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Addressing The Mathematical Achievement Gap Through Improvements In School Facilities: The Case Of Fort Bend Isd School District In Texas

Damian K. Viltz
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ADDRESSING THE MATHEMATICAL ACHIEVEMENT GAP THROUGH IMPROVEMENTS IN SCHOOL FACILITIES: THE CASE OF FORT BEND ISD SCHOOL DISTRICT IN TEXAS

A Dissertation

by

DAMIAN K. VILTZ

Submitted to the Office of Graduate Studies
of Prairie View A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF BUSINESS ADMINISTRATION

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ABSTRACT

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(August 2024)

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In 1966, Americans were introduced to the term achievement gap by James S. Coleman, a Johns Hopkins sociologist. Coleman et al.'s (1966) study explained most of the gap between the achievement of America's White and Black students. Since that study was published, scholars have identified strategies to close the achievement gap. Accordingly, my research investigated the possibility of using the quality of school facilities as a potential strategy to enhance learning equity across racial categories. My findings may fuel policies targeting the development of local communities through inclusive learning achievements.

My empirical methodology was sustained by an expanded theoretical framework that considered schooling, or quality of education, as an output that derives from a combination of inputs, including the quality of facilities. The main dataset contained information from a Texas school district with over 80,000 students. I used the State of Texas Education Agency (TEA) students' categorization and measured their performance using the State of Texas Assessments of Academic Readiness (STAAR) exam results. The results of a comprehensive survey conducted by a consulting firm were used as a measure of the building condition. Alternative datasets were used to check the robustness of the findings.

Keywords: achievement gap, facilities, academic outcomes

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Thank you all for being part of this journey. Your support has not only helped me achieve this milestone but has also made the process a memorable and enriching experience.

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CHAPTER I

INTRODUCTION

Background of the Problem

In 1966, Americans were introduced to the term achievement gap through a study led by James S. Coleman, a Johns Hopkins sociologist and Commissioner of Education in the Johnson Administration. The achievement gap exists in grades, standardized test scores, course selection, dropout rates, and college-completion rates, among other success measures. Coleman et al.'s (1966) study revealed a fact that is still true today. A wide racial gap exists in achievement test scores. Although the average scores in mathematics for nine-year-olds in 2022 were higher than the earliest assessments in the 1970s, the gap between African American and Hispanic students compared to White and Asian students has increased (Nations Report Card, 2024). Since the 1966 study was published, scholars have identified strategies to close the achievement gap.

Education is often heralded as the cornerstone of equality, offering a ladder for all students to climb, regardless of their background. Yet, for some minority students, education can paradoxically act as a barrier rather than a bridge if their learning takes place within low quality facilities. The state of a school's infrastructure is not just a reflection of its immediate needs but serves as a profound statement from the community about the value it places on education. In today's climate of heightened accountability, it is imperative for educational leaders to scrutinize every element that might influence student success, including the very buildings in which students learn.

This dissertation follows the *Publication Manual of the American Psychological Association, 7th Edition.*

Statement of the Problem

The majority of a student's academic journey unfolds within the confines of school facilities, making it essential to consider how these environments impact learning outcomes. There is a pressing need to investigate the potential link between the quality of school facilities and student achievement, behavior, and overall engagement. Modern educational facilities, when well-maintained and equipped, should serve as versatile spaces that accommodate a wide array of learning experiences and pedagogical approaches. The emerging consensus among educational researchers underscores a significant correlation between the condition of school infrastructure and key educational outcomes, including student achievement, attendance, behavior, and even teacher retention rates.

This growing body of research presents a compelling case for the critical role that school facilities play in shaping student success. As such, ensuring that all students have access to high-quality, well-maintained educational environments is not just a matter of physical necessity but a moral imperative. It is clear that to truly equalize the playing field and fulfill education's promise as the great equalizer, investments in upgrading and maintaining school facilities are indispensable.

Purpose of the Study

The purpose of this study was to determine if quality education facilities help reduce academic inequality by promoting inclusive educational achievements among different racial groups. Given the ongoing debate on affirmative actions, addressing this question is crucial as it directly impacts policy decisions and educational reforms. By examining whether improved school facilities can contribute to leveling the academic playing field, this research aims to provide evidence-based insights that could inform the development of more equitable educational policies. Additionally, it is important to explore alternative solutions that could mitigate educational achievement gaps, ensuring that all students have access to opportunities and resources based on their merits rather than their backgrounds. This study, therefore, seeks to contribute to the discourse on educational equity by identifying potential strategies for fostering an inclusive learning environment that supports the success of students from diverse racial and socioeconomic backgrounds.

Significance of the Study

This study intended to establish whether quality of facilities could be an additional tool for educators to use to bridge the academic gaps across students from different racial backgrounds. Numerous studies have shown a link between facilities conditions and academic outcomes. For instance, Cash (1993), Hines (1996), Oneill and Oates (2001), Earthman (2002), and Sheets (2009) examined the relationship between the condition of school facilities and achievements. Improving the quality of school facilities can lead to varying rates of enhanced student performance based on initial performance levels and socio-economic background, ultimately resulting in smaller performance gaps, considering the presence of a maximum performance level.

Verifying this hypothesis through thorough theoretical or empirical analysis could equip policymakers and educational stakeholders with the evidence needed to strategically focus on upgrading school infrastructures as a means to mitigate educational disparities. The achievement gap is defined as the deficiency in academic performance on standardized tests among various student groups (Welner & Carter, 2013). By placing a renewed emphasis on the physical spaces where learning occurs, this study aimed to contribute to a broader strategy for enhancing educational equity and excellence across all student demographics.

Overview of the Study

This research could be linked to four specific threads of existing scholarly works. First, some scholars have analyzed various aspects related to the quality of school facilities. Accordingly, poor school infrastructure is a problem in the United States with the major factors contributing to this issue identified as the absence of comprehensive preventive maintenance programs and reduced funding for school facilities. These factors lead to public schools that are poorly maintained and leave students attending facilities that are in fair or poor condition (Hunter, 2009). Dickerson and Ackerman (2016) identified a study conducted by the American Society of Civil Engineers (ASCE) that supported this theory and recommended the need for systematic, comprehensive preventative maintenance programs and a national data collection system for reporting of school facility condition. Lewis (2001) examined the impact of postponing repairs and maintenance activities, also called deferred maintenance, on schools in Washington State. Uline and Tschannen-Moran (2008) studied building age and upkeep and how those influenced student achievement, attitude, and behavior.

