset of the COVID-19 pandemic in the United States

April 2020–September 2020
Study on hold
Strategizing when and how the study could resume; modifications to the sample

March 25-31, 2020
Correspondence to AIACOF, J+J, Advisory Committee, and participating school districts outlining the progress to date, changes to the study due to COVID-19, and plans for moving forward with the study in Fall 2020

May 15, 2020
Milestone
Deliverable 2 (progress report) submitted to AIACOF and J+J (and shared with the Advisory Committee)

October 2020–January 2021
Modifications to the data collection processes/tools; resubmission to IRBs based on changes to the study; coordination with participating schools to restart data collection

October 6, 2020
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July 27, 2023
Milestone
Final Presentation to J+J and participating school districts

December 2023
Final report completed; submitted to AIACOF and J+J

Addressing a Multi-Billion Dollar Challenge

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Given the use of a mixed methods research design, the study employed a purposeful multi-level sampling procedure (Creswell & Creswell, 2017). A multi-level sampling procedure involves the use of two or more samples from distinct levels of the target population (Figure 2). The higher level of the sample for this study consisted of 28 schools, which were selected from a single pool of potential sites within two urban school districts: Baltimore City Public Schools (BCPS) and District of Columbia Public Schools (DCPS).

Typical of many urban school districts on the east coast of the United States, many of these schools are housed in buildings that were constructed mainly in the periods of 1920–1940, 1960–1980, and 2000–2010. The modernized buildings included facilities that were renovated and often expanded, as well as several new buildings that replaced prior facilities. While some of the non-modernized buildings had additions constructed or minor improvements made to such things as furniture or interior finishes plus some capital reinvestment over time, that work had occurred sufficiently long ago or in such minor amounts for the building to be considered non-modernized at the time of the study.

The 28 schools that made up this study’s sample are being referred to in this report as “School 1,” “School 2,” and so on. Though the research team has strived for confidentiality of the data collected by this study, anonymity of the participating schools or study participants cannot be guaranteed since some features (e.g., design elements, use of the schools) are described that may be recognizable by the public.

The second level of the sample includes internal stakeholders associated with the 28 schools, including school administrators, teachers, staff (from office workers to maintenance/facilities managers to food services support members), students, and students’ parents/caregivers. All internal stakeholders were invited to participate in the quantitative study through census sampling (Creswell & Creswell, 2017). A smaller subset of students’ parents/caregivers (n = 13) were invited to participate in the qualitative study through a combination of purposeful and maximum variation sampling. Further qualitative data collection was intended to occur with more students’ parents/caregivers as well as school administrators, teachers, staff, and students. However, this did not occur due to pandemic-related complications.
A third level of the sample, external stakeholders associated with the 28 schools (i.e., residents and members of the business community in the surrounding neighborhoods), was originally intended for the study as well. However, including these stakeholders was not possible due to the methodological revisions the research team had to make due to the COVID-19 pandemic.

Given the research team would be working with human subjects to collect data (i.e., interviews and focus groups, questionnaires), Institutional Review Board (IRB) approval was pursued for the study. IRB approval was granted by Drexel University on March 26, 2021, and Baltimore City Public Schools on April 29, 2021. Based on COVID-19 pandemic-related modifications that had to be made to the study’s methodologies and data collection tools, the researchers resubmitted for IRB approvals of these changes. The Baltimore City Public Schools IRB granted renewal of this approval for an additional year on April 28, 2022. There was no re-approval required by the Drexel University IRB, though modifications to the original plan were submitted to them in September 2021.

### TABLE 2. Original (Pre-Pandemic) Sample Distribution Between the Participating School Districts

<table>
<thead>
<tr>
<th>Grades</th>
<th>DISTRICT A</th>
<th>DISTRICT B</th>
<th>Schools per Grade-Band</th>
<th>Percent of Schools</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Modernized</td>
<td>Non-Modernized</td>
<td>Modernized</td>
<td>Non-Modernized</td>
</tr>
<tr>
<td>6th to 8th</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PreK to 5th</td>
<td>3</td>
<td>5</td>
<td>22</td>
<td>65%</td>
</tr>
<tr>
<td>PreK to 8th</td>
<td>7</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PreK to 5th, 8th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6th to 8th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle/High School</td>
<td>1</td>
<td>1</td>
<td>12</td>
<td>35%</td>
</tr>
<tr>
<td>9th to 12th</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>17</td>
<td>34</td>
<td>100%</td>
</tr>
</tbody>
</table>

### Original (Pre-Pandemic) Sample Selection Criteria

Using purposeful sampling, 34 schools were originally intended to be part of the study. These schools were selected based on a set of inclusion and exclusion criteria, with the goal of obtaining comparable schools between both groups (i.e., modernized and non-modernized). Purposeful sampling allowed for the selection of schools that would most likely yield the rich data necessary to thoroughly explore the study’s research questions.

The goal in choosing the sample was to select similar schools for both the modernized and non-modernized groups based on criteria such that the research team could control for confounding variables so the potential differences between schools could reasonably be attributed to their modernization status. For example, it was important for this study to include schools that educate students across Pre-Kindergarten through 12th grade-bands. Therefore, elementary, middle, and high schools (or combinations thereof, e.g., PreK-8 schools) were included in the study’s sample. The two participating school districts also requested commensurate representation in the study. Accordingly, the original sample was balanced closely between districts, modernization status, and grade-band (Table 2).
In addition to modernization status (modernized versus non-modernized) and grade-band representation (PreK-12), the schools were chosen by considering the following factors. The sample also included several schools that operate under the Community School model to address aspects of the CC research questions.

YEARS SINCE MODERNIZATION

Building on the Investing in Our Future study (Jauregui et al., 2018), the original qualification for admittance into this study’s sample was that the school had to have been modernized and occupied for at least five years. This timeframe was a consideration because existing research in school reform efforts indicate that it may take three to five years to observe change in school performance (Domitrovich et al., 2008; Rimm-Kaufman et al., 2007; Sugai & Horner R, 2006). This qualification was adjusted for this study, however, for the following reasons:

- In one of the participating school districts, the first schools to open under its current modernization program were occupied in 2017, approximately three years before the initiation of this study’s data collection. The five-year criteria thus had to be adjusted to balance the sample between the districts. A secondary benefit for the district was that, through this study, they would collect valuable data that could be used to adjust and improve their ongoing modernization program.
- The other participating school district’s modernization program had been operating since 2011, with incremental improvements and changes over the past decade. This district wanted to collect data from buildings that had been modernized at the beginning of their program as well as those that had been modernized more recently to measure their program’s progress.

ENROLLMENT AND UTILIZATION

Across the two school districts, enrollment was compared for schools with similar grade-bands. When developing the sample, the intent was to include schools with similar enrollments in both districts and between modernized and non-modernized groups. The mean enrollment for the original 34-school sample was 628 students; the median enrollment was 528 students. In general, the high schools had a higher enrollment than the elementary and middle schools, though there was one high school and three elementary/middle schools that deviated from this trend.

In addition to the size of a school’s enrolled student population, school utilization was also a critical factor for determining if a school was “right-sized” and that the program was using spaces as the designer intended. Accordingly, schools within the two districts that were over- or under-utilized based on 2019-2020 school-year data were excluded from the study where possible. The mean utilization rate for this study’s sample was 79%; the median was 77%.

TABLE 3. Modified (Post-Onset of COVID-19) Sample

<table>
<thead>
<tr>
<th></th>
<th>MODERNIZED</th>
<th></th>
<th></th>
<th></th>
<th>NON-MODERNIZED</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Elementary</td>
<td>Elementary/Middle</td>
<td>Middle</td>
<td>High</td>
<td>Elementary</td>
<td>Elementary/Middle</td>
<td>Middle</td>
</tr>
<tr>
<td>District A</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>District B</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>
STUDENTS’ SOCIOECONOMIC STATUS

For the purpose of this study, the indicator of students’ socioeconomic status was measured slightly differently for each of the participating school districts and was based on the assumption that there is a correlation between lower socioeconomic status and a higher percentage of students that receive free meals at school (Cowan et al., 2012). For one of the participating school districts, the percentage of students eligible for “free meals without the need for household applications” through Direct Certification was used as an indicator of socioeconomic status.* For the other school district, the percentage of students considered “At-Risk” was used as an indicator of socioeconomic status.† The percentage of students eligible for Direct Certification or considered At-Risk ranged from 4% to 82% across the original 34-school sample, with a mean of 54% and a median of 59%.

EXCLUSION CRITERIA

The researchers determined exclusion criteria for the sample with input from BCPS and DCPS, including: no “portable” temporary classroom structures, facilities with known maintenance or HVAC system issues, and schools that were experiencing leadership issues (e.g., poor staff/administrator retention).

Modified (Post-Onset of COVID-19) Sample

Knowing the schools participating in the study would not be fully occupied when classes began again in Fall 2020 (and possibly for the entire 2020-2021 academic year), the research team had to rethink how the remaining field data could be collected under these conditions. The biggest hurdle was related to collecting data on IEQ conditions since several measurements would be directly affected by the reduced occupancy loads (e.g., air quality and acoustics in classrooms). Thus, the researchers decided to use the IEQ data that had been collected to-date from January to March 2020 (21 out of 34 schools in the original sample, at both BCPS and DCPS schools), as well as supplement this dataset with analogous IEQ data that had previously been collected at a similar sample of DCPS schools during the Investing in Our Future study (Jauregui et al., 2018).

Of the 11 DCPS schools that made up the sample for the 2018 study, eight met the current study’s sample selection criteria—with two of these schools already included in the current study’s sample and another school opting out of participation. Thus, five new schools were added to supplement the current study’s sample moving forward. With the addition of these five schools, plus the attrition of some of the schools from the original sample (e.g., a non-modernized school now undergoing renovations and therefore removed from the sample of non-modernized schools), this study’s sample now included a total of 28 schools across the two districts.

Like the original sample for this study, schools in the new sample included both modernized and non-modernized schools and were balanced across the two school districts and various grade-bands as much as possible (Table 3, Table 4). Additionally, in creating the new sample, the research team still took into consideration the years since modernization (for modernized schools), school enrollment and utilization, and students’ socioeconomic status. The same exclusion criteria used for the original sample were also applied.

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† At-Risk means a student who is identified as one or more of the following: (A) homeless; (B) in the district’s foster care system; (C) qualifies for the temporary assistance for needy families program or the supplemental nutrition assistance program; or (D) a high school student that is one year older, or more, than the expected age for the grade in which the student is enrolled. See: § 38-2901. Definitions. D.C. Law Library. (n.d.). https://codeLL.dccouncil.us/dc/council/code/sections/38-2901.html
### TABLE 4. Pre-Pandemic Sample Versus Modified (Post-Onset of COVID-19) Sample

<table>
<thead>
<tr>
<th>ID Code*</th>
<th>Type</th>
<th>District</th>
<th>Part of the Modified Sample†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NON</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>2</td>
<td>NON</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>3</td>
<td>MOD</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>4</td>
<td>MOD</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>5</td>
<td>NON</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>6</td>
<td>NON</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>7</td>
<td>MOD</td>
<td>District A</td>
<td>Removed from sample since IEQ data not collected before pandemic</td>
</tr>
<tr>
<td>8</td>
<td>NON</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>9</td>
<td>MOD</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>10</td>
<td>MOD</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>11</td>
<td>NON</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>12</td>
<td>NON</td>
<td>District A</td>
<td>Removed from sample since IEQ data not collected before pandemic</td>
</tr>
<tr>
<td>13</td>
<td>MOD</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>14</td>
<td>NON</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>15</td>
<td>MOD</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>16</td>
<td>MOD</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>17</td>
<td>MOD</td>
<td>District A</td>
<td>✓</td>
</tr>
<tr>
<td>18</td>
<td>MOD</td>
<td>District B</td>
<td>Removed from sample since IEQ data not collected before pandemic</td>
</tr>
<tr>
<td>19</td>
<td>NON</td>
<td>District B</td>
<td>(IEQ data collected during 2018 study)</td>
</tr>
<tr>
<td>20</td>
<td>NON</td>
<td>District B</td>
<td>Removed from sample since IEQ data not collected before pandemic</td>
</tr>
<tr>
<td>21</td>
<td>MOD</td>
<td>District B</td>
<td>(IEQ data collected during 2018 study)</td>
</tr>
<tr>
<td>22</td>
<td>NON</td>
<td>District B</td>
<td>Removed from sample since IEQ data not collected before pandemic</td>
</tr>
<tr>
<td>23</td>
<td>MOD</td>
<td>District B</td>
<td>✓</td>
</tr>
<tr>
<td>24</td>
<td>MOD</td>
<td>District B</td>
<td>✓</td>
</tr>
<tr>
<td>25</td>
<td>NON</td>
<td>District B</td>
<td>✓</td>
</tr>
<tr>
<td>26</td>
<td>NON</td>
<td>District B</td>
<td>✓</td>
</tr>
<tr>
<td>27</td>
<td>MOD</td>
<td>District B</td>
<td>Removed from sample since IEQ data not collected before pandemic</td>
</tr>
<tr>
<td>28</td>
<td>MOD</td>
<td>District B</td>
<td>Removed from sample since IEQ data not collected before pandemic</td>
</tr>
<tr>
<td>29</td>
<td>NON</td>
<td>District B</td>
<td>Removed from sample since IEQ data not collected before pandemic</td>
</tr>
<tr>
<td>30</td>
<td>NON</td>
<td>District B</td>
<td>✓</td>
</tr>
<tr>
<td>31</td>
<td>NON</td>
<td>District B</td>
<td>Became modernized during the duration of the study (before data were collected), so removed from sample</td>
</tr>
<tr>
<td>32</td>
<td>MOD</td>
<td>District B</td>
<td>✓</td>
</tr>
<tr>
<td>33</td>
<td>NON</td>
<td>District B</td>
<td>Removed from sample since IEQ data not collected before pandemic</td>
</tr>
<tr>
<td>34</td>
<td>MOD</td>
<td>District B</td>
<td>Removed from sample since IEQ data not collected before pandemic</td>
</tr>
<tr>
<td>A</td>
<td>MOD</td>
<td>District B</td>
<td>Added to the sample (using 2018 IEQ data)</td>
</tr>
<tr>
<td>B</td>
<td>MOD</td>
<td>District B</td>
<td>Added to the sample (using 2018 IEQ data)</td>
</tr>
<tr>
<td>C</td>
<td>MOD</td>
<td>District B</td>
<td>Added to the sample (using 2018 IEQ data)</td>
</tr>
<tr>
<td>D</td>
<td>MOD</td>
<td>District B</td>
<td>Added to the sample (using 2018 IEQ data)</td>
</tr>
<tr>
<td>E</td>
<td>MOD</td>
<td>District B</td>
<td>Added to the sample (using 2018 IEQ data)</td>
</tr>
</tbody>
</table>

* Anonymized Identification Code for schools in the sample
† The IEQ data from School 19, School 21, and Schools A-E were collected in 2018 and went through a process called “normalization” in order to be analyzed alongside the IEQ data collected in 2020.
A comprehensive literature review is a fundamentally important initial step in a research process because it situates a study within the field of existing research, provides important methodological frameworks, and establishes benchmarks for comparing results (Creswell & Creswell, 2017). This study’s literature review provided critical insights into the study’s relevancy (see the previous Why This Study Matters section) and was also used to identify and develop appropriate methodologies and tools. The literature review’s scope was defined early on and coalesced around the topic of inquiry and the study’s research questions. Literature topics were organized into three large themes (IEQ, EA, and CC) and were reported through a Narrative Review. This type of review describes existing literature and studies related to the topic of inquiry, providing context for the current study and demonstrating how it contributes and expands on the existing body of knowledge (Grant & Booth, 2009).

Although the review focused on IEQ, EA, and CC, the research team recognized the dynamic nature of literature reviews (Groat & Wang, 2002) and designed it to allow for a response to changing realities and emerging findings, such as recent research based on the effects of the COVID-19 pandemic. This process is particularly relevant to a sequential mixed method study designed to produce data and knowledge that informs proceeding steps. If unanticipated findings emerged that required a change to the scope of literature review, the researchers were able to respond appropriately.
Indoor Environmental Quality Data Logging with Live Measurements

The impact of IEQ on school occupants is a vital area of research. However, most previous studies investigated a single environmental property at a time, meaning they only studied one variable such as daylight or acoustics independent of any others. Few studies attempt to look at Indoor Environmental Quality properties in tandem to assess the overall impact of high-performance design strategies on building occupants. This study, however, explored multiple IEQ properties concurrently, allowing for a more real-world understanding of the impact of IEQ.

This study’s approach to data collection is grounded in the methodology used in the Investing in Our Future study (Jauregui et al., 2018), where a series of IEQ sensors were deployed in each participating school to capture live data on Indoor Environmental Quality factors, including thermal comfort, air quality, acoustics, and lighting. The following sections outline this study’s IEQ process.

Timing

This study was designed to capture IEQ data during the buildings’ heating season, as close to peak winter conditions (e.g., February) as possible, to best assess how each building performed. It is important to look at how the buildings respond during the extreme seasons (i.e., when there is a greater differential between indoor and outdoor temperatures) because it is relatively easy to maintain a thermally comfortable environment when it is (e.g.) 70 °F outside, but extreme winter and summer conditions can truly showcase how well, or not well, a building is able to maintain a quality indoor environment. Because schools are generally not in full session over peak summer conditions, this study targeted the heating months of winter to collect data.

In each school, on-site measurements were captured over a consecutive four-day period during weekdays when the school was in session to allow multiple days of data to be collected so the researchers could establish an average condition. Because not all schools could be studied during the same week due to a limited quantity of IEQ sensors and staffing resources available, an outdoor weather station was included in the IEQ toolkit to allow for weather-normalizing of the data collected across weeks. Thus, the schools, which were studied on a weekly basis, were clustered into groups (referred to as “troupes”) based on their locations. In the original sample of 34 schools, there were ten troupes total, with two to four schools in each troupe, so on-site IEQ data would have taken a total of ten weeks to collect. Each week, one school in each troupe had the weather station mounted on its roof to track the local weather conditions for that week, which was then used during analysis in order to normalize the data across the different weeks of study.

Space Selection

To select the spaces in which data were to be collected in each participating school, the research team followed the procedure outlined in detail in Appendix C. This allowed the researchers to identify typical core-learning spaces to be studied that reflected the variety of learning environments present in each school. The team looked for classrooms that were distributed throughout the school based on their cardinal orientation (north/south/east/west), floor level, regularity of room occupation, and teachers’ willingness to participate in the study. For any classroom that did not conform to these criteria, an alternate classroom was selected that did meet these requirements.
During the winter heating season, on-site IEQ measurements were captured in each school over a consecutive four-day period when the school was in session. Schools were clustered by location, with data collected over a period of weeks, so an outdoor weather station was deployed at a school each week in order to normalize the data during analysis.
In addition to a weather station monitoring outdoor conditions, sensors were placed within four classrooms and one cafeteria in each school being studied.

Training and Deployment

To deploy the IEQ sensors effectively to different schools on a weekly basis, a team of individuals were trained to understand how to launch, place, check, collect, and download data from the tools each week. These individuals were given a toolkit (Figure 3) and a set of detailed instructions (Appendix C). They were trained over a four-hour period around tool use and proper placement of the tools on-site. For each sensor, careful placement is an important step to getting good data, so detailed instructions about sensor placement were provided to the on-site data collectors (refer to Appendix C for placement details).