Second, there are several studies on determinants that is, school spending, funding, and revenues, of students' outcomes. To mention a few, Lafortune and

Schonholzer (2018) revealed that spending on school facilities could enhance students' attendance and boost scores in math and English-language arts. Miller (2018) uncovered that higher spending had positive impacts on test scores and graduation rates. Neymotin (2010) and Akinpelu (2022) studied the effect of per pupil revenues on measures of student outcomes and found that there was little relationship between per pupil revenues and student achievement. Durán-Narucki (2008) evaluated the impact of Title I funding on school finance and student performance in New York City public schools. Lafortune et al., (2018) studied the impact of post-1900 school finance reforms and found that reforms increased the absolute and relative achievement of students in low-income districts.

Third, numerous other scholars have specifically looked at the impact of qualities of school facilities on students' outcomes. Accordingly, Earthman et al. (1995) conducted a statewide survey of all high schools in North Dakota to examine the relationship between achievement and behavior of students and the condition of the building. Lewis (2001) studied the effect of building condition on student test scores. Fisher (2001) concluded that student academic achievement improved with improved building condition. Durán-Narucki (2008) found that the condition of academic facilities might affect the performance of students by directly impeding children's learning. Bowers and Urick (2011) studied the independent effects of high school facility quality on student achievement. Stafford (2015) examined the effect of school indoor air quality (IAQ) on academic outcomes. Maxwell's 1999 study explored the importance of the educational setting and its affect on student learning, performance, attitude, and behavior.

Fourth, scholars have recognized the importance of closing the achievement gap in mathematics (Balfanz & Byrnes, 2006; Kitchen et al., 2017; Strutchens, 2000). Johnson and Kritsonis (2006) identified the wide achievement gap in mathematics as the most significant problem of African American students in America's schools. Flores (2007) and Goldberger (2008) found factors that contributed to disparities in mathematics education. Boaler and Staples (2008) identified factors that have proven to be successful in closing the mathematics achievement gap. Considering the sequential nature of mathematics, closing the achievement gap in this subject may be more impressive than in a subject in which early struggles might affect later learning to a lesser degree (Bjorklund-Young & Plasman, 2020).

Bergman et al. (2018) conducted research to investigate how ambient environmental conditions and the school physical environment simultaneously impacted academic performance among students. Their data set included Maryland students in grades 3-8 at 158 schools. They found that as the quality of buildings decreased, proficiency in math decreased.

In contrast to these existing studies, after an exhaustive search, I found few studies—particularly within the last five to seven years—that addressed the impact of school facility qualities on educational gaps across different types of students. Such analysis may unveil the possibility for building management to be used as a strategic tool in the creation of an inclusive educational system. This study may have the merit to propose a new tool for creation of inclusive educational systems, and thus inclusive access to opportunities and resources in the US.

Theoretical Framework Overview

This research relied on a theoretical economic model that considers education as an output from a production process that uses numerous inputs, including school facilities. Numerous other scholars have considered education as an output, but without school facilities as specific inputs (Wilson, 2001; Bishop & Wossman, 2004). From my expanded theoretical model, an equation was derived to empirically estimate the effect of using multivariate statistical analyses.

The secondary data covered 77 schools from Fort Bend Independent School District (ISD) in Texas. Fort Bend ISD serves over 76,000 students and employs over 11,000 faculty and staff members. The student population is 27.8% African American, 26.6% Hispanic, 14.7% White, 0.4% American Indian, 26.7% Asian, 0.1% Pacific Islander, and 3.7% two or more races. The main independent, explanatory variable quality of school facilities, was captured by the Facility Condition Index (FCI) . This study used results of the STAAR exam to measure academic performance in Mathematics by various types of students, that is, African American, Hispanic, White, and Asian.

From the original data, I developed new variables to capture educational achievement gaps. These variables encompass the cross-sectional standard deviations in educational performance among different student groups, as well as the absolute 2-by-2 gaps in scores between these groups. The inclusion of these multiple potential dependent variables allows for more detailed recommendations and enables a robustness check of my findings.

Research Question

The following research question was used in this study: How can an investment strategy that focuses on improving the quality of school facilities lead to a reduction in the mathematics achievement gap in the United States?

Researcher's Perspective/Positionality

For over six years, I served as the Executive Director of Facilities in Fort Bend ISD. In this role, I was responsible for providing a clean, comfortable, and safe learning and working environment for the students and staff. The support staff in the Facilities Department includes electricians, plumbers, air conditioning technicians, custodians, and many others who maintain and operate the school district's campuses and support facilities. Although the individual tradespeople have specific job roles, they were collectively part of a larger group of professionals known as Facility Managers. The International Facility Management Association defines facilities management as an organizational function which integrates people, place and process within the built environment with the purpose of improving the quality of life of people and the productivity of the core business.

As a facilities manager, I understand the unique challenges associated with maintaining public schools. I have seen the impact of budget cuts, insufficient staffing, and lack of preventive maintenance programs. The challenges faced in Fort Bend ISD are a microcosm of national issues. As a result of decades of underfunding school infrastructure, national spending for K-12 school buildings falls short by an estimated $85 billion annually, as reported by a 2021 analysis from 21st Century Fund.

Delimitations of the Study

The following statements are prescribed delimitations for this study.