To assess acoustics, sound levels (decibels, dBA) were collected using a Tenma 72-947 data logging sound meter. These sound level measurements were then divided into “occupied” and “unoccupied” hours so average background noise levels could be evaluated separately from occupied noise levels. Teachers in each evaluated classroom completed a room-occupancy tracking sheet (available under Appendix C), while a HOBO UX90-006 occupancy data logger tracked occupancy in the cafeteria.

To assess thermal comfort, six factors need to be considered: air temperature, humidity, air velocity, mean radiant temperature, clothing insulation, and metabolic rate. The first four of those factors are environmental and the last two are personal, and therefore not evaluated under this methodology. For this study, the research team measured the four environmental factors using the following sensors: air temperature and humidity were tracked simultaneously using a HOBO MX1102A data logger. Air speed was tracked using a Degree Controls F350-omni sensor connected to a HOBO data logger. Mean radiant temperature was tracked using a HOBO temperature sensor located inside a grey globe, connected to a HOBO data logger. Air temperature and humidity were tracked in every room that was being studied in the school, but the mean radiant temperature and air speed were only tracked in one room per school on a “thermal comfort tripod” that the research team created.

To assess air quality, two sensors were used: a HOBO MX1102A to track CO\textsubscript{2} levels and a PurpleAir PA-II to track particulate matter (PM 10/2.5). Although CO\textsubscript{2} levels alone are not necessarily comprehensive indicators of air quality, they are indicators of ventilation effectiveness and, therefore, can be reflectors of air quality (National Education Association, n.d.). Volatile Organic Compounds (VOCs)
### THERMAL COMFORT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tool Used</th>
<th>Unit of Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Temperature</td>
<td>HOBO MX1102A</td>
<td>deg F</td>
</tr>
<tr>
<td>Humidity</td>
<td>HOBO MX1102A</td>
<td>% RH</td>
</tr>
<tr>
<td>Air Speed</td>
<td>Degree Controls F350-omni with HOBO (UX120-006M)</td>
<td>FPM</td>
</tr>
<tr>
<td>Mean Radiant Temperature</td>
<td>ping-pong with HOBO (UX120-006M) and external sensor (TMC6-HD)</td>
<td>deg F</td>
</tr>
</tbody>
</table>

### AIR QUALITY

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tool Used</th>
<th>Unit of Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>HOBO MX1102A</td>
<td>ppm</td>
</tr>
<tr>
<td>PM10/2.5</td>
<td>PurpleAir PA-II</td>
<td>ug/m3</td>
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</tbody>
</table>

### ACOUSTICS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tool Used</th>
<th>Unit of Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>dBA</td>
<td>Tenma 72-947</td>
<td>dB</td>
</tr>
</tbody>
</table>

### LIGHT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tool Used</th>
<th>Unit of Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>illuminance</td>
<td>Extech EA33</td>
<td>footcandles</td>
</tr>
<tr>
<td>glare</td>
<td>Manual phone app + grasshopper script for false color imagery</td>
<td>lux ratio</td>
</tr>
</tbody>
</table>

### NORMALIZATION

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tool Used</th>
<th>Unit of Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>occupancy</td>
<td>HOBO UX90-006</td>
<td>time</td>
</tr>
<tr>
<td>occupancy</td>
<td>tracked by teacher</td>
<td>time</td>
</tr>
<tr>
<td>weather station</td>
<td>HOBO U30 USB Weather Station Starter Kit, 2-meter tripod, PurpleAir PA-II</td>
<td>deg F, % RH, MPH, ug/m3</td>
</tr>
</tbody>
</table>
themselves were not studied, either individually or holistically (tVOCs), as multiple data logging sensors currently on the market were evaluated and shown to not produce accurate results, with higher-quality sensors not economically feasible to deploy for this study. CO\textsubscript{2} levels were tracked in every room that was being studied in each school, but particulate matter was only tracked in one room per school, as part of the thermal comfort tripod.

To assess light, both daylight and electric lighting were studied in the evaluated classrooms, with measurements of glare as well as the distribution of lighting throughout the spaces. Of all the IEQ parameters, lighting was the only measurement collected live, with point-in-time measurements, as opposed to the other data that were logged over a series of days. Light measurements were taken one day out of the week the classrooms were being assessed, using an Extech EA33 illuminance meter. Measurements were taken of just the daylight levels, as well as measurements of daylight plus electric light distribution, measured on an approximate 5'-0" grid throughout the classroom spaces and on an approximate 10'-0" grid throughout the cafeteria spaces. Glare photos were taken using a manual camera application on a smartphone, where shutter speed and ISO levels were held consistent and the RAW photos could be calibrated to assess luminance throughout the images to study glare.

The Impact of the COVID-19 Pandemic

As noted in this report’s Modified (Post-Onset of COVID-19) Sample section, the research team had completed on-site IEQ measurements at 21 of the schools in the original sample prior to the onset of COVID-19 in March 2020. When it became clear that schools would not be quickly returning to the same full-occupancy or in-person learning, the researchers decided to utilize the IEQ data they had access to that had been collected during the Investing in Our Future study (Jauregui et al., 2018). This supplemental data allowed the researchers to round out the sample and get closer to the study’s initial 30-school target number to be able to study the statistical significance of IEQ factors between modernized and non-modernized schools. Although the previous study did not collect all the factors outlined herein (for instance, the previous study only evaluated classrooms and did not capture IEQ data in cafeterias), that previous study had been conducted using the same methodology and sensors as the data collected for this study before the pandemic hit, so the datasets could easily be integrated.
The Investing in Our Future (Jauregui et al., 2018) precedent study focused largely on Indoor Environmental Quality and its impact on building occupants. However, the definition of a three-fold analysis/model of the educational environment—Indoor Environmental Quality, Educational Adequacy, and Community Connectivity—required an approach that would assess each factor’s impact on the built environment separately as well as collectively.

After considering multiple approaches to assess the built environment for Educational Adequacy, the research team ultimately decided to develop its own Visual Assessment Tool (VAT) that would efficiently evaluate the participating schools’ learning environments. More than 200 questions were developed and input into an online surveying platform used by the research team during their on-site evaluations to consistently measure educational environments against a rubric of EA factors. This section focuses on the creation and implementation of the VAT.

To assess Educational Adequacy, the researchers developed a Visual Assessment Tool, which was used to evaluate schools’ learning environments efficiently and consistently against a rubric of EA factors.

Development of the VAT

The development of the VAT began with a review of literature and precedent tools, followed by defining the study’s areas of EA inquiry. The research team then piloted the tool at schools outside this study’s sample before implementing it across the schools participating in the study.

Precedent studies and existing literature suggested how to focus the VAT on areas that have been found to influence educational outcomes. These studies prompted discussions about a cross-section of factors at different scales of the environment that influenced the development of the VAT. For instance, one study raised issues regarding the spatial organization of the overall building, the circulation layout within the building, and the use of materials and transparency to enhance or alter functionality and establish spatial interrelations between parts of a building (Altenmüller, 2010). Another study identified three types of environmental design factors in the classroom found to impact performance indicators: Naturalness, Individualization, and Stimulation (Barrett et al., 2015). Naturalness closely mapped to the IEQ factors the research team was studying, including light, air quality, temperature, and acoustics. Individualization addressed flexibility and ownership. Stimulation addressed color and the appropriate level of complexity in the visual environment. The literature review also assessed precedent surveying tools (Association for Learning Environments, 2002; Tanner, 1999) that studied Educational Adequacy. Along with the research team’s previous studies, the literature review provided additional input on the factors to be assessed as well as the media and processes that could be used to capture data.

Based upon the literature review and the precedent tools assessment, the research team decided that the VAT would focus on eight evaluation factors: Presence, Safety and Security, Community, Organization, Instructional Space (classrooms, art studios, and science labs), Environmental Quality, Assembly, and Extended Learning Environments (Figure 4).
Learning environments would also be assessed across several scales, including instructional space, internal school community, and response and support to the larger community where the school was located. These factors also reflected both BCPS’s and DCPS’s Educational Specifications, which define each district’s criteria for contemporary learning environments for new and modernized schools.

**Pilot Testing the VAT**

To evaluate learning environments, the research team developed a series of criteria-based questions for each of the eight identified EA factors. The researchers reviewed initial drafts of the questions, while representatives of both participating school districts helped review subsequent versions. The tool was then piloted for further refinements: The prototype VAT was field-tested at two sites in Washington, DC, which were typical of school facilities in the district but not included in the study’s sample. One site had undergone a modernization and building addition while the other was a non-modernized school.

The four research team members who would be using the VAT to collect data on-site participated in the field tests to allow them to discuss and comment on the VAT’s questions and the tool’s digital interface. Each member answered the questions in the VAT individually and then the group discussed their responses while walking through the buildings again, together. This group discussion identified areas of the VAT that were in need of refinement, and helped the team come to a collective understanding of VAT’s questions and their intent. Based upon the piloting, the VAT was then finalized and ready for use.

The final version of the VAT featured 234 questions developed to assess the eight factors defining a learning environment. Leveraging readily available smartphone technology and online surveying software, the questions were input into an online surveying platform. The combination of a handheld smartphone device with cellular or Wi-Fi internet access and a built-in camera for adding field photography, plus a flexible online database with a simple touchscreen-oriented interface, allowed the team in the field to efficiently collect data on-site. Refer to Appendix D for information about replicating the VAT.

**Though the VAT questions and associated online surveying platform were newly developed for this study, the researchers found it useful for evaluating EA in schools and responding to the study’s EA-focused research question.**

**The Impact of the COVID-19 Pandemic**

Half of the building walkthroughs to collect VAT data had been completed prior to the pandemic-related shutdown of schools in March 2020. However, data collection had not yet occurred at 17 of the schools in the original sample. To maintain alignment with the data being collected on IEQ, the remaining VAT data collection occurred after the study’s sample was revised. During the pandemic’s shutdown of schools, the research team conducted walkthroughs at the five schools added to the study based on the revised sample and IEQ dataset that was pulled from the *Investing In Our Future* study (Jauregui et al., 2018). Since these five schools had returned to in-person learning but were still practicing social distancing, some of the VAT questions may have received lower scores than if the schools had been occupied normally. However, this did not impact the overall assessment of these sites.
FIGURE 4. VAT Factors of Evaluation

The VAT featured 234 questions to assess eight factors defining a school’s learning environment.
Stakeholder Questionnaires

Questionnaires “help identify important beliefs and attitudes of individuals” (Creswell, 2012, p. 376). Accordingly, the research team introduced questionnaires as a methodology for this study to understand school stakeholders’ perspectives about, engagement with, and use of the schools in the sample. This method addressed the quantitative aspects of the research questions while also providing context for the visual assessments and qualitative explorations (e.g., interviews). The questionnaires explored aspects of IEQ, EA, and CC. Refer to Appendix E for information about replicating the questionnaires.

Development of the Questionnaires

When developing the questionnaire tool, the researchers started with surveying tools that had been utilized by some of the research team members in their previous investigations that focused on IEQ and its impact on building occupants’ satisfaction and well-being (Jauregui et al., 2018). Thus, though the researchers were replicating portions of previous questionnaires for this study, they were built upon to develop a tool that better aligned with this study’s research questions. Accordingly, the questionnaire and the data collected were part of a piloting process to garner stakeholder perspectives on the areas of not only IEQ but also EA and CC.

There were originally five different versions of the questionnaire, each specific to its intended audience: (1) students who attend a participating school; (2) teachers who work in a participating school; (3) staff/administrators who work in a participating school; (4) parents/caregivers of students who attend a participating school; and (5) neighbors/members of the communities where the participating schools are located. A master list of questions was created so the common questions that were included in the various versions were worded exactly or nearly the same (with minor tweaks as necessary to make them appropriate to their audience). As a result, the researchers were able to compare data across populations during analysis.

A new surveying tool was developed and piloted for this study, based on the research team’s previous investigations. The questionnaires aimed to understand stakeholders’ perspectives about, engagement with, and use of the schools being studied within the realms of IEQ, EA, and CC.

The master list was further refined based on feedback provided by administrators from the two participating school districts and after two pilot tests: First, a 9-year-old child completed the student version of the questionnaire, verbally explaining their thinking about how they interpreted each question and answer choice, such that the researcher who crafted the questionnaire was able to recognize mismatches between the questionnaire’s intent and the child’s interpretation. Second, an experienced third-grade teacher from a school district not involved in the study reviewed the student version for content comprehension and reading-level appropriateness.

Once the questions had been revised and finalized after these two pilot tests, the master list was broken down to define which questions
were to be included in each version of the questionnaire. The pre-pandemic versions of the questionnaires were then translated from English into several additional languages (Amharic, Chinese, French, Spanish, and Vietnamese) so most participants would have the option to complete the questionnaire in their preferred language. The post-pandemic versions, however, had a more limited translation, as described in the next section.

**The Impact of the COVID-19 Pandemic**

The questionnaires had been developed, piloted, translated, and were awaiting distribution when the study went on hold in March 2020. Ultimately, the questionnaire deployment was postponed until Fall 2021. Prior to that, when the study resumed in Fall 2020, the research team recognized that both the study’s process for distribution and the questionnaire content would have to be modified before data collection could proceed.

When the study was originally planned, the research team had expected to deploy paper questionnaires in addition to digital versions that would be completed using an online surveying tool. This dual process was necessary because, prior to the COVID-19 pandemic, not all participating schools were able to secure enough electronic devices for all students to complete the questionnaire online. However, since the pandemic delayed the questionnaire’s deployment, the research team had the opportunity to change the approach. Two factors came into play: First and foremost was the researchers’ desire to safeguard the participants’ and research team’s well-being by limiting in-person interactions. Secondly, to accommodate the remote learning that occurred in the first year of the pandemic, students in the participating schools received digital devices (e.g., tablet computers), thereby ensuring they would have access to an online surveying tool. Accordingly, the researchers felt that online surveying was the safest and most effective way to deploy the
questionnaires at a time when hybrid schooling (i.e., when students and teachers were only sometimes in the buildings) and remote work were still in play. This new approach was beneficial because online questionnaires can streamline the data collection process, improve the precision of questionnaire completion, reduce printing costs, minimize the use of resources and waste, and eliminate the need to securely store paper for confidentiality purposes.

As noted, the questionnaire content was also revised as a result of the pandemic. Modifications included:

- Younger students were eliminated from the sample due to concerns over their ability to complete a digital questionnaire. Participants now were in the third grade and higher.
- Questionnaire content targeting external stakeholders (community members) was removed because in-person engagements were no longer possible. (The research team’s original intent was to engage members of the community in-person at community gathering spots such as libraries and community centers.) Thus, only four versions of the questionnaire were ultimately distributed: those for students, teachers, staff/administrators, and students’ parents/caregivers.
- Several questions were eliminated or reworded to reduce potential bias stemming from the COVID-19 pandemic. For instance, “How does your school building usually make you feel about your health?” was now a loaded question and had to be removed.
- Questions were added or reworded to reflect post-pandemic thinking about “high performance” schools (e.g., the role of a school as a community center when it is not performing its primary academic function).
- Many students, including new students and those transitioning to middle and high school, had never set foot in the schools where they were enrolled due to virtual learning. Questionnaire revisions had to be made as a result.

- Questions were eliminated or reworded to address the fact that some respondents may not physically be in the schools prior to or during the data collection period. The research team then had to revise the questionnaires again once it was known that participants would be back in their schools by the time questionnaires were being deployed.
- The questionnaire had to undergo a major overhaul for questions related to IEQ because of the decision to supplement the study’s IEQ on-site metrics data logging and live measurements data with the sample and data collected in the Investing in Our Future study (Jauregui et al., 2018). (Refer to the previous Sample and Sampling Methods section for an explanation about this change in the sample.) Accordingly, the research team had to eliminate all the original questions about IEQ and, instead, use the questionnaire questions exactly as they had been asked in the previous study to allow for the analysis of comparable datasets (i.e., previously collected 2018 data coupled with the current study’s newly collected data).

The questionnaire had to go through considerable revisions to address potential pandemic-related biases, the revised sample for the study, reduced occupancy loads in the schools, and a switch to online-only questionnaires.

Based on all these changes, the research team presented the revised questionnaire content and distribution process to the participating school districts to review, provide comments, and approve. After final edits, questionnaire content was resubmitted to the two IRB agencies involved in this study for their re-approval.
The final questionnaires ranged from 12 to 36 questions, depending on the version (Table 5). Wording and terminology used within each version was geared to its particular audience, ensuring that only relevant questions were asked of that particular audience and to promote reading comprehension, especially for the younger students.

The questionnaires were offered in multiple languages to aid with comprehension. Students and their parents/caregivers were given the option to read the informed consent information about the study and complete their questionnaire in English, Spanish, or Amharic.* Teachers and school staff/administrators were provided English versions. The selection of these languages was determined by administrators at the participating school districts and was based on their school populations and prior experience with surveying their school stakeholders. During the translation process, the research team asked the translators to consider the intent of the question rather than providing a word-for-word replacement. In addition, post-translation, native Spanish and Amharic speakers reviewed the questionnaires to determine if all translations were comprehensible and appropriate.

## Questionnaires Sample and Deployment Process

Early in the study, the research team developed a strategy for distributing questionnaires to school stakeholders, with the goals of maximizing participation and making the process as straightforward as possible for the schools’ principals (or other designated point-of-contacts within the schools) who assisted with the questionnaire deployment. (Appendix E offers detailed information about the deployment process.)

For someone to participate, IRB approval dictated that, for those schools that required it, all respondents had to provide informed consent and “opt in” to the study. The informed consent form and process varied by respondent type. Teachers, staff/administrators, and parents/caregivers (i.e., those over the age of 18)

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* Note: the online surveying tool used for this study did not support the Amharic language, so PDF forms were created for this language instead. When invited to complete a questionnaire in Amharic, participants were concurrently sent the PDF form as an attachment, which they could fill out and email directly back to the research team.

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### TABLE 5. Post-Pandemic Revised Questionnaire Content, by Version

<table>
<thead>
<tr>
<th>Category</th>
<th>STUDENTS</th>
<th>TEACHERS</th>
<th>STAFF/ADMINISTRATORS</th>
<th>PARENTS/CAREGIVERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informed consent: agreement to participate</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Identifiers, demographics</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Feelings about the school/neighborhood</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Sense of community</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Classroom IEQ description, satisfaction</td>
<td>14</td>
<td>14</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Modes of learning, support for learning activities</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Perceived use of school and campus spaces</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Functionality of school features</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>27</strong></td>
<td><strong>36</strong></td>
<td><strong>12</strong></td>
<td><strong>17</strong></td>
</tr>
</tbody>
</table>
Revised (post-pandemic) Master List of questions sent to both school districts for final review/comments and approval

Comments received by both school districts; questionnaire revisions

Finalized questionnaire and informed consent content sent to translators

Questionnaire Roll-Out Toolkit (schedule and instructions for deployment) shared with school districts and principals at each participating school

Translations completed

Questionnaire deployment meeting with the school districts

Parent/caregiver informed consent for student participation; list of students with informed consent shared with principals for appropriate questionnaire deployment

Links to the questionnaires and instructions for deployment sent to principals; questionnaire data collection begins (original deadline November 5, 2021)

Questionnaire deadline extension announced, with added incentive offered

Second questionnaire deadline extension announced

Questionnaire data collection ends
simply had to provide informed consent prior to completing the questionnaire. Students, being minors (those under the age of 18), had to undergo a different informed consent process. One of the participating school districts only required a Notice of Student Participation to be sent to students’ parents/caregivers. The other participating school district, however, required parent/caregiver informed consent for their child to participate, or opt out as the case may be. For those students who received informed consent by their parent/caregiver in the one district and all of the students in the other district were given time during their homeroom class (or equivalent) to complete the questionnaire.