1. The student achievement data used in this study was confined to the data collected by the Texas Education Agency. The data were confined to the 2021-2022 school year.
2. This study was confined to the overall score as measured in FCI. Individual variables that contributed to the FCI were aggregated in the overall score.
3. There are many variables that relate to educational outcomes. This study was confined to the following variables relating to student achievement: student effort, school facilities, and other resources.
4. This study was confined to the following school district demographic characteristics: math scores for African American, Hispanic, White, and Asian students.
5. Only the results from the 2021-2022 STAAR exam were used in this study.
6. There are many variables that are known to have an impact on educational outcomes that were deemed outside the scope of this study.
7. There are many variables relating to the conditions of school facilities and other school district demographic information that were deemed outside the scope of this study.
8. There are many variables relating to the student achievement gap in mathematics that were deemed outside the scope of this study.

Definition of Terms

Achievement gap: refers to the disparity in academic performance between groups of students. In this study, it is the difference between the average test scores between ethnic sub-groups (National Center for Education Statistics, 2024).

Average income: average income received on a regular basis (exclusive of certain money receipts such as capital gains) before payments for personal income taxes, social security, union dues, medicare deductions, etc. for a specific zipcode (US Census Bureau, 2024).

Educational outcomes: the observable results or achievements of an educational process. These outcomes can include the knowledge, skills, attitudes, and values that students acquire through their educational experiences (Bull & Keengwe, 2019).

Ethnic sub-groups: the Texas Academic Performance Report identifies students as belonging to one of the following groups: African American, Hispanic, White, American Indian, Asian, Pacific Islander, and two or more races. In this study the four groups with the highest representation (African American, Hispanic, White, and Asian) were used (Texas Education Agency, 2022).

Facility Condition Index (FCI): a standard tool used by architects, engineers, and facility planners to compare the condition of school facilities and determine whether it is more economical to fully modernize an existing school or to replace it (National Center for Education Statistics, 2003).

Minority students: students who are classified as non-White students by the Texas Education Agency. The percent of minority students is reported by the Texas Education Agency in their Texas Academic Performance Report (Texas Education Agency, 2022).

State of Texas Assessments of Academic Readiness (STAAR): Texas' testing program and is based on state curriculum standards in core subjects including reading, writing, mathematics, science, and social studies. Outcomes are organized by specific student groups (Texas Assessment, 2024).

Student Achievement: a term that refers to the measurement of a student's overall academic achievement and learning over a particular period of time (Teachmint, 2024).

Texas Academic Performance Report (TAPR): a comprehensive report that pulls together a wide range of information on the performance of students in each school and district in Texas every year. Performance is shown disaggregated by student groups, including ethnicity and socioeconomic status (Texas Education Agency, 2024a).

Texas Education Agency: the state agency that oversees primary and secondary public education in the state of Texas (Texas Education Agency 2024b).

Summary

The research is divided into five chapters and organized in the following manner. Chapter I introduced the research by providing the motivation, the research question, assumptions, and brief overviews of other chapters. Chapter II reviews the literature related to the topic under investigation. Chapter III elaborates on the theoretical framework, methodology, and the data. Chapter IV analyzes the data through simple descriptive statistics, before reporting and discussing the empirical results. Chapter V provides concluding remarks.

CHAPTER II

LITERATURE REVIEW

A Review of Professional and Academic Literature

This chapter elaborates on the four threads of existing scholarly works to shed light on how this current research aligns within the vast landscape of existing literature.

Building Management, Maintenance, and Quality of School Facilities

This section provides details regarding studies and analyses that have focused on issues related to building management, maintenance, and the quality of school facilities. Mangano and De Marco (2014) presented a literature review on the different ways of carrying out facility management and related topics to uncover that there was limited research regarding the impact of facility management on the logistics and operational performance of warehouses. This review provided a comprehensive literature review of the FM function in the logistics and warehousing arena to disclose the interesting fields of available research and identify the weakest areas so that future research directions can be addressed. This paper presents a review of literature available on the main research areas related to the FM discipline applied to logistics and warehousing. The aim of FM is the improvement of the effectiveness and efficiency of physical assets and workplaces to contribute to enhancing operational business performance. In this context, improving logistics performance via FM and maintenance services is a significant factor to achieve continued competitive advantage. The logistics industry is aware of the role of maintenance in improving the reliability of systems and improving performance of the organizations. Nevertheless, there is a need to spend and invest more in maintenance, since the status and the role of maintenance are not highly recognized. Similar challenges exist regarding the need for more investment in maintenance of school facilities.

Jennings et al. (2015) investigated the impact of school quality on various outcomes beyond test scores. They specifically focused on the academic achievement gap by examining college attendance as an additional measure of high school effectiveness across different income groups. While previous studies also used college enrollment as an indicator, the authors argued that exploring a wider range of school outcomes could provide new insights into the relationship between schools and inequality.

Using a large longitudinal dataset containing around 550,000 students from Massachusetts and Texas who started ninth grade in public high schools between 2003 and 2004, the authors found that unexplained differences among high schools had a greater influence on college attendance than on test scores. The dataset included student demographic information, enrollment data, test scores, and college enrollment data, as well as additional factors such as grade level, gender, race/ethnicity, socioeconomic status, and English proficiency. Their research contributed to understanding the broader impacts of school quality on students' educational outcomes.

Stenström et al. (2016) presented a case study with the aim of assessing the value of preventive maintenance (PM). Maintenance data were collected from the Swedish infrastructure manager (IM) Trafikverket (Swedish Transport Administration). Their data comprised both infrastructure related CM activities, that is, functional failure data, and PM data from inspections and rectification of potential failures. The CM data consisted of urgent potential failures, classified as functional failures, reported by the maintenance contractor during inspections, as well as functional failures identified outside the inspections, commonly reported by the train driver, but occasionally reported by the public. The PM data included visual inspections and manual measurements using gauges and non-destructive testing. This case study was used to examine the relationship between PM and CM in practice. Similar analysis of other assets, such as school buildings, will not yield the same result, though the method for assessing maintenance costs is similar in terms of maintenance requirements.

Basri et al. (2017) conducted a literature review that provided comprehensive information on preventive maintenance (PM) planning and methods used in the industry to achieve an effective maintenance system. This paper presented a detailed analysis of PM planning in terms of its research focus and direction for application. Research about PM is known to be extensively conducted and most companies applied the policy in their production line. However, most analysis and method suggested in published literature were done based on mathematical computation rather than focusing on solutions to real problems in the industry. This normally would lead to problems in understanding by the practitioner.