For both the adult and student versions of the online questionnaire, the opening screen provided information about the study, with the first question asking the participant to opt in or out. If they agreed to participate, they continued to the rest of the questionnaire. If they did not agree, they were redirected to the end of the questionnaire (i.e., non-participation).

While the original schedule provided up to 10 business days for completion, the deadline was extended two times to encourage greater participation. Along with the first deadline extension, the research team offered an incentive for completion: A $500 gift card to an office supply store would be given to any participating school that received 50% participation across their student, teacher, and staff/administrator stakeholder groups. None of the schools, however, reached that level of participation.

Questionnaire completion rates were good, ranging from 73% to 97%. However, the overall response rates by school were poor (ranging from 0% to 72%, with a mean of 6%). Although the data were limited and the questionnaire was a piloted methodology, it was useful in adding to the researchers’ ability to respond to the research questions.

Given that the questionnaire was a piloted methodology, the research team feels this was a good first step toward understanding the perspectives about, engagement with, and use of the schools in the study’s sample. The data collected by the completed questionnaires, although limited, added to the researchers’ ability to respond to the study’s research questions, particularly those focused on IEQ and EA.
<table>
<thead>
<tr>
<th>Completion rate (for those who consented to participate in the questionnaire)</th>
<th>STUDENTS</th>
<th>TEACHERS</th>
<th>STAFF/ADMINISTRATORS</th>
<th>PARENTS/CAREGIVERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>73%</td>
<td>79%</td>
<td>97%</td>
<td>81%</td>
<td></td>
</tr>
<tr>
<td>Modernized schools</td>
<td>N = 110</td>
<td>N = 23</td>
<td>N = 10</td>
<td>N = 101</td>
</tr>
<tr>
<td>1.4% of potential respondents, N = 7,729</td>
<td>3.1% of potential respondents, N = 732</td>
<td>1.7% of potential respondents, N = 600</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>11 of the 17 schools represented</td>
<td>3 of the 17 schools represented</td>
<td>2 of the 17 schools represented</td>
<td>5 of the 17 schools represented</td>
<td></td>
</tr>
<tr>
<td>Non-modernized schools</td>
<td>N = 482</td>
<td>N = 23</td>
<td>N = 30</td>
<td>N = 33</td>
</tr>
<tr>
<td>9.6% of potential respondents, N = 5,028</td>
<td>5.8% of potential respondents, N = 396</td>
<td>9.3% of potential respondents, N = 323</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>9 of the 11 schools represented</td>
<td>2 of the 11 schools represented</td>
<td>3 of the 11 schools represented</td>
<td>6 of the 11 schools represented</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>N = 592</td>
<td>N = 46</td>
<td>N = 40</td>
<td>N = 134</td>
</tr>
<tr>
<td>4.6% of potential respondents, N = 12,757</td>
<td>4.1% of potential respondents, N = 1,128</td>
<td>4.3% of potential respondents, N = 923</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>20 of the 28 schools represented</td>
<td>5 of the 28 schools represented</td>
<td>5 of the 28 schools represented</td>
<td>11 of the 28 schools represented</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 6.** Questionnaire Response Rates
The intent underlying the qualitative portion of this study was to explore the “lived experiences” of the various stakeholders of the original sample of 34 schools. The underlying methodology for data collection was a phenomenological approach, where one’s experience is defined by how each individual describes the way they interact with and within the schools, and what that interaction means for them. One of the essential objectives of this study was to understand how school buildings impact those in the surrounding community as well as the performance of people who spend time within those schools. Performance was to be explored in the areas of learning, teaching, leading, and one’s sense of well-being.

Using a phenomenological approach, the interviews and focus groups with school stakeholders provided the research team with an understanding of their lived experiences.

Within the Educational Adequacy investigation, the intent was to interview stakeholders from four distinct groups associated with the use and design of the school, culled from a representative sub-sample of the schools. These four groups included school leadership, teachers, and students from both modernized and non-modernized buildings, and an architect who was part of the design team for the modernized buildings. The sub-sample of schools was to be selected from each district to be representative of each grade band (elementary, middle, and high schools). A small sample of participants associated with the sub-sample of schools would also be identified from each school for participation in a structured interview. Interview questions had been prepared, providing the framework for the interviews, and were targeted to the individuals’ role—student, teacher, school leader, or architect.

For the Community Connectivity portion of the study, the intent was to hold focus group interviews with parents/caregivers from a subset of the original 34 schools in the sample. Six schools—two in School District A and four in School District B—were selected in consultation with the respective school districts to serve as the focal points of this work. The schools were selected based on several factors, including variation in school type and their relationship to particular neighborhoods.

The research team planned to work with school district personnel in both districts, and then with appropriate school staff/administrators on-site who had strong connections to the outside community. The goal was to identify five to ten individuals who could be interviewed regarding their perspectives on the relevant schools. The researchers identified characteristics that were needed within each community stakeholder group to ensure the widest perspective of participants to represent the complexity of the environments being studied. Recruitment was going to be focused, as possible within each community, on a combination of individuals who lived in close physical proximity to the school, who owned or worked in a business near the school, who represented community organizations, and/or who were involved in the city’s political structure.
The Impact of the COVID-19 Pandemic

The interviews and focus groups that were originally planned as part of this study were not only delayed but also quite limited as a result of the COVID-19 pandemic. Interviews that had been planned to help address the EA research questions were not completed due to pandemic-related limitations, including not being able to have in-person engagements as well as school representatives being focused on core educational matters and unable to spare time for this research study.

Regarding the interviews and focus groups planned for the CC research questions, the research team was able to collect some data. However, major adjustments to the original plan to obtain community input had to be made, partly due to the COVID-19 pandemic and partly due to a lack of responsiveness from representatives of the individual schools (which, in turn, may have been because of the pandemic).

Complications due to the COVID-19 pandemic unfortunately resulted in a limited number of CC-focused interviews and focus groups conducted for this study, and none regarding EA.

Having identified the two schools in BCPS and four in DCPS that would serve as the sub-sample for the focus groups, the research team worked with district personnel to engage the leadership at each of these schools. After ongoing efforts over a period of many months, ultimately, only one focus group was conducted with a BCPS school and one with a DCPS school. Each focus group session was approximately 60 minutes in duration and conducted over a virtual meeting platform. The facilitators, both members of the research team, came away with a better understanding of the different ways in which parents/caregivers relate to the school buildings.

The researchers also attempted to work through the school districts to have each of the six schools help identify external community members who could be interviewed individually by one or more of the researchers. In the end, the researchers interviewed community members from just one school in Baltimore through a series of semi-structured virtual sessions that lasted 30 to 45 minutes each.

All questions asked during the interviews and focus groups were open-ended and exploratory in design. The goal was to ask about each group’s understanding, experiences, and sense-making within the context of these buildings. The sessions were digitally recorded and transcribed for use in data analysis. (Refer to Appendix F for detailed information about the interviews and focus groups process.)
The researchers collected archival data about the schools (Appendix G) and used a series of Repeated Measure ANOVAs (RM ANOVAs) to compare differences in enrollment, graduation rates, mathematics scores, and English language arts scores over time, for both modernized and non-modernized schools. Additionally, the research team used a nonparametric Mann-Whitney U test to compute and compare the average changes in enrollment and test scores of modernized and non-modernized schools.

The research team also used archival data to create community profiles related to each school in the sample (Appendix H). The profiles highlighted socio-demographic and other characteristics of each school’s surrounding neighborhood. These profiles were used in an attempt to (1) identify patterns in how the relevant data compared between schools that had been modernized and those that had not been, allowing for examination of how each school’s neighborhood may have evolved over time in relation to the evolution of the school site; and (2) investigate and account for the extent to which differing outcomes observed between modernized and non-modernized schools might be attributable to underlying community-level differences. The definition of each school’s neighborhood was based on the census tract in which that school is located. Each of the 28 schools in the sample was in a separate census tract.

Archival data regarding school enrollment, graduation rates, mathematics scores, and English language arts scores over time were analyzed to determine if there were differences between modernized and non-modernized schools. Socio-demographic data were also used to create community profiles for the sample.

The researchers also obtained archival data from both BCPS and DCPS, and supplemented the BCPS data with information from the State of Maryland online database. More specifically, from BCPS’s Office of Achievement and Accountability, data on school suspension rates was received and the research team focused on the School Report Card data from the online database. The team then obtained 10-year archival data from the public DCPS website to measure school and student performance. In each case, the research team examined enrollment, truancy, graduation rates, and English and math scores on the standardized tests of student proficiency that are administered to all students in eligible grade levels.
The general approach for data analysis in this study is provided in Table 7, organized by research question and data source. Most data sources were used in both a quantitative (inferential/descriptive statistics) and qualitative (thematic) analysis.

### Table 7. The Study's Research Questions and Analytical Approach

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Literature Review</th>
<th>Floor Plan Analysis</th>
<th>IEQ Data Logging &amp; Live Measurements</th>
<th>Visual Assessments, with Still Photography</th>
<th>Questionnaires</th>
<th>Interviews and Focus Groups</th>
<th>Archival Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Question #1</td>
<td>Modernized schools have better Indoor Environmental Quality than non-modernized schools</td>
<td>Descriptive/Inferential Statistics</td>
<td>Descriptive/Inferential Statistics</td>
<td>Descriptive/Inferential Statistics</td>
<td>Descriptive/Inferential Statistics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research Question #1</td>
<td>Modernized schools offer greater Educational Adequacy than non-modernized schools</td>
<td>Descriptive/Inferential Statistics</td>
<td>Descriptive/Inferential Statistics</td>
<td>Descriptive/Inferential Statistics</td>
<td>Descriptive/Inferential Statistics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research Question #1</td>
<td>Modernized schools provided more Community Connectivity than non-modernized schools</td>
<td>Descriptive/Inferential Statistics</td>
<td>Descriptive/Inferential Statistics</td>
<td>Descriptive/Inferential Statistics</td>
<td>Descriptive/Inferential Statistics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research Question #1</td>
<td>Faculty/staff and students of modernized schools have more positive well-being outcomes than those in non-modernized schools</td>
<td>Descriptive/Inferential Statistics</td>
<td>Descriptive/Inferential Statistics</td>
<td>Descriptive/Inferential Statistics</td>
<td>Descriptive/Inferential Statistics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research Question #2</td>
<td>Qualitative, exploratory research</td>
<td>Thematic Analysis</td>
<td>Thematic Analysis</td>
<td>Descriptive Statistics</td>
<td>Thematic Analysis</td>
<td>Descriptive Statistics</td>
<td></td>
</tr>
</tbody>
</table>

**ABOUT THE STUDY**

**Analysis**

Addressing a Multi-Billion Dollar Challenge
**Quantitative Data Analysis**

This study’s quantitative analytical approach consisted of both descriptive and inferential statistics. Descriptive statistics were used to report frequencies of responses for categorical data and means and standard deviations for interval data. Such descriptive statistics provided useful insight for developing the qualitative interview and observation protocols, as well as comparing the IEQ performance of the school to national standards (i.e., referencing LEED BD+C for Schools v4 criteria for air quality: ASHRAE Standard 62.1-2010; thermal comfort: ASHRAE Standard 55-2010; acoustics: ANSI Standard S12.60-2010; and daylight). Inferential statistics were used to directly answer the hypothesis within the first research question through a combination of Mann-Whitney U tests and Spearman Rho correlations. Given the limited sample size, it was not possible to statistically control for every potential confounding variable of interest. Instead, the use of purposeful sampling allowed for a relatively homogenous group of schools to be selected such that the schools primarily differed on their modernization status.

A comparison of data between BCPS and DCPS was not an intention of the study; only comparisons between modernized and non-modernized schools are reported.

**Qualitative Data Analysis**

The qualitative analysis focused on identifying and analyzing themes within the qualitative data, using a priori with emergent coding, as well as descriptive statistics comparisons across groups to the extent possible. Specifically, the first stage of data analysis involved the coding of the interview and focus group transcripts, which took place in two phases. The first phase used NVivo qualitative data analysis software for emergent coding, by reading each transcript and creating a list of significant statements from each interview/focus group participant. The use of emergent coding allowed for the participants’ own words to be used to generate codes that materialized from the data. Additionally, some a priori coding was used such that findings from the quantitative analysis identified certain patterns that were expected to be observed during the interviews and focus groups. The second phase of the coding process was theming the data. Theming allows for the creation of sentences that identify what the data are about or what the data mean. It is at this stage of analysis that the observational data were examined to enrich the developing themes.
Once the themes were identified, they were triangulated with the data generated by the quantitative investigation, including the questionnaires and VAT. Triangulation is a research technique used to improve the credibility and reliability of the qualitative findings by corroborating evidence from different datasets (Creswell & Creswell, 2017). Triangulation is achieved by examining each information source and finding evidence to support the themes that emerge from the interviews and focus groups. Since this was a mixed methods research study, the triangulation of data and information from both quantitative and qualitative methods adds to both the credibility and reliability of the study’s findings.

**Data Analysis for IEQ and EA**

To address the study’s IEQ-focused research hypothesis, IEQ on-site measurements and IEQ-related questionnaire data were compared between modernized and non-modernized schools using a series of Mann-Whitney U tests and Spearman Rho correlations. To answer the study’s EA-focused research hypothesis, VAT scores and EA-related questionnaire data were compared between modernized and non-modernized schools using a series of Mann-Whitney U tests.

The Mann-Whitney U test is the non-parametric equivalent to the independent samples t-test and does not require the same assumption of normality as an independent samples-test. Specifically, the Mann-Whitney U test is appropriate for these data given the small sample size, non-normal data, and at least ordinal-level data (Tomkins & Hall, 2006). The Spearman Rho correlation is the non-parametric alternative to the Pearson correlation and does not require continuous data nor the assumption of normality to be satisfied. Since the data are at least ordinal and the association between variables are monotonic, the Spearman Rho correlation is appropriate to measure the relationship between two ordinal variables with more than two levels or two continuous variables that do not satisfy the parametric assumptions of the Pearson correlation (Tomkins & Hall, 2006).

An alpha of 0.05 was used for determining statistically significant results for all inferential analyses. Significant differences for Mann-Whitney U tests were further evaluated through the eta-squared measure of effect size, which identifies the magnitude of the differences between the two groups (i.e., how large the significance difference is between the two groups). Eta-squared values were interpreted such that 0.10 to 0.29 were small effects, 0.30 to 0.49 were moderate effects, and 0.50 or greater were large effects (Cohen, 1988).

Mann-Whitney U tests were used for the following comparisons:

- Differences in IEQ measurements between modernized and non-modernized schools for thermal comfort, air quality, acoustics, and daylight, by core-learning and cafeteria spaces
- Differences in student IEQ questionnaire responses between modernized and non-modernized schools for thermal comfort, air quality, noise comfort, and daylight comfort
- Differences in teacher IEQ questionnaire responses between modernized and non-modernized schools for thermal comfort, air quality, noise comfort, and daylight comfort
- Differences in student IEQ questionnaire responses regarding thermal comfort, air quality, noise comfort, and daylight comfort between modernized schools selected to participate in this study and the modernized schools carried over from the 2018 study
- Differences in student EA questionnaire responses between modernized and non-modernized schools for friendliness feeling of the school, ease of navigation, safety of spaces, feelings about spaces, distractions of interior windows, school design, community-feeling spaces, and school design feel
• Differences in VAT scores between modernized and non-modernized schools for Community, Instructional Space, and summary VAT scores
• Differences in VAT scores for Presence, Safety and Security, Community, Organization, Instructional Space (classrooms, art studios, and science labs), Environmental Quality, Assembly, and Extended Learning Environments between modernized and non-modernized schools

Spearman Rho correlations were used for the following relationships:

• Relationship between each of the three particulate matter values
• Relationship between each particulate matter value and average CO$_2$
• Relationship between IEQ measurement and corresponding IEQ questionnaire response for thermal comfort, air quality, noise comfort, and daylight comfort
• Relationship between VAT scores and IEQ measurements between windows and IEQ daylight and between transparency and IEQ daylight

Data Analysis for CC

For the Community Connectivity portion of the study, the research team focused on responses to the parents/caregivers’ questionnaire and from the interviews and focus groups. Because the sample size was so small, the research team reviewed cumulative totals for the questionnaire answers, focusing on responses from individuals associated with the two schools for which the researchers were able to do community profiles. The research team also recorded the virtual meetings for the two focus groups with parents/caregivers and then analyzed the recording transcripts, coding them for key themes. The same was done with the recorded interviews with the external community members.
This section of the report focuses on the outcomes of the data collection and the interpretation of the study’s results. It is organized such that IEQ, EA, then CC results are shared separately. Note that within this report the term “significant” is used to identify a statistical significance, and the term “slightly” is used to indicate a noted difference that did not result in a high level of statistical significance. For more information on the statistical analysis that was undertaken on the study’s datasets, refer to the previous section highlighting the analysis methodology.

In this report, the term “significant” is used to identify a statistical significance, and the term “slightly” is used to indicate a noted difference that did not result in a high level of statistical significance.
To answer the research question regarding how modernized schools compare to non-modernized schools in terms of Indoor Environmental Quality, all IEQ data collected was grouped: modernized schools versus non-modernized schools, summed and averaged accordingly. The data were then studied to not only understand the difference between modernized and non-modernized schools, but also to understand if that difference was statistically significant. Overall, the results around Indoor Environmental Quality support the study’s hypothesis: In general, the modernized schools outperformed non-modernized schools in terms of IEQ factors of thermal comfort, air quality, acoustics, and light.

KEY FINDING

This study found that the modernized schools in general outperformed non-modernized schools around key Indoor Environmental Quality factors of thermal comfort, air quality, acoustics, and light.

Thermal Comfort

Thermal comfort is an important consideration in school design because research has shown that uncomfortable temperatures can cause feelings of fatigue, irritability, and stress (Shalchi, 2023). Further, for every 1.8°F reduction in temperature from 77°F to 68°F, student performance improves in terms of speed by 2-4% (Wargocki & Wyon, 2006). For this study, the four environmental factors associated with thermal comfort were assessed on-site using data-logging sensors for air temperature, humidity, air velocity, and mean radiant temperature. But personal factors (occupants’ clothing and metabolic rate) were not measured in the evaluation.

Modernized schools spent around 24% more time in the comfort zone, on average, compared to non-modernized schools (Table 8). Temperature swings at modernized schools were also an average of around 4°F lower (Table 9). The coldest and hottest temperatures documented during this study, furthermore, came from non-modernized schools (Table 10).
TABLE 8. Thermal Comfort Measurements
Modernized schools spent around 24% more time in the comfort zone, on average, compared to non-modernized schools.

TABLE 9. Thermal Comfort Temperature Swings
Modernized schools had lower temperature swings, on average, compared to non-modernized schools.
Students in modernized schools reported on the questionnaire feeling warmer, in both summer and winter conditions, and they were significantly more satisfied with the temperature of their classrooms throughout the year compared to students in non-modernized schools. Teachers, on the other hand, felt significantly cooler in the summer and slightly cooler in the winter in modernized schools, but they were significantly more satisfied with thermal comfort in the winter as compared to teachers in non-modernized schools.