Therefore, this paper presented research works on PM planning and suggested methods that were practical, simple, and effective for application in the real industry. The authors advanced a method for simplifying maintenance operations by grouping systems, which can enhance PM planning. Yet, the condition of systems should be taken into consideration when developing an optimal plan prior to the ratification of a grouping process. Therefore, it is preferable to have a model or framework to act as guidance in the proper procedures necessary for optimal PM planning.

Dickerson and Ackerman (2016) presented a literature review on risk-based maintenance management and compared this approach to condition-based management systems. The paper further described an ongoing study to develop and validate a Failure Modes and Effects Analysis (FMEA) system for maintenance management risk analysis for public school facilities. FMEA was one of the first systematic techniques for risk analysis. It was developed by reliability engineers in the 1950s to study problems that might arise from malfunctions of military systems. As a pilot ‘proof-of-concept’ test of the utility of the FMEA tool for school facility maintenance prioritization, an FMEA system was developed for asbestos-containing building components. Therefore, facility managers could use this ranking to aid their decision-making regarding management of these hazardous building materials.

Lafortune and Schonholzer (2018) examined the effects of school facilities spending on student and neighborhood outcomes, linking data on new facility openings to administrative student and real estate records in Los Angeles Unified School District (LAUSD). To study the effects of increased capital expenditures on student outcomes, they used administrative records from LAUSD from the 2002-2003 school year to the 2012-2013 school year. Every student who attended LAUSD during this time period was included, and the data allowed for longitudinal links across years for students who remained in the district. These data provided one record per student year with information on student grades, test scores, demographics, attendance records, school assignment, and teacher assignments.

To analyze the effects of increased capital expenditures on the real estate market in Los Angeles, they used administrative records from the Los Angeles County Assessor’s Office. Records contained information for each property in Los Angeles County, and included data on the three most recent sales, as well information on property characteristics from the most recent assessment. The authors addressed three questions. First, did increases in school capital expenditures improve student outcomes? Second, if they did, what were the mechanisms through which capital expenditures improved outcomes? And third, how were these capital expenditures valued in the real estate market and what were their welfare implications? This study identified the impact of capital investment, like new construction schools, on outcomes such as academic, attendance, and property values.

Hawkins and Lilley (1998) created a guide appraising school facilities. This guide provided a comprehensive method for measuring the quality and educational effectiveness of school facilities and could be used to perform a post-occupancy review; to formulate a formal record; to highlight specific appraisal needs; to examine the need for new facilities or renovations; or to serve as an instructional tool. In the absence of any other formal evaluation of a facility, this guide could be used as a tool for facility assessment.

School Outcomes

This section presents literature that have focused on various aspects related to school outcomes. For example, Akinpelu (2022) investigated the impact of per pupil school spending on the high school graduation rate. A quantitative correlational study involving per pupil school spending and the academic achievement data from 100 high schools in the Piedmont Region of South Carolina was conducted. Secondary data obtained from the South Carolina Department of Education (SCDOE) and South Carolina Revenue and Fiscal Affairs Office databases and websites was utilized to conduct a simple linear regression analysis as well as two subsequent multiple regression analyses to test hypotheses concerning poverty and socioeconomic status.

Findings revealed that there was no existing correlation amongst per pupil school spending and high school graduation rates nor correlations concerning poverty and socioeconomic status. The findings from this study revealed valid proof of continued underachievement among a considerable number of students despite continued efforts to increase educational funding. This information is helpful because it identifies a variable that should be considered as an input in the revised education outcome model.

Van der Klaauw (2008) evaluated the impact of Title I funding of compensatory education programs on school finance and student performance in New York City public schools during the 1993, 1997 and 2001 school years. The analysis in this study was based on school-level data from the largest school district in the nation, New York City, on all public elementary and middle schools in 1993, 1997 and 2001. These data were collected by the New York City Board of Education's Office of Research, Evaluation, and Assessment, and provided by NYU's Institute for Education and Social Policy.

The data set contained school level information on a set of student characteristics which varied across years. These included poverty rates, ethnic composition as well as performance measures, including grade attendance, suspension, and criminal incidence rates, and average reading and mathematics test scores and, in 1993, gain scores by grade. These data were matched to school budget data as well as information on average teacher characteristics. This study provided a new evaluation of the impact of Title I funding on school finance and student performance at public elementary and secondary schools in New York City. The estimates indicated that Title I had not led to better student outcomes. A more detailed analysis of the interrelationships between various school funding sources, in studying the effectiveness of various school programs, including those funded by Title I in school districts other than New York City represents an important area for future research.

Toenjes (2021) examined whether the funds designated for Economically Disadvantaged (ED) students helped reduce the academic achievement gap between ED and non-ED students. The specific purpose of this study was to address two questions. The first question related to the extent to which schools with greater proportions of ED students exhibit greater total operational expenditures per pupil than other schools in the same district with lower levels of ED students. The second question related to whether expenditures per pupil were unequal in schools with at least 70% of their students classified as Economically Disadvantaged, comparing the averages for these schools within each district to those in the other districts. The data, for the school year 2017-2018 were restricted to 3,453 elementary and middle schools in 90 large Texas districts. The schools in each district were divided into high and low poverty groups. There were three key relevant pieces of data for each school: the school enrollment; the percentage of students eligible for the free or reduced-price lunch program (ED students); and the Total General Fund (GF) expenditures, minus expenditures for maintenance.

García and Weiss (2015) aimed to develop an understanding of disparities in school readiness among America's children when they begin kindergarten. Their study used data from the National Center for Education Statistics' Early Childhood Longitudinal Study, Kindergarten Class of 2010–2011 (ECLS-K 2010–2011), a cohort of students who entered kindergarten in 2010. The nationally representative sample provided information about the children—their race or ethnicity, socioeconomic status, language spoken at home, etc.—and their experiences in their early years, such as how actively their parents engaged them in enriching activities and whether they received prekindergarten care. Knowing which groups of children tend to start school behind, how far behind they are, and what factors contribute to their lag, can help educators develop policies to avert the early gaps that become long-term problems. This study not only identified which groups of children started kindergarten with disadvantages, but also linked to why.