This data highlighted the fact that non-modernized schools are typically worse at maintaining thermal comfort through the winter months compared to modernized schools. While the non-modernized schools are sometimes cooler (meaning they cannot provide enough heat to maintain comfort), they are mostly hotter, suggesting their heating systems are over-providing heat. Thus, not only are non-modernized schools typically lacking in thermal comfort and not meeting occupants’ needs, but they are simultaneously wasting energy, which is not ecologically sustainable and results in higher operational costs.

**KEY FINDING**
The non-modernized schools in the study generally provided less thermal comfort in the winter months than the modernized schools, often over-heating their interiors, which creates uncomfortable conditions and wastes energy and funds.

Another interesting finding stemmed from the questionnaire data, which showed a discrepancy in preferences between teachers and students. Regardless of the season, students reported being more comfortable when the indoor temperatures were warmer, whereas the teachers said they were more comfortable with cooler indoor temperatures. Given that children’s and adolescents’ metabolic rates are typically higher than adults’ metabolic rates, it is not surprising that these age groups’ perception of comfort varies. However, it is interesting that children (i.e., those with higher metabolic rates) seem to prefer being warm, even though from an ASHRAE Standard 55 perspective, following the PMV and PPD method*, it would be assumed they should prefer cooler temperatures, and that the opposite would be true for teachers. These findings indicate that perhaps either (1) students are accustomed to feeling warmer in indoor environments due to their higher metabolic rates and adults are accustomed to feeling cooler, (2) teachers, perhaps being more active while teaching than students are while learning, desire cooler temperatures to regulate their body heat, and/or (3) that the ASHRAE Standard 55 calculations warrant closer investigation related to the perceived comfort differences between children and adults.

**KEY FINDING**
Students (i.e., children who typically have higher metabolic rates) seemed to prefer being warm, while teachers were more comfortable with cooler indoor temperatures. This dichotomy brings into question ASHRAE Standard 55 calculations, which would suggest the opposite.

---

* Predicted Mean Vote (PMV) and Predicted Percentage of Disatisfied (PPD) are methods to determine thermal comfort.
Modernized schools spent around 24% more time in the comfort zone as compared to non-modernized schools.

Modernized schools had lower temperature swings on average 4° Fahrenheit lower.

Non-modernized schools are wasting energy!

Students in modernized schools felt warmer and were more satisfied.

Teachers in modernized schools felt cooler and were more satisfied.

Perceived comfort varies!

**TABLE 10.** Lowest and Highest Thermal Comfort Measurements

Both the coldest and hottest temperatures documented during this study came from non-modernized schools.
Non-modernized schools had both the lowest and highest CO₂ readings documented during the study. However, on average, they had slightly lower CO₂ levels than the modernized schools, although the difference was not statistically significant. Further, non-modernized schools had significantly higher average particulate matter (PM 1.0, 2.5, and 10) values (Table 11). The data showed no significant correlation between CO₂ and particulate matter within the schools studied.

Both students and teachers in modernized schools reported on questionnaires as being significantly more satisfied with the air quality in their classrooms than their counterparts in non-modernized schools. Teachers in modernized schools also rated the air significantly fresher, and they were significantly more satisfied with the air quality, compared to teachers in non-modernized schools.

The data from this study showed a wide variability in CO₂ levels, and no clear correlation between CO₂ levels and modernization status. Some modernized schools had very high CO₂ levels while other schools were very low; the same was true for non-modernized schools. This seems to indicate that the current best-practices being implemented for school modernization efforts are not having a significant impact on improving CO₂ levels, warranting further study. Perhaps standards such as LEED or even local building codes can do more to improve minimum ventilation requirements to help maintain low CO₂ levels and reduce other indoor air pollutants.

Air quality is a complex factor, however, and this study only assessed CO₂ and particulate matter. Even though the on-site CO₂ measurements showed no difference in the modernized versus non-modernized schools, significant differences were found between particulate matter values. Further, questionnaire data showed a difference in terms of occupants’ satisfaction. This could mean that CO₂ may not be the best indicator to correlate to satisfaction with air quality, suggesting that particulate matter may be a more relevant metric to connect to or perhaps even predict occupants’ satisfaction. The divergence between CO₂ and particulate matter data may also speak to the variability of how air quality is impacted within a space—through, on the one hand, ventilation (which may be more correlated with CO₂) versus, on the other hand, filtration and cleaning practices (which may be more correlated with particulate matter). Either way, more multi-factor assessments of air quality in school environments are necessary to better understand air quality comprehensively, and to begin to prioritize air quality metrics to use in evaluations moving forward.

Another possible reason for the disconnect between measured CO₂ levels and occupants’ reported satisfaction on the questionnaires could stem from how modernized schools are perceived compared to non-modernized schools. One could wonder: Does a shiny, new building influence an individual’s perception of and satisfaction with air quality, even if the hard data say otherwise?
No significant difference in CO₂ between modernized and non-modernized schools

Modernized schools had lower average particulate matter

Ventilation needs more focus in modernization efforts!

Filtration and cleaning practices are better!

Students and teachers in modernized schools reported being more satisfied with air quality

Particulate matter and satisfaction more interrelated?

TABLE 11. Particulate Matter Measurements
Modernized schools had significantly lower average particulate matter (PM 1.0, 2.5, and 10) values, compared to non-modernized schools.

AIR QUALITY
Modernized schools had significantly lower average background noise levels, though with a small effect size and not a dramatic decrease at only 2.4 dBA lower (Table 12). However, when occupied noise levels were measured, the lowest and highest values documented during the study were also found within modernized schools.

On the questionnaire, students in modernized schools reported classroom noise levels as significantly louder (both for inside and outside noises*). Students in modernized schools were also slightly more satisfied with noise levels than students in non-modernized schools. Teachers in modernized schools reported their classrooms as slightly louder from an inside noise perspective and slightly quieter from an outside noise perspective. The teachers in modernized schools were also slightly more satisfied with both indoor and outdoor noise levels, as compared to teachers in non-modernized schools.

Proper acoustics can affect students’ ability to hear their teachers and can reduce fatigue in teachers (Mogas-Recalde et al., 2021). Research has also shown that students who attend school in noisy environments, such as near a highway or under regular flight paths, have lower academic performance (National Academies of Sciences, Engineering, and Medicine, 2017). To assess acoustics, sound levels (decibels, dBA) were collected on-site using data-logging sensors, with data divided during analysis into “occupied” and “unoccupied” hours so average background noise levels could be evaluated separately from occupied noise levels.

<table>
<thead>
<tr>
<th></th>
<th>42.0 dBA</th>
<th>39.6 dBA</th>
<th>40.0 dBA LEED v4 prerequisite</th>
<th>55.4 dBA</th>
<th>54.4 dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>NON-MODERNIZED</td>
<td>Background Noise</td>
<td>Occupied Noise</td>
<td></td>
<td>MODERNIZED</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 12. Average Background and Occupied Noise**

Modernized schools had lower background and occupied noise levels on average, compared to non-modernized schools, but not by much.

* Inside noise for the questionnaire was defined as noise that comes from people inside the room, whereas outside noise was defined as noise that comes from the building or from outside (e.g., street noise, hallway noise, etc.).
The fact that modernized schools had significantly lower average background noise levels and they had all been designed to comply with the LEED for Schools prerequisite for acoustics suggests that the LEED requirements are succeeding in reducing background noise levels (Table 13). However, since there was no significant difference in occupied noise levels between modernized and non-modernized schools, more research is necessary to better understand and address acoustics within school environments.

**KEY FINDING**

Modernized schools in the study had significantly lower average background noise levels compared to non-modernized schools, suggesting that the LEED for Schools requirements for acoustics, which were used for the sample’s modernization efforts, are succeeding in reducing background noise levels. More research needs to be done, however, to address occupied noise levels in modernized schools.

There were also some interesting findings that warrant more study: Schools that were perceived as louder in the questionnaire data actually had lower measured occupied noise levels. The data also showed that higher satisfaction on the questionnaire was correlated with louder occupied noise levels. This could mean a few things: First, it may be more “fun” to be loud, as classrooms with higher occupied noise levels may be engaging in more dynamic learning, and that this type of learning increases satisfaction with higher occupied noise levels. Second, there is such a thing as a space feeling too quiet. A certain amount of “buzz” in a classroom may actually be enjoyable, as long as it does not impact intelligibility or hamper the capacity for learning. The research team recommends further research to understand how these results would vary when considering the needs of special education and non-native-language learners in a classroom environment.

**KEY FINDING**

This study saw perceived satisfaction with noise levels contrasting with actual measured data, indicating further research is necessary to understand the complex relationship between noise, engagement, and learning. Understanding the acoustic needs of special education students and non-native-language learners in classroom environments would also be of value.
TABLE 13. Acoustic Measurements
The average background noise level in modernized schools fell under the LEED v4 prerequisite of 40 decibels, whereas the average for non-modernized schools was over the prerequisite.

ACOUSTICS

Modernized schools had **lower** average background noise levels
LEED for Schools prerequisite is working!

A modernized school also had the **highest** measured occupied noise level
Occupied noise levels need more study!

Students in modernized schools felt their classrooms were **louder** and were more satisfied
Is noise a sign of engagement?

Teachers in modernized schools felt their classrooms were **louder** in terms of occupied noise but **quieter** in terms of background noise and were more satisfied
As long as it’s not from background noise levels!
The study's data showed that modernized schools had, on average, significantly less floor area that was under-daylit (18.2% less under-lit) compared to non-modernized schools. However, modernized schools also had slightly greater floor area that was over-daylit (Table 14). This difference, though, was largely balanced with electric lighting, leaving next to no variation between modernized and non-modernized schools once electric lighting was turned on and the IEQ lighting measurements were remeasured (i.e., electric light plus daylighting values).

Students in modernized schools reported on the questionnaire that their classrooms were slightly darker on sunny days, but significantly brighter on cloudy days. However, the students in modernized schools were slightly less satisfied with the daylighting on average compared to students in non-modernized schools. Teachers in modernized schools reported their classrooms as significantly brighter on both sunny and cloudy days, and were significantly more satisfied during both sunny and cloudy conditions, though especially on cloudy days, compared to teachers in non-modernized schools.

This study’s data showed that modernized schools performed better when all electric lighting was turned off compared to non-modernized schools, meaning that non-modernized schools are more reliant on electric lighting for both function and occupants’ satisfaction (i.e., comfort). This likely associates with a higher usage of electric lighting, resulting in higher energy demand and greater operating costs. Additionally, modernized schools did a better job at distributing daylight, especially on cloudy days (Figure 5). This may be a result of better design decisions such as building orientation, window-to-wall ratios, shading, the influence of technology, material selection, and the use of tools to study predicted daylight levels during the design process. While designers cannot always control for all these factors, such as building orientation during a renovation, many can be modified during the modernization process to achieve optimal daylight conditions.

**KEY FINDING**

Non-modernized schools in this study were more reliant on electric lighting for both function and comfort compared to modernized schools, likely leading to higher energy use and operating costs.

Higher daylight satisfaction on the questionnaire also correlated with a higher percentage of well-lit floor area on both sunny and cloudy days. While this correlation indicates that the more well-lit a classroom then the higher the...
TABLE 14. Daylighting Measurements

Modernized schools, on average, had significantly less floor area that was under-daylit, but slightly greater floor area that was over-daylit compared to non-modernized schools.

FIGURE 5. Daylight Distribution

Modernized schools had, on average, better daylight distribution and were more evenly lit than classrooms in non-modernized schools, although they also were slightly more over-lit on average.
modernized schools were on average 18% less underlit but were slightly more overlit.

teachers in modernized schools felt their classrooms were brighter and were more satisfied.

non-modernized schools are more reliant on electric lighting.

occupants’ satisfaction will be. It also suggests that this metric is more “visible,” or tangible as an experience, for people to understand than some of the other indoor environmental quality metrics, as the occupants’ surveyed perception of daylight aligns well with the actual on-site data measurements.

key finding

this study found the correlation that the more well-lit a classroom then the higher the occupants’ satisfaction will be.

ieq data normalization

as a result of myriad covid-19 pandemic-related challenges described in earlier sections, the evaluated ieq datasets were a merger of data collected during two different timeframes (2018 and 2020/21). accordingly, the research team conducted statistical analyses to confirm that the merger of these two datasets was valid. the results between the two datasets showed no significant differences between the quantitative metrics. the student questionnaires from 2021, however, showed a better perception of and satisfaction with air quality than those from the 2018 sample, and a significantly higher satisfaction with daylight on both sunny and cloudy days.

additionally, weather station data showed that the outside air temperature remained between 35 °f to 55 °f for over 75% of the study period, with the highest outdoor temperature spike recorded being 70 °f for a very brief period. precedent research has shown there is little correlation between outdoor and indoor temperatures in buildings, especially when the outside air temperature is less than 55 °f (nguyen et al., 2014; nordman & meier, 1988). therefore, the research team determined that no adjustments to the data needed to be made to account for an outside weather differential.
To answer the study’s research question regarding Educational Adequacy, data were collected using the VAT assessment tool and questionnaires. EA was evaluated across eight categories on the VAT: Presence, Safety and Security, Community, Organization, Instructional Space, Environmental Quality, Assembly, and Extended Learning Environments. The category-based scores were then compiled into an overall summary score for each school. Each of the eight categories was equally weighted to create the overall summary score, which revealed that the modernized schools in the study’s sample generally outperformed the non-modernized schools by statistically significant margins (Table 15).

It is important to note, however, that several non-modernized schools did score higher than some of the modernized schools. Table 15 shows that modernized Schools 3, 10 and 13 scored lower than six of the non-modernized schools. This finding is possibly due to the fact that these three schools had been modernized earlier than other schools in the sample, therefore designed under older design criteria and Educational Specifications. Despite these buildings’ poorer performance, the modernized schools outperformed the non-modernized schools overall.

The questionnaire responses related to EA were analyzed to understand the statistically significant differences between modernized and non-modernized schools. The research team only analyzed student responses, however, because teacher participation was too limited to allow for statistical comparison. Students rated modernized schools more favorably in terms of the presence of the school, the organization of the building, the sense of community within the building, the ambiance of the classrooms, and the perceived safety of the buildings and grounds.

### TABLE 15. VAT Overall Summary Scores

This chart shows the VAT’s overall summary scores for all 28 schools in the sample, listed here by their anonymized identification code (see Table 4). The higher the percentage indicates the greater the Educational Adequacy, such that a score of 100% would equate to the best possible summary score on the VAT. As can be seen, modernized schools generally outperformed the non-modernized schools on the VAT.
Compared together, the EA analysis of VAT scores and student questionnaire responses confirms that the modernized schools in this study generally outperformed the non-modernized schools. The comparison of the VAT and questionnaire data also confirmed the general utility of the VAT to assess EA and its correlation with students’ satisfaction with the learning environment.

**KEY FINDING**

Based upon the VAT data and student questionnaire responses for Educational Adequacy, the researchers found that the modernized schools in this study generally outperformed the non-modernized schools.

The following sections review the findings among VAT categories that returned the most significant EA results.

**Instructional Space**

The VAT evaluation of instructional spaces revealed a statistically significant difference between the modernized and non-modernized schools in the study’s sample. Table 16 shows the widest differential in three categories: Transparency/Connectivity, Instructional Space–Ambiance–Color and Finishes, and Instructional Space–Ambiance–Infrastructure.

Instructional Space–Ambiance–Infrastructure and Instructional Space–Ambiance–Color and Finishes had the largest statistical effect size between modernized and non-modernized schools (Figure 6, Figure 7). One example of infrastructure is easy to see: the VAT found that non-modernized schools often had HVAC equipment installed sometime after the original construction of the building. These installations frequently occupied significant floor, window, or wall space within the classrooms. Similarly, the non-modernized buildings were more likely to have conduit or piping exposed on the walls or ceiling. While likely well-intended, the integration of the newer building systems into the existing buildings regularly resulted in adverse changes to the instructional spaces’ ambiance, ranging from the loss of usable floor area to reduced daylight and views. Further, these renovations may introduce noisy HVAC equipment, creating the potential for poor acoustic conditions for teaching and learning. The added conduit or piping serving these or other interventions can also diminish the original clarity of the architecture and interior design, contributing to a visually chaotic environment.

The major differences between modernized and non-modernized buildings in the evaluation of Instructional Space–Ambiance–Color and Finishes was found to be whether the interior finish materials fostered a “warm” ambiance versus one that was “cold” and “institutional.” Even small interventions such as an accent color could reduce monotony and ease eye strain (Figure 7).

While a correlation between the questionnaire and particular VAT questions was not statistically established, within the students’ responses on the questionnaire, a significant correlation was found between modernization status and students’ positive feelings about the classrooms. Students in modernized schools rated classrooms more positively than students in non-modernized schools. For instance, 37% rated their classroom design as “exciting or inspiring” while just 2% of students in non-modernized schools felt the same.
A significant correlation was found between modernization status and students’ feelings about the classrooms, with students in modernized schools rating classrooms more positively than those in non-modernized schools.

While the study focused on buildings that had been completely modernized versus those that had not, the findings of the Instructional Space category highlight the benefits and detriments of some smaller-scale interventions that had occurred over time in some of the non-modernized buildings. These included HVAC equipment in the classrooms of non-modernized buildings that had adversely impacted the scoring on Ambiance. On the other hand, newer furniture and more furniture options reportedly improved the classroom environment. Furniture was assessed on whether there was a variety of types, it could be easily reconfigured, whether it allowed students to move (rock, fidget, swivel), and had sufficient storage for students’ belongings. These smaller-scale interventions can have meaningful impact—either good or bad—on how students assess their learning environments.

Transparency (e.g., glazed sidelights at doorways, interior windows between formal and informal program spaces) was among the lowest-scoring attributes across all the instructional spaces evaluated, except at two schools that were specifically designed around extended learning spaces. A statistically significant number of students reported that they found these types of windows to be distracting in the schools that had them. With the absence of interview data to clarify the students’ questionnaire responses relative to the varied design of each of the buildings, additional research is necessary to draw conclusions about the benefits or distractions from classroom transparency.

**TABLE 16. VAT Instructional Space Average Scores**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Modernized</th>
<th>Non-Modernized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
<td>69%</td>
<td>79%</td>
</tr>
<tr>
<td>Evident Mode of Instruction</td>
<td>89%</td>
<td>91%</td>
</tr>
<tr>
<td>Furniture</td>
<td>72%</td>
<td>52%</td>
</tr>
<tr>
<td>Presentation Capacity</td>
<td>82%</td>
<td>77%</td>
</tr>
<tr>
<td>Display / Personalization</td>
<td>63%</td>
<td>66%</td>
</tr>
<tr>
<td>Windows / Exterior Views</td>
<td>69%</td>
<td>70%</td>
</tr>
<tr>
<td>Biophilia - Exterior Views</td>
<td>89%</td>
<td>91%</td>
</tr>
<tr>
<td>Transparency / Connectivity</td>
<td>51%</td>
<td>37%</td>
</tr>
<tr>
<td>Ambiance - Colors &amp; Finishes</td>
<td>89%</td>
<td>66%</td>
</tr>
<tr>
<td>Ambiance - Infrastructure</td>
<td>88%</td>
<td>80%</td>
</tr>
<tr>
<td>Educational Technology</td>
<td>72%</td>
<td>72%</td>
</tr>
</tbody>
</table>
Instructional Space–Ambiance–Infrastructure had a statistical effect size of 0.76. For example, modifications to a school’s infrastructure, like the HVAC unit that blocks a window and adds unsightly conduit to this classroom, were often found to negatively impact the VAT scoring for an instructional space’s ambiance.