Jones and Zimmer (2001) examined the impact capital had on academic achievement. The authors collected data of the insured value of school assets by surveying a sample of 60 schools in Michigan. The data used to estimate the model's parameters were from Michigan Department of Education (1994b) Michigan School Report, and the Michigan Department of Education Bulletin 1014. Data on demographic characteristics came from the National Center for Education Statistics, Common Core Data (CCD) School Years 1987–88 through 1992–93, CD-ROM, and Michigan's Jobs Commission Employment Service Agency Information web page.

By using school districts' level of bond indebtedness as a proxy for capital, the authors found evidence that capital stock did affect academic achievement. In light of these findings along with the general lack of research on capital inputs, they concluded that capital expenditures should be given greater attention in future research. Their results illustrated that at the margin, variations in capital stock were positively associated with variations in academic achievement, suggesting that capital was significant in the production of education. The results can be used as another variable in the revised production function model.

Downey and Condron (2016) presented a perspective on schools and inequality guided by the assumption that schools may shape inequalities along different dimensions in different ways. From this more balanced perspective, schools might indeed reproduce or exacerbate some inequalities, but they also might compensate for others, socioeconomic disparities in cognitive skills in particular. At the core of their framework was the idea that schools were *refractors* of inequality. Much like light is refracted when it enters a new medium, like from air to water, they argued that inequalities were refracted when children entered schools. Light refracts in different ways, depending on whether it enters a slower, faster, or similar speed medium. Similarly, how inequality changes once children enter schools depends on how the new medium, that is, schools, influences inequality's trajectory vis-a`- vis the previous medium, that is, the non-school environment. Schools' role could be (1) neutral, in other words, no change to inequality, (2) exacerbatory, which means makes inequality worse, or (3) compensatory, or reduces inequality. The authors encouraged scholars to acknowledge that inequality exists and to rigorously isolate school effects, carefully weighing the magnitude of exacerbatory and compensatory mechanisms, and placing school effects in context.

The No Child Left Behind Act (NCLB) is the reauthorization of the initial Elementary and Secondary Education Act (1965), while the Every Student Succeeds Act (ESSA) (2015) reauthorized NCLB. Mathis and Trujillo (2016) examined the impact of NCLB and presented ideas for the successful implementation of ESSA. They offered recommendations on both broad and focused implementation issues for policymakers, highlighting strategies that represented wise educational investments.

One of the authors' conclusions was that the greatest conceptual and most damaging mistake of test-based accountability systems has been the pretense that poorly supported schools could systemically overcome the effects of concentrated poverty and racial segregation by rigorous instruction and testing. The law established a test-based accountability system which is the basis for my research. Additionally, the accountability system identified sub-groups of students. My research offers another variable, condition of the facility, that can impact learning.

Egalite et al. (2016) summarized the state of competition in American K–12 education. The researchers paid particular attention to the prevalence and market penetration of charter schools, private school vouchers, and tax-credit scholarships as market reforms. These summaries and analyses suggested that growing educational competition from charter schools, vouchers, and tax-credit scholarship programs held the promise of improving the productivity of district schools, subject to the effective design of school choice policies. The authors identified improving the condition of facilities as a strategy to replicate successful programs. They recommended that states should step in by offering school expansion loans with competitive interest rates or dedicated facilities funding to enable private schools to retrofit public-school buildings that have fallen out of use due to declining enrollment.

Lafortune et al. (2018) examined the impacts of school finance reforms on student achievement. The authors use an event study research design that exploited the apparent randomness of reform timing. They showed that reforms led to sharp, immediate, and sustained increases in spending in low-income school districts.

They used data from the National Assessment of Educational Progress (NAEP), also known as the *Nation's Report Card*. State-representative samples of 100,000–200,000 students in the fourth and eighth grades in math and reading tests administered every two years from 1990. They used NAEP data to construct a state-by-year panel of relative achievement in low-income school districts, covering 1990 to 2011.

The authors found that finance reforms reduced achievement gaps between high- and low-income school districts but did not have detectable effects on resource or achievement gaps between high and low-income or White and Black students. Attacking these gaps would require policies aimed at the distribution of achievement within school districts, something that was generally not a focus of the reforms that they study. My research addresses this identified gap.

Miller (2018) analyzed the impact of school spending on student achievement by estimating the effect of education spending on district-level student outcomes in 24 states by leveraging changes in revenue driven by property value variation. Administrative data on property values for over 7,000 school districts was used in this study. The data for this project were combined from several sources. The primary source of data was the National Center for Education Statistics' Common Core of Data (CCD). CCD data was supplemented with additional district-level information including a database of district property values collected from individual states, test scores, and median household income.

The author created an instrument that is highly predictive of changes in revenue and spending. These results suggested that market variation in property values affected student outcomes through existing school finance formulas. It is important to understand the impact of these formulas especially if this variable is considered as an input to my production model.

Tubbs and Garner (2008) presented a case study that provided insight into an elementary school whose climate issues appeared to plague and impact its performance as measured by its Annual Yearly Progress (AYP). The target population for this study was a Northwest Georgia Elementary School. The school served approximately 600 students in pre-k through fifth grade. The school employed 42 faculty and staff, 31 of which 75% were Caucasian, nine percent were African American, and 6 and 15% were Hispanic.

The instrument for data collection in this study consisted of 29 Likert scale questions and three open-ended questions that related to faculty and staff disposition toward their overall school climate. The results of this study suggested that the school climate may be in an early toxic state which appeared to show early stages of a negative impact on student performance. The author recommended that the principal concentrate on building a better environment by providing the climate and interpersonal support that enhanced faculty and staff opportunities for fulfillment of individual needs for achievement, responsibility, competence, and esteem. Facility condition was not considered in this study.

Neymotin (2010) studied the relationship between school funding and student achievement in Kansas public schools. Between 1997 and 2006, the state of Kansas underwent significant changes in its financial approach to educational reform, as documented in the School District Finance and Quality Performance Act (1992). These changes impacted the distribution of per-student financial support to school districts across Kansas. Information on school district level measures of student achievement test scores, graduation rates, and dropout rates came from the Kansas State Department Board of Education. Information on school district characteristics, revenues per student, as well as an alternative measure of student achievement, by the diploma rate, came from the National Center for Education Statistics.

The analysis of the amended Act (2006) found different conclusions from those in an earlier study, which analyzed the Act before its recent amendments. The analysis employed a differencing approach using district-level data for the years before and after

2005. A differencing approach for this particular time period was justified due to the large number of amendments to the School District Finance and Quality Performance Act which occurred in the year 2005. The study concluded that changes in the School District Finance and Quality Performance Act over 1997 - 2006 had little effect on student persistence or test scores. However, the increased funding did not address facilities.

Ziomek and Schoenenberger (1983) investigated the relationship of school and Title I program attendance to student achievement. Data from Title I mathematics and reading programs in grades two to six in a large midwestern school district were chosen for this study. Both programs had been operating for more than 10 years and served an average of at least 1,500 students annually.

This study identified some of the challenges with implementing the Title I program as designed and intended. High school attendance rates for the Title I program were significantly higher when compared to school attendance than those of elementary students. One of the limitations identified by the authors was that parental or student attitude measures were incorporated in the study. The existing production model that I plan to use accounts for student effort.

Turner (1999) examined the relationship between fifth grade reading Iowa Test of Basic Skills scores, per pupil expenditure (PPE), and other factors in selected Georgia public schools. This study is important at that time because of the rising concern of the academic performance of America's students. Data were collected and analyzed from the 1997-98 school year of selected public schools in Georgia. Fifth grade reading ITBS scores and their relationship to district enrollment, percentage of students receiving free and reduced lunch, percentage of total budget used for salaries and benefits, average years of teacher experience, and percentage of teachers with a master's degree or higher were also analyzed. The sample included 40 public school districts in Georgia.

An implication from this study was that increasing school spending did not necessarily increase student achievement, and that targeting specific programs may lead to more significant academic gains. The author concluded that more consideration should be given to other variables such as student mobility, socioeconomic status, and family background that may be related to student achievement. I will consider these variables in the development of my model.

Effects of the Quality of Facilities on School Outcomes

In this section, I present literature that focused on potential impacts of quality of school facilities on their various outcomes. Literature in this section connect the two previous threads of the literature.

Bowers and Urick (2011) attempted to isolate the independent effects of high school facility quality on student achievement using a large, nationally representative U.S. database of student achievement and school facility quality. These authors aim was to address the previous methodological issues in the research on the relationship of school facility condition to student achievement.

They analyzed the public-school component and the facilities checklist of the Education Longitudinal Study of 2002 (ELS:2002) survey that represented 8,110 students in 520 schools, using a two-level hierarchical linear model to estimate the independent effect of facility disrepair on student growth in mathematics during the final two years of high school. The authors controlled for multiple covariates at the student and school level. This study only used math as a measure of academic achievement and only assessed high school students.

The authors were not able to conclude whether facility conditions directly influenced student achievement in the elementary, middle or early high school years. They did not find a direct effect of facilities on achievement, but they did identify differences in student and school attributes by facility disrepair. As the initial descriptive statistics demonstrated, facility disrepair did not appear to be evenly distributed across the sample, but appeared to vary by student ethnicity, poverty, and multiple school variables. My research will include scores on standardized tests for 3rd grade through high school and address impact of facilities on academic achievement as moderated by ethnicity.

Lewis (2001) conducted a study of 139 K-12 Milwaukee public schools that examined the effect of building condition on student test scores compared to other influences such as family background, socioeconomic status, race/ethnicity, attendance, and student discipline. The study analyzed performance on the Wisconsin Student Assessment System Mathematics, Science, Language, and Social Studies tests of fourth, eighth, and 10th grades of each school in 1996, 1997, and 1998. Three separate kinds of data were provided by the Milwaukee Public Schools: facility condition and educational adequacy scores, student test scores by school level, and indicators of the characteristics of students in the 139 schools used in the analysis.

This study demonstrated several significant relationships between facility condition and student achievement. The findings were inconsistent. This inconsistency can be linked to the gap of time between the facility assessments and student test scores. Elimination of gaps can lead to better results.

Uline et al. (2008) explored the interplay between quality facilities and school climate, charting the effects of facility conditions on student and teacher attitudes, behaviors, and performance within schools slated for renovations in a large metropolitan school district. The research applied a school leadership-building design model to explore how six characteristics of facility quality-movement, aesthetics, play of light, flexible and responsive classrooms, elbow room, and security interacted with four aspects of school climate: academic press, community engagement, teacher professionalism, and collegial leadership.

Quantitative data analysis from surveys administered to faculty was conducted simultaneously with qualitative data coding and analysis. The study was conducted in two overlapping phases using mixed-methods research design. The authors recommended tracking changes in climate and achievement as renovations are complete to gain an accurate impact of those changes.

Stafford (2015) examined the effect of school indoor air quality (IAQ) on academic outcomes. Of the 74 elementary schools in the district, 66 had at least one IAQ-related renovation project funded by the bond initiative and the majority had more than one project completed. The school district provided administrative data on all students who attended and all teachers who taught at each elementary school within the district at any point between the fall of 2002 and the spring of 2007. Student-level performance data include school attendance rates and scores on the annually statewide-administered Texas Assessment of Knowledge and Skills (TAKS) in math and reading. This study can be expanded by looking at more than one set of data.

Martorell et al. (2016) provided a comprehensive assessment of achievement effects from school facility investments initiated and financed by local school districts. The first part of the analysis examined the impact of nearly 1,400 capital campaigns initiated by 748 school districts in the state of Texas over a 14-year period. The authors studied the achievement effects of nearly 1,400 capital campaigns initiated and financed by local school districts, comparing districts where school capital bonds were either narrowly approved or defeated by district voters. The second part of the study directly measured the effect of capital investment on students actually exposed to it by analyzing more than 1,300 major campus renovations.