Instructional Space–Ambiance–Color and Finishes had a statistical effect size of 0.58. For example, this modernized classroom features an accent color on one wall that adds to a “warm” ambiance and helps reduce visual monotony and eases eye strain.
Presence

This VAT category assessed the first impression or “civic presence” of the building and its site, plus a school’s ability to be welcoming to the neighboring community (Table 17). In this category, all but one of the modernized schools in the study’s sample ranked higher than the non-modernized schools.

While the Site and Vehicular Circulation categories scored nearly equally across modernized and non-modernized schools, there were notable departures in Architecture and Community Access. Architecture, in particular, had the second largest effect size distinguishing modernized from non-modernized buildings (Figure 8). Interestingly, while many of the non-modernized buildings scored well as “civic architecture” (i.e., architecture that feels “important”), it was the accumulation of noisy and unsightly interventions over time, such as added HVAC equipment or window security grills, that significantly diminished the overall scores.

A school’s entry also had a significant effect on a school’s presence (Figure 9). The modernized and non-modernized buildings differed notably when it came to the ease of identifying the school’s primary entrance, whether that entrance was inviting, and whether there were sight lines from within the building to supervise people approaching. Some non-modernized buildings in the sample had their entrances relocated away from the original entrance to address accessibility or other concerns, which resulted in lower scores on the VAT. These relocations also frequently created confusion as to where to enter the building.

In response to the question, “When you come to this school, how does the building and campus/grounds feel to you?,” a significant number (67%) of students felt that the modernized schools were “very friendly and welcoming” while 27% opted for “a little friendly and welcoming.” Meanwhile, equal numbers (45% each) of students at non-modernized schools rated their campus and grounds either “very” or “a little” friendly and welcoming.

TABLE 17. VAT Presence Average Scores

<table>
<thead>
<tr>
<th>Category</th>
<th>Modernized</th>
<th>Non-Modernized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curb Appeal / Site Impression</td>
<td>87%</td>
<td>72%</td>
</tr>
<tr>
<td>Entry</td>
<td>86%</td>
<td>58%</td>
</tr>
<tr>
<td>Site</td>
<td>84%</td>
<td>83%</td>
</tr>
<tr>
<td>Architecture</td>
<td>95%</td>
<td>48%</td>
</tr>
<tr>
<td>Community Access</td>
<td>74%</td>
<td>40%</td>
</tr>
<tr>
<td>Vehicular Circulation</td>
<td>85%</td>
<td>83%</td>
</tr>
</tbody>
</table>
Presence–Architecture had a statistical effect size of 0.75. For example, this school embodies civic architecture that feels “important.”

Presence–Entry had a statistical effect size of 0.59. For example, this school has an entrance that is easily identified and inviting.
Presence–Community Access had a statistical effect size of 0.45. For example, this school has an auditorium that supports community-facing events, a plus in this category.

Safety and Security–Entry had a statistical effect size of 0.59, and Safety and Security–Building Design had a statistical effect size of 0.38. For example, modernized buildings notably allowed for supervision of the approach to their entrances, provided secure entry vestibules that would limit access to visitors, and more seamlessly integrated security features into the buildings’ designs.
**KEY FINDING**

Students in the modernized buildings reported their schools to be “very friendly and welcoming” at much higher rates than those at non-modernized schools.

Regarding community access, the VAT found that non-modernized schools often lacked the ability to close and lock doors to limit after-hours access between community-facing spaces and the rest of the building. In addition, modernized buildings more often had “impressive” community-facing facilities, such as gyms, auditoria, and dining spaces (Figure 10).

**Safety and Security**

This category broadly assessed sight lines, transparency, program locations, and other factors that represent both “hard” and “soft” approaches to school safety (Table 18). Overall, all but four of the modernized schools rose to the top of the VAT scoring.

New and renovated schools have placed considerable attention on controlling building access due to the rise of school gun violence over the past 15-plus years. As a result, nearly all the modernized schools in the study’s sample scored as well as or better than the non-modernized schools regarding entry and building design. The assessment rated approach visibility, having a secure entry vestibule and sufficient space to wait to enter, and integrating security equipment while also offering a welcoming impression. These differences were reflected in the significant effect sizes found between the modernized and non-modernized schools on the VAT criteria addressing Safety and Security–Entry and Safety and Security–Building Design (Figure 11).

When looking at the corresponding questionnaire data, students reported feeling safer in modernized schools. A significant number of students in the modernized schools reported feeling either “safe” or “very safe” across a variety of spaces, including the neighborhood surrounding their school; the school’s campus/grounds; the parking lot and car/bus loop; entrances; open interior spaces; bathrooms;

**TABLE 18. VAT Safety and Security Average Scores**

<table>
<thead>
<tr>
<th>VAT Score</th>
<th>Modernized</th>
<th>Non-Modernized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry</td>
<td>78%</td>
<td>43%</td>
</tr>
<tr>
<td>Building Design</td>
<td>78%</td>
<td>67%</td>
</tr>
<tr>
<td>Organization &amp; Interior Space</td>
<td>61%</td>
<td>47%</td>
</tr>
<tr>
<td>Instructional Space</td>
<td>59%</td>
<td>45%</td>
</tr>
</tbody>
</table>
KEY FINDING

Students’ reported feelings of safety were significantly more favorable in modernized schools, both inside and outside of the buildings.

Similarly, when asked, “What kind of feelings do you get in each of these spaces in your school?,” with regard to their school’s neighborhood, the campus/grounds, the school building, open spaces within the building, classrooms/labs, library/media center, cafeteria, gym, and assembly space, a significantly greater number of students in the modernized schools selected “some” or “many” good feelings in contrast to students in the non-modernized schools. Among the modernized schools, these students found the surrounding neighborhood, the school’s campus/grounds, and the library/media center to be more favorable.

Community

The Community category of the VAT assessed aspects of the buildings that help foster a sense of a strong learning community (Table 19). Among the ten highest-scoring schools in this category, all but one were modernized. The high-scoring non-modernized school appeared to have had some capital reinvestment (new paint, furniture, etc.) that may have influenced its standing.

Most schools scored well on the quality of the entry in the Community assessment, with an average score of 91% across all the schools. The high scores imply that a school’s entry offers a strong first impression of its culture, was clean and uncluttered, and allows sufficient space to gather. However, more than half the schools were found not to have a discernable “heart”—a place where the whole school can gather, typically at a crossroads, which organizes assembly and other publicly-oriented spaces, and connects multiple levels of the school (Figure 12).

The modernized schools also scored higher for convenient collaborative space for teachers, having “academic neighborhoods” that support a sense of community, and improved dining

<table>
<thead>
<tr>
<th>Entry</th>
<th>Heart of the School</th>
<th>Cafeteria/Dining</th>
<th>Assembly Space</th>
<th>Academic Neighborhoods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modernized</td>
<td>96%</td>
<td>42%</td>
<td>64%</td>
<td>80%</td>
</tr>
<tr>
<td>Non-Modernized</td>
<td>85%</td>
<td>17%</td>
<td>42%</td>
<td>70%</td>
</tr>
</tbody>
</table>

TABLE 19. VAT Community Average Scores
facilities. The differential, however, was not statistically significant compared to non-modernized schools.

Students echoed these results in their questionnaires, with a statistically significant correlation to the VAT scores. Overall, they reported the modernized buildings contributed to a feeling that they belonged to “one big community.” Sixty-four percent of students in modernized schools reported that the building helps “a lot,” and an additional 29% percent said that the building helps “a little” in contributing to the school’s sense of community. Students in non-modernized schools rated the building’s contributions toward sense of community as 48% “a lot” and 45% “a little.”

KEY FINDING

Students in modernized schools reported a greater sense of community than their peers in non-modernized schools.

However, when asked, “How much do the following spaces help you feel like part of the school community?” (with a list of spaces including open spaces and hallways, classrooms/labs, library/media center, cafeteria, gym, assembly space/theater, and auditorium), student responses indicated there was no significant difference between modernized schools versus non-modernized schools.

FIGURE 12. Example of Community–Assembly Space

Community–Assembly Space had a statistical effect size of 0.42. For example, this school provides a “heart” of the school where the whole school can gather, typically at a crossroads that organizes assembly and other publicly oriented spaces, and connects multiple levels of the school.
Organization

This category of the VAT evaluated the overall academic organization of the school (Table 20). Students also gave statistically significant responses about wayfinding, in that the modernized schools were generally easier to find one’s way around than non-modernized schools.

The main office location and its ability to control the school’s entrance provided the greatest ratings differential between the modernized and non-modernized schools in the study’s sample (Figure 13). This aligns with the VAT’s Safety and Security category where the modernized buildings also scored higher when it came to having a secure entry vestibule connected to the main office. This variation was not surprising, however, considering non-modernized schools were constructed when design principles regarding a school’s arrival and approach were notably different.

KEY FINDING

The location of the main office and its ability to control the school’s entrance was the greatest organizational difference between the modernized and non-modernized schools.

VAT and IEQ Effect Sizes

The study revealed that school modernization made a significant impact across multiple Indoor Environmental Quality and Educational Adequacy factors (Table 21). The greatest differences between modernized and non-modernized schools occurred within the following areas:

- Instructional space ambiance in terms of infrastructure, color, and finishes
- Exterior presence in terms of the building’s architecture, entry, and community access
- Safety and security in terms of the building’s entry and overall design
- Community assembly space
- Main office location
- IEQ air quality, in terms of particulate matter; thermal comfort; acoustics, in terms of background noise; and daylight

TABLE 20. VAT Organization Average Scores
TABLE 21. Ranked Statistical Effect Size of IEQ and VAT Factors

School modernization had a statistically significant impact on multiple IEQ and VAT factors, with more than a dozen achieving a high effect size. While statistical significance means there was a difference between the modernized and non-modernized schools and that the findings were not due to chance, a large effect size indicates the finding has practical application.

FIGURE 13. Example of Organization–Main Office

Organization–Main Office had a statistical effect size of 0.57. For example, this school’s main office is adjacent to its front door, directly accessible from the entry lobby, and can limit public access to the rest of the school.
When determining the results related to Community Connectivity, the research team focused on the hypothesis that modernized schools provide more Community Connectivity than non-modernized schools.

**CC Questionnaire Responses**

Questionnaire data from parents/caregivers of children attending a school in this study’s sample were insufficient for true statistical analysis. However, the available data did yield impressions that warranted examination and suggest areas for further research.

One of the findings was that parents/caregivers whose children attend modernized schools reported a greater sense of safety than those whose children attend non-modernized schools. The researchers also found that the majority of respondents whose children attended modernized schools agreed or strongly agreed that their school:

- Is a hub for neighborhood activities
- Provides a community anchor for the neighborhood
- Attracts people to the neighborhood
- Is a physically attractive addition to the neighborhood
- Served as an important source of information and/or services during the COVID-19 pandemic

Many of these responses were similar among the parents/caregivers of children who attend non-modernized schools, but there were several notable differences, including the fact that more than half saw their non-modernized school as a greater provider of neighborhood services (such as healthcare, food pantry, etc.), particularly during the COVID-19 pandemic.

The questionnaire responses also revealed a tendency for parents/caregivers everywhere to rate their school favorably on positive measures but disagree with negative ones. A majority at both modernized and non-modernized schools either disagreed or strongly disagreed with the statements “This school is a nuisance (due to things such as traffic or noise from the children)” and “This school creates dangerous and unsafe conditions.”

An important caveat to these responses is that the respondents’ demographics may not be representative of a school’s overall parent/caregiver population. For example, at one modernized school, most of the questionnaire respondents identified as Caucasian and reported household incomes over $100,000. The school’s enrollment, however, is comprised mostly of children of color, and nearly 26% are eligible for free or reduced lunch.

**CC Community Profiles**

The community profiles developed for this study, albeit limited, also yielded a few insights into Community Connectivity. The modernized schools tended to be in neighborhoods characterized by higher proportions of Caucasian residents and higher socioeconomic status (e.g., higher median income, fewer residents living in poverty, and a higher proportion of residents with a college degree). The non-modernized schools were more likely to be in neighborhoods that lack access to healthy food and green space.

**CC Qualitative Case Studies**

Despite the limited qualitative information the researchers were able to collect through interviews and focus groups, the research team gained insight into the impacts that two different school buildings (School C and School 2) have on their communities. The following case studies are based on a series of interviews/focus groups with school stakeholders associated with these two schools.
The majority of parents/caregivers from modernized schools felt their school...

- is a hub for neighborhood activities
- anchors the neighborhood’s sense of community
- attracts people to the neighborhood
- was an important source of information and/or services during the COVID-19 pandemic
- is a physically attractive addition to the neighborhood

The majority of parents/caregivers from non-modernized schools felt...

- their school is a provider of important neighborhood services
- the community’s perception of their school changed in a positive way during the COVID-19 pandemic

SCHOOL C

School C, renovated within the past decade, is considered a modernized school in the sample. Its neighborhood is culturally diverse, contains residential rowhouse blocks, and is known for dining and nightlife. In fact, several members of the parent/caregiver focus group for School C noted that they knew the neighborhood as “a place to party” when they were in college or graduate school, and some also stated the school grounds has a rodent problem that may be linked to the nearby restaurants (Anonymous participants, interview with author, November 14, 2022). The neighborhood has also long been a gateway community for immigrants from Latin America and Africa, among other places.

The parent/caregiver focus group, which was held virtually for parents/caregivers of six students, offered generally favorable impressions of the school. They said the school’s renovation had improved their perception of School C, with one parent noting that she would not have considered sending her child there in its prior condition. While they believed that the school-community partnership could be improved, they all praised the fact that the school shares a campus with another city-operated facility, which attracts many community members to the campus, including some who may not realize that a school building is on the property. (Anonymous participants, interview with author, November 14, 2022)

However, it is important to acknowledge that, similar to the questionnaire data, a limitation of the narrative data is that while the school’s student population is majority Latinx and Black, the focus group was comprised mainly of parents/caregivers who are Caucasian.

Combining the qualitative data with student questionnaire responses, the researchers were able to conclude that School C’s modernization has contributed to increased enrollment, positive parent/caregiver perceptions, improved student performance, and improved community awareness of the presence of the school. The analysis of the school’s archival data also showed a statistically significant correlation between the school’s modernization and increases in enrollment and academic performance. But to gain a fuller understanding of School C’s role in its community, more data is necessary, especially from community members and parents/caregivers of students of color and lower family incomes.
SCHOOL 2

School 2, a non-modernized school, is located between two neighborhoods, one more affluent than the other. It has operated under a Community School model for about ten years and shares a campus with a non-profit community center. It has partnerships with numerous local organizations, including a well-regarded university that renovated two of its classrooms and offers programming to some of the students.

The research team conducted a virtual focus group with parents/caregivers of eight students, all of whom saw the school as a positive presence in the neighborhood. They noted that many residents of the surrounding community use the school’s playground, and that numerous programs and after-school offerings contribute to the life of both the school and the neighborhood. These offerings include a food bank, vaccination clinic, and a cooking program. It is worth noting that some of these programs actually may be provided by the on-site community center rather than the school itself, as there is some evidence that the focus group participants did not distinguish between the two operations. (Anonymous participants, interview with author, March 9, 2022)

The parents/caregivers acknowledged that the school building is in poor condition, but they felt that what goes on inside its walls is more important than its physical structure. One parent described the school as a “hidden jewel” and another remarked that the school is “a great school, a special school.” Others described it as being “like a village” and a place where “I get a good vibe when I go there.” (Anonymous participants, interview with author, March 9, 2022)

In addition to the focus group, the research team conducted one-on-one interviews with members of the greater community, including a parent of a first grader who attends School 2, people who had current or past ties to the school, and community partners. A few of the many viewpoints they expressed are worth noting:

- Although the age/condition of the physical plant was an issue, they felt that “it’s not really about the building; it’s about going to school where you live,” and that “stakeholders don’t believe ‘new and shiny’ is a fix; it’s about what happens inside [the school].”
- Several people reported School 2 is not as connected to the community as it could be, with some attributing this notion to the administration’s lack of focus on this aspect, though with varying opinions as to why this might be.
• There was mixed reaction to the idea that the school’s attractiveness plays a role in whether parents/caregivers send their children there. One interviewee said families try to send their children to School 2 even if they do not live in the neighborhood, while another long-time resident was of the belief that “none of my neighbors send their kids” there.

(Anonymous participants, interview with author, April 15, 2022 and June 6, 2022)

Again, a much larger set of data should be collected to garner a comprehensive view of School 2’s Community Connectivity. However, based on the interviews conducted, parents/caregivers and the community partners give the school high marks. Its numerous community partnerships will hopefully continue to be sustaining features of the school.

COMMUNITY CONNECTIVITY FINDINGS

There are several observations worth making based on the albeit limited data collected. Perceptions of the physical condition and spaces within the school buildings did matter in how community members (i.e., parents/caregivers and external stakeholders) viewed the school overall. But the two-way-street between the community and the school makes this relationship complex and hard to fully understand. For example, those who expressed negative opinions appeared to rely on second-hand information about a school, while others were willing to dismiss poor physical conditions in a non-modernized school because they had so many other positive feelings about it. Even community members who made statements like “the building does not reflect what the school actually does” were prone to add that modernization could only serve to enhance the positive aspects of the school’s operations. Community Connectivity can exist whether a school is modernized or not—but overall, modernization seems to be a positive factor in supporting this phenomenon.

KEY FINDING

Community Connectivity can exist whether a school is modernized or not—but overall, modernization seems to be a positive factor in supporting this phenomenon.

The results of this study tended to confirm the study’s hypothesis that Community Connectivity would be better in modernized schools, albeit based on a small sample size. For example:

• Parents/caregivers who may never have considered sending their children to a particular school can be swayed by the school’s modernization.
• The modernization process, if done well, can result in greater Community Connectivity once the work is completed.
• Partnerships between schools and outside entities, as well as the presence of external partners in the school, can enhance Community Connectivity regardless of whether a school has been modernized.
• A school’s outdoor spaces play a considerable role in developing or contributing to Community Connectivity and should not be overlooked.
When evaluating the study’s collective findings in relation to the research questions and hypotheses, the research team discovered that, in multiple categories, the modernized schools offered greater Indoor Environmental Quality and Educational Adequacy than the non-modernized schools, while Community Connectivity returned mixed, though favorable, results.

Modernized schools outperformed non-modernized schools in a statistically significant manner on multiple Indoor Environmental Quality factors, including greater thermal comfort, better air quality in terms of reduced particulate matter, lower background noise levels, and better daylighting. However, modernized schools were not as successful at addressing some IEQ factors, such as CO₂ levels and occupied noise levels, suggesting these are areas for future study.

The modernized schools also came out ahead on several Educational Adequacy categories, including Presence, Instructional Space, Safety and Security, Community, and Organization. In particular, the modernized schools provided a more positive first impression, an enhanced learning ambiance, and more safety strategies than non-modernized schools.

There were more mixed results when it came to Community Connectivity. Parents/caregivers tended to rate their own children’s school favorably, regardless of whether or not the school was modernized. Those who have children in non-modernized schools tended to place a higher value on the fact that the school provides community services rather than the school’s modernization status. They also focused on a school’s overall strengths even while recognizing the shortcomings of the physical facilities. They recognized, however, that a modernized building would enhance the good work their school was already doing.

Across multiple categories, the study found that modernized schools offered greater Indoor Environmental Quality and Educational Adequacy than the non-modernized schools, but results were mixed, though favorable, for Community Connectivity.

Regarding the school districts’ archival data, the research team examined enrollment, truancy, graduation rates, and student scores on the Partnership for Assessment of Readiness for College and Careers (PARCC) test. Only data about DCPS schools were available for these analyses. The goal was to determine what relationship, if any, exists between these performance indicators and a school’s modernized or non-modernized status.

Two sets of series of Repeated Measure ANOVAs were conducted to compare the changes in enrollment, truancy, and graduation rates from the 2011-2012 academic year through the 2021-2022 academic year. The researchers analyzed PARCC scores from the 2014-2015 school year (the first year of available data) through the 2021-2022 academic year. Analyses did not test for correlation but instead were used to determine whether there were general differences on each measure over time for modernized versus non-modernized schools.
In the school enrollment category, modernized schools had significant enrollment increases over time; non-modernized schools did not. Thus, the data show that a school’s enrollment is likely to increase over time after a school is modernized. For student performance on the PARCC test, significant differences in English language arts and mathematics scores over time were found for students attending modernized schools.*

In the areas of truancy and graduation rates, the research team found mixed results. For truancy, there was a significant increase over time for students attending modernized schools—a finding that ran counter to the research team’s expectations. There was no significant difference in truancy over time for students attending non-modernized schools. Graduation rates improved over time at most of the modernized schools, but these increases were not statistically significant. The researchers could not analyze graduation rates at non-modernized schools nor compare them to the modernized schools due to insufficient data.

From these analyses, the research team concluded that students in modernized schools had better English language arts and mathematics test scores; and modernized schools experienced statistically significant growth in enrollment, while graduation rates also trended upward.

Based upon the study’s findings, the research team developed the following recommendations for the planning and design of modernized school facilities, with the goal of creating environments that positively impact school stakeholders and the communities surrounding schools, helping to prepare students for success in the 21st century.

**Design recommendations based on this study’s findings include:**

- Improve the learning ambiance in instructional spaces
- Enhance civic presence, arrival, and community access
- Control access for safety and security
- Invest in indoor environmental quality for healthier, higher-performing spaces
- Create a “heart” of the community
- Accommodate community partners on-site to magnify their impact
- Consider how the community can engage with a school’s campus/grounds
- Recognize that modernization impacts community members differently

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* Note, no PARCC scores were reported for the 2019-2020 academic year, and there was a slight decrease in both English language arts and mathematics scores for modernized and non-modernized schools during the 2020-2021 academic year. These anomalies are likely the result of disruptions related to the COVID-19 pandemic.
Improve the Learning Ambiance in Instructional Spaces

Learning ambiance is a way of thinking about the experience of the learning environment, and asks the questions: Is the environment visually appealing, orderly, well-maintained, and comfortable, or is it chaotic, haphazard, poorly maintained, and/or monotonous? As this study demonstrated, large-scale modernization efforts have considerable opportunity to create a positive learning ambiance, but when carefully planned, even smaller-scaled interventions in existing buildings can have a notable impact.

Most of the students in modernized schools surveyed for this study indicated that their classrooms were either “calming” or “exciting and inspiring.” These positive responses significantly correlated with the visual assessment of the modernized schools’ instructional space in the VAT’s Ambiance category. However, it is important to note that updates to a school building also frequently occur incrementally over time, and these smaller changes can either enhance or detract from the ambiance.

Ambiance, the visual impact of building infrastructure in the classroom, was found to have the highest effect size in the VAT analysis. Ad-hoc installations over time at non-modernized schools were the biggest culprit behind their poor ambiance ratings. In contrast, the modernized schools were identified as having “warmer” and “less institutional” material palettes. Enhancements like these were statistically significant within the VAT’s Ambiance category for instructional spaces.

Accordingly, it is recommended that school districts carefully coordinate infrastructure interventions that occur over the course of a school building’s lifecycle to avoid diminishing the learning ambiance. For instance, avoid exposed HVAC equipment, conduit, piping, and other interventions that contribute to a chaotic visual environment and sacrifice instructional space, wall surfaces, and daylight in the classrooms. Facility maintenance also matters. A lack of investment in the building can be interpreted as a lack of care for the people who work and learn there, too.

On the other hand, design interventions, such as updated paint colors or new finishes and furniture, can positively impact the learning environment. While full-scale modernization can have many benefits, districts can still take incremental steps to enhance their schools’ interiors and thereby have a positive impact on teaching and learning through smaller, more targeted investments in the fixed and semi-fixed features of a school.

Enhance Civic Presence, Arrival, and Community Access

First impressions matter. Arriving at a school is the first opportunity to show students, teachers, staff/administrators, and even community members that they are valued. It also demonstrates to the greater community that what happens within the walls of the building, and on the campus more broadly, is important. A significant number of students who responded to this study’s questionnaire felt that the modernized schools were friendly and welcoming.

The researchers also found that in terms of Presence (the first impression or “civic presence” of the building and its site, plus a school’s ability to be welcoming to the greater community) all but one of the modernized schools in the study’s sample ranked higher than the non-modernized schools.

Architectural style can vary, but a school’s front door should be accessible, welcoming, and free from visual clutter. The façade and landscaping should be well-maintained. Windows should be clear and allow staff in the main office to subtly monitor arrivals. The study also found that the ability to close off portions of a school to facilitate after-hours community access, and the quality of its assembly spaces, were also critical areas where modernized schools scored highly for Presence. Thus, not only does the building’s streetside design make a difference but so does its interior layout.
Welcoming the educational community while providing a safe and secure place to foster learning begins at the entry to the school. It should be orderly and welcoming while limiting access to people from outside the school community. A secure vestibule should control access to the instructional environment beyond the entry. The main office should be directly adjacent to and accessible from the entry lobby to facilitate wayfinding while serving as a checkpoint for arriving visitors. Windows with views of the arrival area in front of the of the building and within the secure lobby can also help enhance the safety of students, teachers, and staff/administrators within the school.

A significant correlation was discovered between a school’s modernization status and students who said they felt like they belonged to “one big community.” Ninety-one percent of students in the modernized schools said the building helps support their schools’ sense of community. Even in the non-modernized schools, 87% of students reported the same.

Further, this study found value in the creation of a place that centers the learning community and the building around a “heart” of the school. These centralized interior spaces, typically located at a crossroads in the school, could be either a programmed space (e.g., dining or the library) or informal gathering spaces/extended learning environments. Inclusion of this kind of space can extend both formal and informal learning opportunities and supports a school’s overall sense of community.

Students in modernized and non-modernized schools reported near-equal rates (86% to 84%) that open spaces, like an atrium, and hallways contributed to their feeling like they were part of the school community. Thus, a “heart” of the school can go a long way toward boosting a school’s overall sense of community.

School modernization efforts can make significant improvements to the quality of the indoor environment, which in turn can influence student and teacher health, satisfaction, and performance. The researchers found that current modernization strategies are bettering thermal comfort conditions by stabilizing temperatures within the comfort zone, improving air quality by reducing particulate matter, decreasing background noise levels typically caused by mechanical equipment, and increasing daylight distribution and exposure to natural light. Modernization was also found to result in higher satisfaction ratings of the educational environment among teachers and students alike, suggesting that even though Indoor Environmental Quality factors may be “invisible” to building occupants, they have a tangible impact on occupant satisfaction.
Accommodate Community Partners On-Site to Magnify Their Impact

Community agencies and service providers can have a greater impact when they partner with a school. These partnerships, in turn, greatly increase Community Connectivity. Co-location on the school’s campus can be valuable, as well. This was evident in both modernized and non-modernized schools, demonstrating that community programming can enhance engagement with a school and its surrounding neighborhood, regardless of a school’s modernization status. In fact, the parents/caregivers of children in non-modernized schools involved in this study placed a higher value on the school being a provider of neighborhood services than those whose children attend modernized schools. That might be because community partners sometimes renovate or upgrade areas within those schools, as stakeholders cited these improvements as a benefit to students, teachers, and staff/administrators.

Consider How the Community Can Engage with a School’s Campus/Grounds

Open space adjacent to or surrounding a school greatly enhances Community Connectivity. That space can take different forms and be used in various ways. For example, a review of the study’s community profiles revealed that non-modernized schools in the sample were more likely to be in neighborhoods that lack access to healthy food and green space. Accordingly, providing an outdoor garden, or even a lawn, can help fill that void. Playgrounds, ballfields, running tracks, and other positive features on a school campus can also create opportunities for community members to benefit from a school modernization program, even if they never enter the building. In turn, these benefits may stimulate increased community support for the school.

Recognize That Modernization Impacts Community Members Differently

Parents/caregivers tended to rate their children’s school favorably on positive measures and disagree with negative response options, regardless of whether the school had been modernized. Some noted they were committed to sending their children to their neighborhood school regardless of the school’s modernization status. In addition, community members with a long history in the neighborhood rated a school’s non-modernized status as less of a concern than the parents/caregivers who had less history in the community. However, families new to the neighborhood will typically enroll their children in a school after it has been modernized, whereas they often would not have considered the non-modernized version as an option. This aligns with the upward trend in school enrollment found among the modernized schools in the study’s sample.

Care must be taken, however, to ensure that community members across a wide demographic spectrum can benefit from a modernization. The process of planning for a new school or renovation of an existing facility can boost Community Connectivity. Engaging long-time residents in the modernization process can help to mitigate the potential for gentrification that may drive those individuals and families out of the school and neighborhood. School Improvement Teams or similar advisory groups can engage a broad array of stakeholders—teachers, staff/administrators, parents/caregivers, and community members. These groups can improve students’ educational experiences, enhance parent/caregiver involvement in the school, bolster community support, and provide more opportunities for community members to use the school facilities.
Modernization Can Be a Powerful Tool for Enhancing Educational Outcomes and Well-being

In summary, this study’s findings demonstrate that as school districts strive to enhance educational outcomes, continued investment in the quality of the school’s educational environment plays a critical role in achieving that goal. The researchers found that school modernization had a significant and positive impact on key educational indicators, including test scores and enrollment over time, that modernized learning environments improved their occupants’ well-being and satisfaction, and that the modernization process can enhance community engagement and connectivity.

The findings from this study underscore that Indoor Environmental Quality, Educational Adequacy, and Community Connectivity are valuable means of analyzing the impact of school modernization efforts. Further, the study identified where planning and design strategies focused on improving areas within these variables can derive the most value from continued and enhanced investment in modern and modernized learning environments, thereby creating environments that positively impact school stakeholders and the communities surrounding schools, helping to prepare students for success in the 21st century.
Tool Kit for Study Replication
Limitations and Complications of the Research
Though this was a robust investigation with statistically significant outcomes, the research team recognizes limitations of the research and complications that impacted the study, mainly as a consequence of the COVID-19 challenges that occurred during the data collection phase. Limitations and complications of the research are as follows.

**Limitations**

- Like all design research conducted in the field, rather than in a lab where variables can be isolated and controlled, there is the always the potential that confounding variables may unknowingly influence a study’s findings. For instance, data collected in schools could be influenced by the quality of the teachers or principals at each school, or the existence of programs that are designed to impact some of the outcomes of interest (e.g., resources unrelated to the building design, such as literacy interventions or whole child interventions).

- Exposure to the school environments being studied may have varied across the range of study participants. For instance, within the student participant group, there were elementary school students, who typically spend most of their day in one primary classroom, as well as high school students, who generally move from room to room for each class period. Likewise, there were teachers who work out of one room for most of the day and others who may move between spaces. The amount and type of exposure to the classroom environment would, accordingly, differ for those who spend hours in a space versus minutes. There was an attempt to address this limitation, such as wording questionnaire and interview guide/focus group questions to reference “the typical classroom” one would experience. However, this difference in exposure and spatial experience may have influenced the participants’ responses.

- Though conflicts of interest were carefully avoided, it’s worth noting:
  - Perkins Eastman plans to publish and present findings from this study to leverage the company’s thought leadership for marketing and communications.
  - Perkins Eastman designed new buildings and renovations for some of the schools participating in this study. In some cases, members of the research team who are also associated with Perkins Eastman conducted site evaluations in the same buildings the firm designed.
  - Perkins Eastman, Drexel University, and Invontics each received a portion of the grant funding from the American Institute of Architects College of Fellows and J+J Flooring to conduct the study.
  - Perkins Eastman hopes to secure new clients and project contracts based on the thought leadership and expertise this study provides.

- The research team followed appropriate procedures throughout the study, obtaining informed consent from all participants or their legally authorized representatives. However, it is possible the study may have been impacted through undue influence in seeking participation, such as when school administrators asked parents/caregivers to participate.

- The researchers conducted this study using the participating school districts’ definition of what a 21st-century learning environment looks like. The research team recognizes, however, that a 21st-century school might look different in various parts of the country or internationally. The study also did not address 21st-century learning in virtual or home-school settings.

- Regarding IEQ, school occupants’ perceptions of environmental conditions may be influenced by such things as windows that remain closed during the winter, or the fact that teachers, rather than students, typically control the lighting and operate the windows.
Due to COVID-19 pandemic complications, the research team was unable to perform any interviews or focus groups to address Educational Adequacy. The original intent had been to interview, within a representative sub-sample of the schools, school leadership, teachers, and students from both modernized and non-modernized buildings, and an architect who was part of the design team for the modernized buildings. The EA analysis, therefore, was solely reliant on the VAT data and limited questionnaire responses. Without the qualitative understanding from the interviews and focus groups, the EA findings may not have captured a holistic understanding of the impact of modernization on EA.

A significant gap in the CC data developed when the research team was unable to hold a focus group with Spanish-speaking parents/caregivers at School C, whose children comprise a sizable portion of that school’s enrollment. Without this input, the qualitative data comes from a focus group that is not demographically representative of the student/family population of School C, therefore potentially skewing the results.

Complications

The COVID-19 pandemic stretched the limits of schools everywhere. Staff/administrators, teachers, and even students did not want, nor need, the added burden of anything above-and-beyond their primary responsibilities. The stressors faced by school stakeholders during this time made data collection for this study challenging, both in terms of getting schools to commit to assisting with data collection (e.g., helping organize parent/caregiver focus groups) to providing data themselves (e.g., completing a questionnaire or providing district-wide archival data).

A similar challenge the research team faced, which others seeking to study public schools will also confront, is the need to work through school district personnel and school leadership to accomplish the parent/caregiver focus groups and community data-gathering. Without questioning the good intentions of district and school personnel, the fact is that at any time—let alone during the COVID-19 pandemic and its aftermath—these people have numerous priorities, and a research study is unlikely to rise to the top of anyone’s list. This means that, at a minimum, the speed of the study can be severely hampered and, even more problematic, there may be an inability to engage with knowledgeable people with the connections needed to recruit study participants. Having school leadership on board (and identifying the right point-of-contact to engage with at each school) is key.

There was a challenge related to the participation of minors (i.e., the students) in the study. The study’s Institutional Review Board and one of the participating school districts requested that parents/caregivers first sign off before researchers could seek informed consent from a child. This step added a layer of complexity when issuing the questionnaire and likely contributed to the smaller number of student participants from that district compared to the other one, which only required Notice of Student Participation be sent to the parents/caregivers before seeking students’ consent.

Some of the VAT assessments may have received diminished scores because, while the schools in the study had returned to in-person learning, they were still practicing social distancing as a COVID-19 precaution, meaning things like furniture configurations were not typical.

The research team collected significantly less data than anticipated for the CC portion of the study. The original plan was to develop a Community Connectivity scale that could be used beyond the endpoint of this study; and the research team intended to cross-analyze community profiles with the data gathered from questionnaires, interviews, and focus groups. However, due to the limited responses, a meaningful synthesis of the data was not possible. Thus, the research team could not detect any significant patterns between school modernization and the conditions of a school’s greater community.
Suggestions for Future Research
While the research team developed a comprehensive analysis of the built school environment through this study and found significant benefits from modernization across the three variables of Indoor Environmental Quality, Educational Adequacy, and Community Connectivity, the investigation also raised new questions that warrant further research and potential modifications to the data collection methods/tools used for this study, as follows.

**Indoor Environmental Quality: Further Research**

The research team suggests the following to further expand the exploration of IEQ in schools.

- Collect IEQ data not only in cold seasons but also in warm months.
- Although this study’s evaluation of school modernization did show improvements in air quality (in terms of particulate matter), there was no significant difference from non-modernized schools in \( \text{CO}_2 \) or occupied noise levels. Despite research that has shown the effect \( \text{CO}_2 \) levels have on cognitive function, this study revealed that current modernization efforts are not having a significant impact on \( \text{CO}_2 \) levels in classrooms. Research-based modernization strategies should be developed to reduce \( \text{CO}_2 \) levels in classrooms.
- Air quality is a complex factor, with many possible contributors and indicators to consider. More multi-factor assessments of air quality in school environments should be conducted to better understand this metric and to begin to prioritize air quality metrics to use moving forward. For instance, in addition to \( \text{CO}_2 \) and particulate matter, volatile organic compounds (VOCs) data could also be collected when assessing air quality.
- Given the different metabolic rates between children and adults—and the preferences they have between warm and cool classrooms as a result—future researchers should more closely analyze their ASHRAE Standard 55 calculations following the PMV and PPD method* so they can better understand the two groups’ perceived comfort differences.
- Explore thermal comfort factors holistically (i.e., dry bulb temperature, relative humidity, mean radiant temperature, air speed, clothing level, and metabolic rate) and over time, and the impact across a variety of (e.g.) ages, genders, and races.
- Even though people are typically dissatisfied with acoustics in schools, current modernization efforts are not making significant progress to reduce occupied noise levels. Further investigation should be pursued to generate design strategies aimed at improving occupied noise conditions in modernized classrooms.
- This study revealed a disconnect between perceived satisfaction with classroom noise levels and the noise levels measured on-site. Further research needs to be conducted to understand the complex relationship between noise, engagement, and learning.
- Investigate the acoustic needs of special education and non-native-language learners in classroom environments.
- Better tools/methods could be deployed to measure glare in an indoor environment so comparisons can be made between design level modeling of Annual Sunlight Exposure (ASE) and real-world measurements in the built environment.

**Educational Adequacy: Further Research**

The research team suggests the following for further exploration on EA in schools.

- One of the factors that generated the most questions from the EA portion of this study was the use of transparency—often through glazed sidelights at doorways and interior windows between formal and informal program spaces, like the view from classrooms into circulation or extended learning spaces. The use of transparency was inconsistent throughout the sample, even among the modernized buildings. In addition, students in their questionnaires said this visual connectivity could be distracting. Unfortunately, given the overall poor response rates from participating schools, there were no questionnaire responses available from the schools that do have transparency.

* Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) are methods to determine thermal comfort.
features, where the design purposefully organized instructional spaces around extended learning environments. The issue of transparency should be a topic of further research since these aspects of school design relate to pedagogy, extended learning environments, and the passive supervision and general safety within a learning environment.

- Subsequent iterations of the VAT might consider revising or removing the questions about the “heart” of the school, because the sample did not include enough schools with these types of spaces to adequately test the VAT’s associated criteria and scoring rubric around this feature.
- Build out the VAT to include criteria related to schools’ exterior features (e.g., campus/grounds, parking, pathways).
- The weighting given to the VAT’s overarching categories should be evaluated, including potentially emphasizing Instructional Space and Safety and Security.

Community Connectivity: Further Research

The research team suggests the following for further exploration on CC in schools.