The analysis drew on four sources of data at the student, district, and campus levels (bond election data, district- and campus-level longitudinal data, age and condition of school facilities, and student achievement, attendance, migration) which were then aggregated to the district-year level for most of the regression discontinuity analysis. Event-study analysis used disaggregated student microdata combined with campus-level information. The authors recommended that future research should examine whether there were benefits, including to student outcomes of facility investments in poor areas that may have difficulty generating funds for facility improvements.

Maxwell (1999) explored the importance of the educational setting and its effect on student learning, performance, attitude, and behavior. This study was an important step in assessing the effect of the renovation of school facilities on student performance. Many districts are faced with convincing taxpayers that additional dollars are needed for facility improvements. Research of this type can therefore be useful to school administrators and local governments in making the case for additional funds for local School facilities.

The study, conducted in cooperation with the Syracuse, New York, City School District (SCSD) focused on the facilities planner's perspective and raised important questions needing further investigation. New York State evaluated its third-and sixth-grade students in math and reading statewide annually via the Pupil Evaluation Program (PEP) test. This provided a convenient, time-tested, and well-documented means of measuring student achievement in these areas. The authors suggested that future research might also consider including data on teacher and student turnover, absenteeism, and student disciplinary occurrences. Such research would permit the testing of a model stating that physical environmental features affect student and teacher attitudes and these attitudes towards learning and teaching are related to student achievement.

Earthman (2002) presented a literature review of studies that concluded that school facility conditions did affect student academic achievement. The following variables were discussed: thermal quality, acoustic quality, school building age, overall building condition, and overcrowding. All of the studies cited in this analyses demonstrated a positive relationship between student performance and various factors or components of the built environment. The strength of that relationship varied according to the particular study completed; nevertheless, the weight of evidence supported the premise that a school building had a measurable influence on student achievement.

Ramli et al. (2018) examined the contributing variables for student achievement in Universiti Malaysia Kelantan, Malaysia. This study examined eight independent variables of e-learning; MIS (system management); classroom, teaching aid and library (learning environment) and hostel, sports facilities and parking and transportation (infrastructure); and their impact on student academic achievement, in UMK City Campus. In this study, the City Campus was chosen because of its unique conditions of using shop lots as the campus building.

Data were distributed to 500 students during the 2016/17 academic calendar at the Universiti Malaysia Kelantan (UMK) City Campus. A total of 364 returned and usable questionnaires were received, given a response rate of about 73%. This study revealed important insights into the facilities that influenced the students‟ academic achievement. The results found that teaching aid and hostel were the most important facilities to influence academic achievement of UMK students in City Campus. These factors were not given sufficient consideration when the campus opened. The results of this research can aid decision makers when opening a new higher ed facility.

Uline and Tschannen-Moran (2008) examined the proposition that at least part of the explanation for the link between school building quality and student outcomes was the mediating influence of school climate. This exploratory study was undertaken to examine the interdependent relationships between the physical environment and the social environment of schools, as well as the relationship of each to student achievement. Teachers from 80 Virginia middle schools were surveyed employing measures including the School Climate Index, a seven-item quality of school facilities scale, as well as three resource support items. Data on student SES and achievement were also gathered.

Bivariate correlational analysis was used to explore the relationships between the quality of facilities, resource support, school climate, student SES, and student achievement. In addition, multiple regression was used to test school climate as a mediating variable between the quality of facilities and student achievement. One of the limitations of the study was that the measure of teacher perceptions of school facilities was self-reported and subjective in nature. No attempt was made to align these perceptual data with more objective measures of the same buildings. A standardized method for collecting/validating input would lead to more robust results.

Sheets (2009) examined the relationship between the condition of rural public high school facilities in Texas and student achievement, student attendance, and teacher turnover. The condition of facilities variables selected for this study included: general condition of school facilities, percent portable to total square feet per student, percent of over/under capacity, average age of facilities, number of years since last renovation, and percent deferred maintenance. The measurements for the condition of facilities variables used in this study were obtained from the 2006 Texas Comptroller's Facility Survey of the 1,037 public school districts in Texas. The participants for this study were 72 rural public high schools out of the 309 total responses to the survey from all district types.

This study found that the student wealth level contributed most to the variance in student achievement. However, the condition of school facilities had a measurable effect over and above socioeconomic conditions on student achievement and teacher turnover. The demographic variables selected for this study included: student wealth level, measured by the percentage of Economically Disadvantaged students, school district wealth level measured by property value per student, and percent of minority students. My study will include race groups as a variable.

O'Neill (2001) investigated the possible impact of school facilities on student achievement, behavior, attendance, and teacher turnover rate in selected Texas middle schools in Region XQI Educational Service Center (ESC). The secondary purpose was to identify those environmental aspects of the school facility which had the potential to enhance learning.

These findings had possible policy implications regarding the design specification for new construction and renovation. Building condition was determined by the Total Learning Environment Assessment (TLEA) which was completed by middle school principals in the population. Student data and teacher turnover rate was obtained from the Public Education Information Management System (PEIMS) which is a Texas statewide reporting system. The data gathered and analyzed can assist administrators and school boards in directing funds to meet the academic needs of their students.

The goal was to identify those environmental aspects of the school facility, which had the potential to enhance learning. A research study could be conducted using the same survey methodology to examine potential differences according to ethnicity. Since the research showed learning style preferences were closely related to ethnicity, perhaps the influence of facility conditions on student performance measures is related as well.

Earthman and Lemasters (1998) examined the validity of the impression that buses and buildings consumed too much of the budget and had no direct relationship to the student. It provided a definition of what constitutes part of a facility and included features such as color, maintenance, age, classroom structure, climate conditions, student density, noise, and lighting. The study described the difficulties inherent in this kind of research and examined some of the research syntheses that focused on the correlation between student learning and the condition of facilities.