- Given the relatively small number of responses to the questionnaire and the limited focus groups and interviews conducted, future studies would benefit from more data to support or clarify CC findings. This further research could be conducted (1) on the sampled schools in Baltimore and Washington, DC, (2) with different schools in those two school districts, or (3) by working with schools in other districts.
- In the midst of the pandemic, the research team decided not to ask external community members to complete a questionnaire, though the researchers would have preferred to have that data. Each community surrounding a school will have physical locations in which a future research team could either personally be present for defined periods of time to recruit participants or hand out paper copies of the questionnaire for people to complete. Ideally, the research team would also circulate an online questionnaire through a reliable community partner-organization that can reach a wide audience.
- Researchers should pose additional questions in the questionnaire, interview guide, and/or focus groups to gather more information from school stakeholders about ways in which schools facilitate connectivity or not. They should also seek to better understand the impacts of that connectivity, such as asking community members exactly how they use open space on the school’s campus/grounds.
- The research team still believes that developing a “Community Connectivity scale” would be a worthwhile endeavor. This would require collecting more data from stakeholders so there is a sufficient base from which to identify patterns in their responses. Questionnaires, focus groups/interviews, and additional or different archival data are good ways to gather this information, followed by statistical analysis and then another analytical process to seek connections between stakeholder responses and the community profiles data. Such a scale would enable communities, school districts, and designers to evaluate whether school facilities are truly meeting the needs of their community—data that can inform decision-making and prioritizations for a school modernization.

General Improvements to the Study

In addition to the above suggestions for future research specific to IEQ, EA, and CC, the research team recognizes that general improvements to the study could include the following.

- Refine the questionnaire to get deeper into IEQ, EA, and/or CC data, in particular.
- Hold additional interviews/focus groups with a more diverse and representative sample of school and community stakeholders.
- Engage principals to a greater degree to increase the number of questionnaire respondents and interview/focus group participants. District administrator
buy-in is certainly important as well, but based on the researchers’ experience with this study, it does not guarantee access to desired audiences—especially parents/caregivers of students and external community members. The principal would likely know the most effective way to reach their students’ parents/caregivers and also be able to make a connection between the research team and the appropriate staff member or parent-teacher representative, or directly do the outreach to parents/caregivers, themselves. The principal could also publicly endorse the study, which would make it more likely that others will participate with or provide support to the researchers.

- In schools that employ a Community School strategy, work with the Community School coordinator, who could play an important role in identifying appropriate individuals and making introductions to arrange the data collection.
- Engage with the participating schools’ facility maintenance personnel through questionnaires and/or interviews/focus groups to provide context for IEQ on-site measurements and EA building assessments.
- Seek other kinds of archival data. In this study, the research team was able to identify certain ways modernization impacted trends such as graduation rates and school enrollment. While the research team had access to publicly available data on enrollment, graduation rates, truancy, and standardized test scores—where the researchers uncovered valuable connectivity to modernization status in three of the four measures—schools and school districts routinely collect a wealth of additional data that could lend further support for the modernization of school facilities. Data on such things as the quantity and purpose of student visits to the school nurse, incident reports of bullying, and teacher and staff/administrator recruitment and retention rates, for example, could provide insights into whether teachers, staff/administrators, and students in modernized schools have more positive well-being and performance outcomes than their peers in non-modernized schools.
- Consider recruiting teachers and students as data collectors so they can use the experience as a learning opportunity.
Indoor Environmental Quality Replication
Replicating the Indoor Environmental Quality (IEQ) on-site measurement portion of this study should consider the following.

**Step 1: Determine the factors to measure**

The first thing to do before beginning a study of IEQ is determine what factors are of interest. As was done for this study, it is recommended that the factors selected for study fall under the four main categories of IEQ: thermal comfort, air quality, acoustics, and daylight. Selecting factors within each category will depend on the available resources and technology, the level and length of access provided to the schools, who is available to assist with data collection, and what may be a priority interest to the school/district, themselves. For more information on the factors studied and tools used for this study, see the List of Sensors under the IEQ Replication Resources section.

**Step 2: Identify spaces**

Once it is known what is being studied, the next step is to determine where the IEQ factors will be studied. Deploying IEQ sensors across an entire school is oftentimes impractical and unnecessary. Akin to this study’s approach, the researchers recommend identifying a handful of “typical use” spaces to capture a sense of the schools’ average conditions. For more recommendations on this step, see the Sensor Location Selection document under the IEQ Replication Resources section.

**Step 3: Prepare the toolkits and train people for deployment**

Once the what and where are determined, the how and who can be planned. This is also the time for IEQ sensor identification and acquisition and the training of data collectors. Depending on the scope of study, a team could collect data within as little as one week with just a few sensors if the research takes place in one or two schools. But if the scope is larger, as with a district-wide study, more planning and greater detail is necessary to decide (1) the number of sensors needed and how many can be available at one time, and (2) how many weeks they need to be deployed to complete the data collection. If a multi-week study is necessary, establish a data normalization process to ensure that any exterior temperature variations during the data collection timeframe can be accounted for in the data tracking and analysis.

There are several options for acquiring IEQ sensors. If the research team does not have its own tools to deploy, a nearby university with an architecture or building science program, or even the local utility company, may have a tool-lending or rental library. If the researchers have their own tools, it is important to prepare the sensors following the manufacturers’ instructions to calibrate them properly in advance of the study. Each sensor should also be labeled with a unique identifier, so it is easy to determine what tool was placed in which space, particularly for data download.

A team of individuals may be needed to help deploy the sensors, depending on the scale of the study. During a week-long study, one individual may be able to cover two schools, depending on their proximity to the schools. However, it often becomes challenging for one person to reach much more than two schools without disrupting the schools’ instructional hours. No matter how many assistants are involved, it is helpful to gather everyone together alongside the toolkits before the study begins to walk them through each step of the Training and Deployment Guide, found under the IEQ Replication Resources section, to ensure everyone knows how to prepare and deploy the tools properly.

**Step 4: Prepare the schools for deployment**

When coordinating data collection within schools, the research team should work with a person from each participating school to help identify typical classrooms and coordinate dates and access to the school for data collection. Before that happens, the research team should inform a broader school audience that the study is occurring. In particular, the team should communicate in advance with every teacher occupying each room selected for the study. A summary should be provided to these teachers, perhaps in an email sent by the school’s principal, which outlines the purpose of the study, the tools that will be deployed, and how it might impact them and their students. Involving the teachers is crucial to proper data collection; otherwise, sensors could be turned off, moved around the room, or even returned to the main office.

To minimize impact during school instructional hours, most of the tools selected for this study are data-logging, meaning they can be left unattended in a classroom and collect data over time. Typically, sensors are deployed outside of school hours, either before class begins in the morning or after school lets out in the afternoon. The data collector may have
to arrive at the school an hour or more before classes begin on the first day of the data collection period to successfully deploy all the sensors, which makes for an early morning. Thus, it is important to coordinate with each school’s point-of-contact so the data collector can get into the building that early and gain access to the necessary spaces.

**Step 5: Deploy the tools**

Once everything has been coordinated, the sensors can be deployed. Follow the Training and Deployment Guide under the IEQ Replication Resource section for more information.

During deployment, the researchers recommend the following for each room being studied.

- Make sure the researchers have coordinated with each teacher who occupies that room. If the teacher(s) are in the room when the sensors are being deployed, make sure they understand the study and their role in it.
- If the research team is interested in tracking occupancy to more closely analyze the data, ask the teachers in each room to complete an Occupancy Tracker (available under the IEQ Replication Resources section).
- Properly place the sensors, making note of which sensors are being placed in which locations so the data can be easily tracked after the fact.
- The researchers should also leave a business card next to each sensor, alongside a document that briefly outlines the study and what the sensors are measuring. That way, if anyone has any questions, they can call the research team directly.
- The sensors should be checked at least once each day during deployment to ensure they are still working as expected and that nothing has been moved or unplugged. The team should coordinate the time and access for this check-in before the study begins. In some cases, they can arrange with someone at the school to perform the check, such as a maintenance or facilities supervisor, as long as that person is trained in how to do it.

**Step 6: Download data and analyze results**

Once the data collection period is complete, collect all sensors and download the data to a central location. Each sensor will have a different interface, and ultimately there may be a variety of spreadsheets from each sensor. It is best to group the data by room and then aggregate the per-room data into one spreadsheet to create a summary (refer to the IEQ Replication Resources section for a sample data summary). Analysis of the data may involve things like separating and comparing data of occupied versus unoccupied conditions, averaging data, and visualizing information for easy comparison.

**IEQ Replication Resources**

To help replicate this study’s Indoor Environmental Quality on-site measurements, the following resources are available for download from this site:


- IEQ — List of sensors
- IEQ — Training and deployment guide
- IEQ — Sensor location selection
- IEQ — Occupancy tracker
- IEQ — Sample data summary
Visual Assessment Tool Replication
Replicating the Visual Assessment Tool (VAT) and implementing it for further study should consider the following.

**Step 1: Develop the VAT**

The VAT developed for this study was inspired by precedent evaluation tools, was based on the participating school districts’ Educational Specifications, and informed by research current at the time of its development in 2019. The VAT evaluation criteria (available under the VAT Replication Resources section) were developed to assess the building and campus/grounds of a school across several areas of inquiry: Presence, Safety and Security, Community, Organization, Instructional Space (classrooms, art studios, and science labs), Environmental Quality, Assembly, and Extended Learning Environments.

The existing criteria can be adopted to replicate this study, or it can be modified as necessary to suit the research pursuit. To use the VAT as a precedent for a site-specific adaptation, it is helpful to review several areas of focus. First, it is important to understand the focus of the VAT relative to specific instructional spaces and the overarching issues addressing the organization and quality of the school building and campus/grounds. Regarding instructional spaces, for example, the VAT focused on a sample of classrooms, art rooms, and science labs. Additional spaces within a school, however, could be assessed as needed or desired, such as music rooms and other instructional spaces, administrative space, or the main office. The school district(s) participating in the study should review and approve the final draft of the VAT.

**Step 2: Develop a method for collecting data on-site**

While it would be entirely possible to print the VAT and do the assessment manually, with no more than a clipboard, writing implement, and measuring device (e.g., laser tape measure), online software can greatly facilitate data collection if cellular or Wi-Fi access is available at each school site. This study, for example, relied on SurveyMonkey.com. (Other widely available online surveying software could certainly be used instead.) By creating a digital version of the VAT, the surveying team was able to use their smartphones to collect and upload both data and photography in real-time as they walked each site.

It is also important to consider the data formatting and output once data has been collected. The research team found that preparing the data for analysis was one of the more labor-intensive aspects of the process.

**Step 3: Test the VAT and train the team**

The VAT should be piloted in at least one representative school site before the study begins to test the data collection process, the technology being used, and the data output. Review the school’s floor plans and identify the spaces for surveying. For example, this study’s research team identified four classrooms in each school, with varying solar orientations, to coordinate with the IEQ assessment. Once on site, test the entire VAT by completing all its questions.

This piloting process is also an opportunity to train the surveying team on the VAT’s content, the methods and sequencing of the building walkthrough, and to ensure inter-rater reliability. For this study, the five people identified to conduct VAT data collection each evaluated the same building using their own assessment form. They then gathered to discuss the criteria and compared each person’s scoring relative to the overall team scoring. This process created a shared understanding of the VAT’s criteria while underscoring any aspects that needed further refinement or clarifications to ensure inter-rater reliability.

**Step 4: Plan and implement the on-site walkthroughs**

With the final VAT ready and the data collection team trained, the on-site walkthroughs can begin. The research team should coordinate with school administrators to determine when this can happen. The schedule should allow for sufficient time to complete the evaluation of each site in...
a single visit. For reference, this study’s VAT surveying team took approximately two consecutive hours to walk through a typical elementary school, and about three hours at larger schools.

In terms of site photography, the researchers used their smartphones to capture examples of site conditions, such as the design of instructional spaces. They uploaded their images directly into the online surveying tool (the VAT on SurveyMonkey.com) as they were photographed in the field, simplifying the data collection processing necessary following the walkthrough. Be aware that school districts may limit the use of photography that includes people. Before beginning VAT data collection, future researchers should consult with school/district administrators to understand any limitations associated with on-site photography and its use in publication.

Step 5: Process the data

The research team can process data collected by the VAT after each on-site evaluation or at the end of the entire process. If the time allows, however, the former approach might be preferable because researchers could immediately flag and address any issues arising from the data collection process.

Processing the data should include a means of compiling and visualizing it for comparison across schools on each of the VAT factors and the questions under each of those categories, a sample of which is available under the VAT Replication Resources section. A variety of software can help accomplish this task, such as Microsoft Excel and Microsoft PowerBI. The compiled data can then provide the rubric for evaluating each school’s VAT score relative to others. It can also provide the inputs for statistical analysis, as desired.

VAT Replication Resources

To help replicate this study’s EA visual assessment on-site measurements, the following resources are available for download from this site:


- VAT — Evaluation criteria
- VAT — Sample data summary
APPENDIX E

Questionnaire Replication
The questionnaire for this study was a pilot test for a new surveying tool aimed at capturing stakeholder perspectives on the topics of Indoor Environmental Quality (IEQ), Educational Adequacy (EA), and Community Connectivity (CC) in elementary, middle, and high school buildings. School stakeholders were defined as students, teachers, staff/administrators, parents/caregivers of students who attend the school, and members of the community in which the school is located.

The research team was not able to deploy community questionnaires due to the pandemic, so this part is not included here. However, the research team recommends that future studies include members of the community to achieve a more robust dataset for the CC portion of the study. Community questionnaire data can supplement information gathered by interviews/focus groups to provide a more holistic picture how connected a school is to its neighborhood.

Though the overall questionnaire response rate for this study was poor, the research team felt this tool was a good first step to engage with the school stakeholders and understand their perspectives. The questionnaire data, albeit limited, helped the research team respond to the study’s research questions—particularly those questions regarding IEQ and EA. The following content provides information on how to replicate the questionnaire process.

Step 1: Create and review the questionnaire

The questionnaire used for this study was designed such that participants would only be given questions relevant to their particular experiences in the school (e.g., questions for teachers would not necessarily be the same as the questions for staff/administrators). However, several questions were relevant across the participant groups, with perhaps only minor tweaking of the wording. To ensure these types of questions remained as similar as possible across the different versions of the questionnaire so comparisons could be made during analysis, the research team created a Master List (available under the Questionnaire Replication Resources section).

The Master List was then edited as necessary for each participant group, resulting in four different questionnaires:

- Students: 27 questions*
- Teachers: 36 questions*
- Staff/administrators: 12 questions*
- Parents/caregivers: 17 questions*

The researchers recommend sharing the finalized questionnaire(s) and the intended data collection process with administrators at the school(s) and/or school district(s) participating in the study for their input and approval. This will help gain buy-in for the study, and if the school administrators have any feedback, concerns, or suggested revisions, the research team can address them prior to questionnaire distribution.

Step 2: Translate content as necessary

The researchers highly recommend translating the questionnaire into any language necessary for equitable participation among the school’s stakeholders. The school or district’s Language Acquisition Division (or similar department) should be consulted about the translation process for the questionnaires, the informed consent forms, and the invitations to participate in the study.

For instance, in this study, the participating school districts recommended translations in three languages, as shown on the next page. Where SurveyMonkey.com did not support a language for the online survey (the research team could not set up an Amharic version), the research team provided that translation as a PDF that a participant could download, fill out, and email back to the research team.

Step 3: Obtain Institutional Review Board approval

Once the questionnaire content and the process for data collection are established, then Institutional Review Board (IRB) approval can be sought. This approval is necessary because the questionnaire process will engage with human subjects. Researchers wishing to replicate this study’s questionnaire will need to have the questionnaire content and associated data collection protocols approved by their governing research body.

It should be expected that the IRB will provide guidance related to such things as participants’ informed consent, working with minors (i.e., the students), and data security.

* Not including additional informed consent and identifier/demographic questions
Be sure to revise the questionnaire content, data collection process, data storage procedures, or any other aspect as necessary based on the IRB’s requirements.

For example, in this study, the IRB laid out several requirements the researchers had to meet, including several related to informed consent. For someone to participate in the questionnaire for this study, IRB approval dictated that, for schools that require it, questionnaire respondents must provide informed consent and “opt in” to the study. The informed consent form and process varied by respondent type. Those over the age of 18 simply had to provide informed consent prior to completing the questionnaire. These groups’ informed consent forms were included as the first question of their questionnaires. If they agreed to participate, they continued on to the rest of the questionnaire. If not, they were redirected to the end of the questionnaire. In addition, parents/caregivers were instructed that if they receive multiple invitations to complete the questionnaire, because they have multiple children in one or more schools participating in this study, they should only complete one questionnaire and focus on the one school they are most familiar with.

Students, being minors, had to undergo a different informed consent process. One of the participating school districts only required a Notice of Student Participation (available under the Questionnaire Replication Resources section) be sent to parents/caregivers. The other participating school district, however, required parents/caregivers to opt in for their children to participate (or opt out, as the case may be). Accordingly, the research team provided these schools’ principals with a web link to be sent directly to the students’ parents/caregivers. The link directed them to online information about the study and the option to provide informed consent, or not, for their student to participate (available under the Questionnaire Replication Resources section). They had six consecutive days to respond. The research team then received direct notification about which students had received permission to participate.

Once it was known which students in which schools were able to participate, the researchers shared this information with the school’s principal so they could coordinate with the teachers to give these students access to the online questionnaire. Unfortunately, because very few parents or caregivers opted their children in under this process, this district saw minimal student participation. Many more students completed the questionnaire in the other district, however, because the research team did not face that obstacle. As a result, where possible, the researchers recommend issuing a Notice of Student Participation to parents/caregivers that does not require a response.

**Step 4: Prepare for data collection**

One of the first things that must be decided when planning the distribution of a questionnaire is in which format data will be collected—either paper questionnaires or using an online surveying tool, or some combination of the two. The research team feels that online surveying is best, when appropriate, because it allows for streamlined data collection, little or no printing costs or material waste, and it eliminates the need for the confidential storage of physical materials. An important consideration, however, is whether the study’s participants have equitable access to digital devices (e.g., a smartphone, tablet, or laptop) and an internet connection to complete an online questionnaire. If not, then distribution of paper copies should be coordinated, including arrangements for printing, distribution of blank copies, collection of completed copies, and the subsequent manual data entry.

Communication about the questionnaire is an important factor for achieving a high participation rate. The school’s principal can easily inform students, teachers, and staff/
administrators about the study and invite them to complete the questionnaire. The principal or a parent-teacher representative can also reach out to parents/caregivers. To encourage a high response rate, the researchers recommend the following for distribution:

- Students should be given time to complete the questionnaire during their homeroom period or an alternative core class.
- Teachers and staff/administrators should be given time during a pre-determined professional development day.
- School personnel who have already-established communication channels with parents/caregivers are the best ones to reach out to them. For instance, the school’s principal or a recognized parent-teacher representative could send an email and/or flyer about the study with a link and/or QR code to access the online questionnaire.
- Advocates could use social media, such as the school’s Facebook group or a NextDoor post, to reach out to community members with a link and/or QR code to their online questionnaire. A school could also invite them to participate in person, such as having a research team member with a tablet or laptop set up at a community center, area grocery stores, the library, or a school-sponsored event. Outreach to members of the greater community can be challenging, so exploration and plans are needed for how best to engage them.

In addition to instructions on how to access the questionnaire, either a paper copy or online, any outreach to potential participants should have accompanying information about the study, including its value to the stakeholders and any requisite informed consent forms.

Once the format for the questionnaire deployment is established, planning can begin. Goals for questionnaire deployment include maximizing participation and making the process as straightforward as possible. It is also critical to establish a main point-of-contact at each school participating in the study. The research team should clearly communicate the importance and requirements of the study and questionnaire to that person, as well as encourage a high degree of participation. Suggested questionnaire deployment steps are as follows.

1. Research team to identify point-of-contact at each school who will be responsible for distributing the questionnaire (hardcopies and/or web link to online version). This person is often, but not required to be, the school’s principal. Engagement can begin with an email—simply edit the red text in the “Email to Point-of-Contact” template available under the Questionnaire Replication Resources section and send that to the point-of-contact.
2. The point-of-contact and research team to discuss and confirm the multi-week window during which questionnaires will be deployed. Consider holidays, vacations, professional development days, and standardized testing as potential conflicts.
3. Research team to prepare and share a calendar outlining the deployment plans for each of the following groups: students, teachers, staff/administrators, and parents/caregivers (sample available under the Questionnaire Replication Resources section). The point-of-contact should review and confirm the proposed timeline and tasks.
4. Research team to provide messaging templates for each of the following groups: students, teachers, staff/administrators, and parents/caregivers. Messaging should be appropriate to each participant group and include, as necessary, either the link/QR code to that group’s particular online questionnaire, the PDF form(s) for language options, and/or instructions on where to obtain a paper version. Samples of this messaging are available under the Questionnaire Replication Resources section, with red text indicating where the research team can customize the communication. Schools may have a variety of ways in which they would like to distribute the questionnaire’s invitational messaging, web links/QR codes or hardcopies, and study information, so it is important for the research team and each participating school/district to determine the best means of distribution and draft the communications accordingly to yield the highest rate of response.

Mapping out the deployment process may be a useful technique to communicate with the point-of-contact, or others, on the steps along the way. As an example, the research team sent a “Questionnaire Roll-Out Toolkit” to each of the participating school districts. The toolkit included an introductory email to the participating schools’ point-of-contact, deployment timeline/task calendars for each questionnaire participant group, and separate email templates to invite teachers, staff/administrators, and parents/caregivers to participate. The kit also included
information about parent/caregiver informed consent for student participation (or a Notice of Student Participation, depending on the school district). The intent was for the questionnaire to be distributed as indicated in the figure on the previous page. Once the questionnaires were translated and ready for distribution, the toolkit was re-sent to the points-of-contact, now including the links to the online questionnaires in English and Spanish, and an Amharic PDF—ready for distribution to the participant groups.

Step 5: Collect Data

The researchers recommend the following schedule for questionnaire deployment.

- Week One (if Notice of Student Participation is insufficient):
  - Distribute parent/caregiver informed consent forms at the beginning of the week
  - Collect signed parent/caregiver informed consent forms by the end of the week; identify which students may participate

- Week Two:
  - Distribute the questionnaire (preferably online) to the students who may participate
  - Distribute questionnaire (preferably online) to teachers, staff/administrators, and parents/caregivers

- Weeks Three and Four:
  - Questionnaires remain “open” for two weeks
  - On-site engagement with community members to garner completed questionnaires from this participant group

- Week Five (if necessary/for paper completion):
  - Begin manual data entry for completed paper questionnaires

If the study’s budget allows, and the IRB and school district administrators permit, the researchers can provide incentives to encourage participation. Examples include a doughnut or pizza party for the class with the highest response rate per school, food for a professional development day for each school’s teachers and staff/administrators, or entrance into a raffle for a gift card (e.g., to a local grocery store) for parents/caregivers and community members.

Incentives can be offered from the start, or added later if necessary (e.g., if response rates are lower than anticipated). As an example, this study originally scheduled ten business days for completion, but the deadline was extended two times to encourage greater participation. Along with the first deadline extension, the research team offered a $500 gift card to an office supply store for any participating school that received 50% participation across their student, teacher, and staff/administrator groups. Only one of the two participating school districts accepted this incentive, while the other declined. To calculate whether a school met the incentive requirements, the districts provided the research team with the total number of possible questionnaire respondents for the student, teacher, and staff/administrator stakeholder groups. (Parents/caregivers were not included in the incentive calculation because the total number of potential parent/caregiver respondents could not easily be determined.)

Questionnaire Replication Resources

To help replicate this study’s questionnaire, the following resources are available for download from this site: https://bit.ly/Billion-Dollar-Challenge

- Questionnaire — Master List
- Questionnaire — Email to Point-of-Contact
- Questionnaire — Messaging for Students
- Questionnaire — Messaging for Teachers
- Questionnaire — Messaging for Staff/Administrators
- Questionnaire — Messaging for Parents/Caregivers
- Questionnaire — Notice of Student Participation
- Questionnaire — Parents/Caregivers informed consent for student participation
- Questionnaire — Calendars
Interview/Focus Group Replication
The qualitative investigation of this study followed a phenomenological approach, with the goal of understanding stakeholders’ lived experiences in relation to their modernized or non-modernized schools. Unfortunately, the COVID-19 pandemic severely hampered the researchers’ plans to address this side of the methodology.

As such, there were minimal Community Connectivity-oriented interviews and focus groups, and none to address the study’s Educational Adequacy lines of questioning. Under non-pandemic circumstances, the research team recommends conducting EA interviews/focus groups with the sample’s school leadership, teachers, and students from both modernized and non-modernized buildings, plus an architect who was part of the design team for the modernized buildings. This qualitative data would supplement the questionnaire and VAT data, providing a more holistic picture of a school’s Educational Adequacy.

For the CC portion of the study, the research team conducted focus groups with parents/caregivers of students who attended a select sub-sample of the schools in the study’s larger sample; and one-on-one interviews took place with members of the community surrounding those selected schools. As noted in the report, the research team intended to conduct more CC-focused interviews/focus groups than were ultimately possible during the pandemic. Any research team replicating this work needs to consider the resources available for data collection to determine how many focus groups and individual interviews can be conducted for a study. The greater the quantity, the greater likelihood of meaningful results. With that in mind, the following are the steps the researchers would recommend for replicating this study’s interviews/focus groups.

**Step 1: Obtain Institutional Review Board Approval**

Institutional Review Board (IRB) approval is necessary because the interviews/focus groups will engage with human subjects. The IRB will need to approve the interview guide, focus group questions, and data collection protocols—from participant recruitment to how the sessions will be held. The IRB will likely provide guidance related to such things as participant recruitment and informed consent, working with minors, and data security. Be sure to revise the interview guide/focus group questions, data collection process, data storage procedures, or any other aspect as necessary based on the IRB’s requirements.

**Step 2: Schedule and Conduct Interviews/Focus Groups**

It does not matter whether interviews or focus groups are held first or concurrently, especially since the timing of data collection is often determined by the availability of the interviewees.

**INTERVIEWS WITH COMMUNITY MEMBERS (OR OTHERS)**

The goal of the one-on-one interviews with community members from the school’s surrounding neighborhood is to obtain perspectives on the school building and its impact on stakeholders from a diverse set of individuals who live or work in the nearby area. The research team from this study recommends consulting with school district personnel and/or school staff/administrators to determine the appropriate geographic boundaries of this area. These school professionals should be asked to help identify possible interviewees, once the profile of individuals with whom the research team wishes to speak is provided.

The research team should outline an interview guide listing the questions and possible probes to ask participants, particularly if the research team wants different lines of questioning based on the type of community member (e.g., questions for local homeowners versus business owners). For reference, this study’s interview questions are available under the Interview/Focus Group Replication Resources section.

The number of interviewees for each school should be determined by the resources available to the research team. The researchers of this study suggest at least one individual from each of the following categories: homeowner who lives in close physical proximity to the school, a local
business owner, a representative from a local civic group, a representative from a local religious institution, and a local politician representing the area. It will not always be possible to schedule an interview with each type of person, but attempting to get the widest range of perspectives should be the goal.

The research team should contact the school’s principal as a first step to scheduling these interviews, explaining their interest in holding several one-time interviews to gather community members’ perspectives on the school building. The principal may appoint another appropriate staff member or a parent-teacher representative as a point-of-contact to help coordinate these events.

Whether the school’s point-of-contact or research team members themselves reach out to potential participants, a one-page description of the purpose of the interviews and the specifics about participation (e.g., time and duration, location, any compensation for participation, if childcare will be provided, etc.) should be prepared for use in recruiting participants.

Once an individual agrees to be interviewed, the research team should provide them with an informed consent form to be signed in advance, or at least read to them out loud prior to beginning an interview. (Refer to the Interview/Focus Group Replication Resources section for a sample informed consent form.) The research team may also opt to share the interview questions in advance so the interviewee can think about their responses beforehand.

Interviews should be held at a time/date that is mutually convenient for the participants and the research team. The sessions may be conducted in-person or via an online meeting platform (e.g., Zoom, WebEx, Microsoft Teams, Google Meet). Interviews should, with the interviewee’s permission, be recorded for later transcription for analysis. It is also a good idea to have at least two members from the research team involved in each interview: One to moderate the discussion and another to take notes and be available to address any issues that develop, so the moderator can remain focused on the discussion. Interviews should be scheduled for no more than one hour; this study’s research team found that 45 minutes was sufficient.

If possible, provide snacks and beverages, and offer childcare for the in-person interviews. If the study’s budget allows, provide a token of thanks for their participation, such as a gift card to a local grocery store.

**FOCUS GROUPS WITH PARENTS/CAREGIVERS (OR OTHERS)**

Similar to the interviews, the goal of the focus groups with parents/caregivers of students who attend a sub-sample of the schools participating in the study (or others, as the research team deems necessary) is to understand their perceptions about the school and its impact. When planning these focus groups, the research team must first decide what questions to ask. For reference, this study’s focus group questions are available under the Interview/Focus Group Replication Resources section.

For each school participating in the study, the research team should contact the principal to explain interest in conducting a one-time focus group of five to ten parents/caregivers to gather their perspectives on the school building. The principal may appoint an appropriate staff member or a parent-teacher representative as a point-of-contact to help coordinate this event. Whomever the primary contact is, the research team should communicate the need for a diverse array of participants, and that they should be associated with a student who has attended this school for multiple years to ensure meaningful knowledge of the building. Also, if possible, the group should include individuals who are not necessarily the “usual suspects” when it comes to parent/caregiver involvement to improve the chances for a holistic perspective on this group’s connections to their children’s school.

A one-page description of the purpose of the focus group and the specifics about participation (e.g., time and duration, location, if there will be compensation for participation, if childcare will be provided, etc.) should be prepared and provided to the point-of-contact for use in recruiting participants. (Refer to the Interview/Focus Group...
Replication Resources section for a sample recruitment letter.) If the research team receives interest in participation from more than the requisite number of attendees, they can decide how to choose among the potential participants, although simply selecting the first five to ten might be the most appropriate, or opting to hold more than one focus group session if time and resources allow.

The school’s point-of-contact will have the best sense of which conditions will be ideal for hosting the focus group, including the time and date that works best for parents/caregivers and whether it is more convenient to host them in person or online to garner the best attendance.

The focus group should be scheduled for no more than 75 minutes. The research team should hand out informed consent forms for participants to complete at the outset, and also request permission to record the session for later transcription, emphasizing that it is solely for the research team’s use during analysis. (For reference, the consent form from this study’s focus group is available under the Interview/Focus Group Replication Resources section.) It is also a good idea to have at least two members from the research team involved in each focus group: One to moderate the discussion and another to take notes and be available to address any issues that develop so the moderator can stay focused on the discussion.

If the focus group is in person, provide snacks and beverages, and offer childcare if possible. If the study’s budget allows, offer each participant a token of thanks for their participation, such as a gift card to a local grocery store.

Interview/Focus Group Replication Resources

To help replicate this study’s interviews and focus groups, the following resources are available for download from this site:

For parent/caregiver focus groups:
• Focus Group — Recruitment letter
• Focus Group — Informed consent form
• Focus Group — Questions

For community member interviews:
• Interview — Informed consent form
• Interview — Questions
Archival Data Replication
In addition to the original data produced by this study (from the IEQ data logging with live measurements; visual assessments, with floor plan analysis and photography; stakeholder questionnaires; and stakeholder interviews and focus groups), it is important to identify and secure as much relevant archival data as possible about the participating schools, school districts, and surrounding communities. This data can supplement the research team’s understanding of the Educational Adequacy and Community Connectivity of each school in the study’s sample.

The following steps are recommended for collecting archival data.

• Obtain archival data from publicly available school district and state Department of Education websites. Note, how robust such data are will vary from district to district and state to state.
• Focus on archival data relating to school performance measures (e.g., enrollment rates, graduation rates, truancy, standardized test scores) to develop a holistic picture of a school’s Educational Adequacy.
• If possible, collect data spanning at least a ten-year period prior to when the research study is initiated to have a sufficient depth of data for statistical analysis.
• Aggregate archival data at the school level, if available, for such things as enrollment, performance on standardized tests, truancy, and graduation rates, since this study’s findings suggest that most, if not all, of these metrics can be related to the modernization of school buildings.
• Determine whether any datasets may be skewed because of extraordinary circumstances, such as disruptions that occurred during the COVID-19 pandemic. For instance, in this study, the research team could not use truancy data because the pandemic severely skewed that metric.
• Create two datasets, one for modernized schools and one for non-modernized schools, so comparisons can be made during data analysis.
• Identify any upward or downward trends in data categories, noting any differences in data trends that align with a school’s modernization status.
• In cases where differences between the data for modernized versus non-modernized schools are observed, use Repeated Measure ANOVAs to determine whether changes in a performance measure were statistically significant over time.
APPENDIX H

Community Profiles
One of the novel approaches taken by this study was to use aggregated neighborhood-level data to paint a picture of the geographic neighborhood surrounding each school in the study’s sample to explore if there were patterns in the relationship between a school’s modernization status and characteristics of the neighborhood where it is located. This information may be useful for informing efforts to maximize the benefit of school modernization initiatives by facilitating integration of the school into the surrounding community as an asset and resource.

There might be variation in the available data for any given school district and its associated neighborhoods, but the research team recommends the following approach.

**Step 1: Identify each school’s census tract**

Once the schools are selected for the study’s sample, determine which census tract each school is located within.

- Census tract identifiers for specific addresses can be found at [https://geocoding.geo.census.gov/geocoder/geographies/address?form](https://geocoding.geo.census.gov/geocoder/geographies/address?form)
- Geocodes for schools are available through the National Center for Education Statistics (NCES) at [https://nces.ed.gov/programs/edge/Geographic/SchoolLocations](https://nces.ed.gov/programs/edge/Geographic/SchoolLocations)

**Step 2: Determine available metrics**

Identify relevant available measures to incorporate into a school’s community profile. For reference, the data sources and measures incorporated into this study are listed below. Additional or alternative metrics may be identified for each location and study.

(A) Census data, available at [https://data.census.gov/](https://data.census.gov/)

For this study, the research team looked at census tracts to understand the demographic and socioeconomic characteristics of the neighborhood surrounding each school in the study’s sample. In some cases, a school’s student and/or staff populations were similar to the surrounding neighborhood in terms of socio-demographic characteristics, but not in others.

To understand the socioeconomic characteristics of the neighborhoods, consider:

- % Residents living in poverty
- % Median household income
- % Residents unemployed
- % Residents age 25+ with a high school diploma or higher education
- % Residents age 25+ with a bachelor’s degree or higher education

To understand the community population’s demographic composition, consider:

- % Non-Latinx Caucasian residents
- % Non-Latinx Black residents
- % Non-Latinx Asian residents
- % Latinx residents
- % Foreign-born residents
- % Residents aged <18 years
- Total population

To understand neighborhood residential stability, consider:

- % Residents living in the same residence for the past five years
- % Owner-occupied housing

(B) Child Opportunity Index (COI)

The COI is a combined index developed by researchers at Brandeis University and the Kirwan Institute for the Study of Race and Ethnicity at The Ohio State University to measure the quality of resources and conditions across multiple domains that are important for child health and development. The index combines data from 29 different indicators in three broad domains: education, health and environment, and social and economic. The indicators are combined into a single, composite measure that ranges from 1 to 100 (where a higher number equates to greater opportunity). The research team can use the nationally normed score, which compares each census tract to the national average. Index values, as well as detailed documentation, are available at [http://diversitydatakids.org/child-opportunity-index](http://diversitydatakids.org/child-opportunity-index).
Additional measures developed and made available by Drexel University’s Urban Health Collaborative (UHC) were used in this study. The UHC’s mission is to improve health in cities by increasing scientific knowledge and public awareness of urban health challenges and opportunities, and by identifying and promoting actions and policies that improve population health and reduce health inequities. It conducts research, disseminates evidence, and builds capacity by partnering and exchanging information with the community, decision-makers, and other academic institutions. The UHC maintains an extensive repository of community-level measures, which can be found at https://drexel.edu/uhc/resources/data/.

(C) Gentrification
Gentrification in the community surrounding a school can have large impacts on a school’s enrollment, student composition, and available resources. Conversely, the schools located in a community may also factor into gentrification processes.

For this study, the research team used a gentrification measure developed by Drexel University’s UHC, where census information is calculated using a two-step process. First, census tracts are classified as “eligible” or “ineligible” for gentrification at baseline. Tracts are ineligible if they are either sparsely populated (less than 50 people) or are already wealthy (in their city’s top quartile for median household income). Eligible tracts are then classified as “gentrified” or “not gentrified” during the ten years following baseline. To qualify as gentrified, a census tract must experience an increase in the proportion of residents with a college education that was above the city’s median increase, in addition to a similarly elevated increase in gross rent or median home value compared to the city’s. Documentation is available at https://drexel.edu/uhc/resources/briefs/Measure-of-Gentrification-for-Use-in-Longitudinal-Public-Health-Studies-in-the-US/.

(D) Retail Food Environment
Schools can play an important role in food access through school-sponsored meal programs and/or community food distribution programs. Understanding food availability in the neighborhood surrounding a school can provide insight on assets the community brings and needs that the school may help to address.

For this study, the research team used two measures of census tract-level retail food availability developed by Drexel University’s UHC, using purchased data from the National Establishment Time Series (NETS) database, which can be found at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1022962. Information about the measures available at UHC can be found at https://drexel.edu/uhc/resources/data.

- Density per square kilometer of unhealthy food retail locations (includes convenience stores, small grocery stores/bodegas, fast food, bakeries, coffee shops, and pizza shops)
- Density per square kilometer of healthy food retail locations (includes supermarkets and produce stores)

(E) Green Space
Green space can promote health and healthy behaviors like exercise and socializing. The research team used a census tract-level measure of the absence of green space developed by Drexel University’s UHC, using publicly available data from the 2011 National Land Cover Database (NLCD). The NLCD, developed by the United States Geological Survey (USGS) in association with the Multi-Resolution Land Characteristics (MRLC) Consortium, is the definitive Landsat-based, 30-meter resolution, land cover database for the United States. The NLCD uses a classification of twenty values of land space modified from the Anderson Land Cover Classification System. Thirteen categories are classified as “green space.” To create a percentage of green space, the 2011 green space area values are divided by the GIS-derived 2010 census tract total land area. More information about the NLCD is available at https://www.usgs.gov/centers/eros/science/national-land-cover-database.
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Coalition for Community Schools. (n.d.). About Community Schools. [https://www.communityschools.org/about/](https://www.communityschools.org/about/)


The locations and names of the schools pictured in the photography used throughout this report are not identified because the schools participating in this study were anonymized for publication. In addition, the photographs herein are intended to be exemplars and, therefore, do not necessarily reflect the actual schools that participated in the study.

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