Buckley et al. (2004) investigated whether there was a relationship to the quality of the school facility, why teachers quit, and how they might be better induced to stay. The authors investigated the importance of facility quality using data from a survey of K-12 teachers in Washington, D.C. The main variable of interest was the condition of the school facility, reflected by the grade that the teacher assigned to their school facilities on the familiar A-F scale, which they treated as a continuous measure. In addition, they included a series of measures that reflected individual, school, and community factors that could affect the propensity to leave. These included such individual measures as the respondents' age, (actually measured categorically but assumed to be continuous here, and their age squared to account for a likely nonlinear effect, whether the respondent was female; whether they were "very dissatisfied" with their present salary; the number of years spent at their present school; whether they held D.C. teaching certification; and dichotomous variables for self-reported race as White or other. Black was the excluded, modal category.

The research showed that increasing teacher salaries appeared to improve retention. Research also suggested that the benefits of facility improvement for retention could be equal to or even greater than those from pay increases. Furthermore, a major facilities improvement was likely to be a one-time expense, last for many years, and have supplemental sources of state or federal funding available. It could thus be more cost effective teacher retention strategy than a permanent salary increase for teachers in the medium- to long-term.

Durán-Narucki (2008) examined the role of school attendance as a mediator in the relationship between facilities in disrepair and student grades in city and state tests. This study provided empirical evidence of the effects of building quality on academic outcomes and considered the social justice issues related to this phenomenon. Data on building condition and results from English Language Arts (ELA) and Mathematics (Math) standardized tests were analyzed using a sample of 95 elementary schools in New York City. Variables relevant to academic achievement such as ethnicity, socioeconomic status, teacher quality, and school size were used as covariates. The data for this study was accessible online through the New York City Board of Education's website. Qualitative methods could provide more in-depth information regarding how school buildings affect children.

Fisher (2001) examined studies concerning the relationship between student outcomes and behavior based on the overall building condition as well as the influence of individual building elements. This literature review concluded that student academic achievement improved with improved building conditions. Another discovery was that individual factors, such as lighting levels, air quality and temperature and acoustics, had an effect on student behavior and outcomes, although there was limited quantitative evidence available on some of these factors. Further research into the contribution of design factors to student behavior and outcomes may assist architects, educators and policy makers to better understand the real impact of investment in school infrastructure.

Heschong et al (2002) conducted a study to see whether they could demonstrate a clear relationship between the presence of daylight and human performance in buildings. The performance data used were gathered from three school districts located in Orange County, CA; Seattle, WA; and Fort Collins, CO. Each district provided extensive databases, including math and reading test scores, attendance records, and student demographic characteristics. Demographic information included gender, ethnic background, and socio-economic status. The data included indicators of participation in special programs, such as bi-lingual programs or gifted and talented programs. The methodology used to analyze the impact of lighting on outcomes can be used to determine the impact of other specific building conditions on academic outcomes.

Bishop and Wossmann (2004) presented a model of educational production that tried to make sense of recent evidence on effects of institutional arrangements on student performance. They developed a basic model of educational production that was created to reflect the principal–agent structure of the education process and that allowed them to analyze the impact of institutional features on students' educational performance. The model was applied to assess the impact of different institutional features of the schooling system on the quality of schooling output. This model forms the basis of my model.

The proposed research is more related to this third thread of the literature but deviates from the existing literature by the outcome variables intended to be used. This research intends to use outcome variables that will capture gap in educational achievement across various socio-economic groups.

Mathematics Achievement Gap

This section focuses on efforts to close the achievement gap in mathematics. Bjorklund-Young and Plasman (2020) used standardized math test performance to explore whether schools were able to eliminate the achievement gap across middle-level education. Additionally, they examined how schools worked to improve the performance of their lowest-performing students. Their study brought additional insight and perspective on achievement gap closure. The authors restricted their search to states that administered either the Partnership for Assessment of Readiness for College and Careers (PARCC) or Smarter Balanced Assessment Consortium (SBAC) math tests for at least three consecutive years in the four-year period between 2014–15 and 2017–18. Of the 144 total schools in their sample, none of them was able to eliminate the math achievement gap over the course of middle school.

Flores (2007) identified unequal opportunities to learn as factors that contributed to the achievement gap in mathematics. The author used NAEP data to show that African American, Latino, and low-income students were less likely to have access to experienced and qualified teachers, more likely to face low expectations, and less likely to receive equitable per student funding. The data also showed that there was a considerable gap in test performance between students from poor families and those from non-poor families.

Boaler and Staples (2008) employed a mixed methods longitudinal study to determine whether a school could successfully employ equitable and successful teaching to address inequitable mathematics performance. Participants included approximately 700 students as they progressed through three California high schools. Student performance and attitudes were assessed through statistical methods, while the behaviors and methods of teachers and students were recorded and analyzed qualitatively, employing coding strategies.

Summary

Johnson and Kritsonis (2006) identified several factors contributing to the mathematics achievement gap. This includes a decline in per-pupil spending, the underrepresentation of children of color in gifted programs, and a lack of targeted intervention programs. However, no studies within the last five to seven years were found that examined the quality of facilities as a potential factor influencing the achievement gap in mathematics.

CHAPTER III

METHODOLOGY

Scholars have theoretically modeled educational outcomes differently. For instance, Wilson (2001) used a structural model where family background, neighborhood, and school quality were allowed to impact the expected return to education and utility of acquiring education. Bishop and Wossman (2004) built a theoretical model of educational production in schools where rational actors maximized the difference between their individual benefits and costs and assumed that schooling outcome was a function of educational spending and the effort of each student. Following the work of Bishop and Wossman, this research considered education as an output from a production process that uses learning ability and student effort (A), school facilities (X), and other resources (Z) as inputs.

This research deviated from the work of Bishop and Wossman in three ways. First, I included explicitly the quality of facilities as a distinctive input. Second, I considered the inputs as complementary in production, which means all the inputs, that is, A, X, and Z, were needed to produce education and it was not possible to produce education if at least one of the inputs was missing. Third, learning ability and student effort are heterogeneous, highly depending on socio-economic backgrounds. There is a plethora of literature regarding various socio-economic factors that impact student performance (Caldas & Bankston 1997; Zhang et al. 2020).

The Cobb-Douglas production function is a widely used mathematical equation in economics that describes how the output of a firm or an industry depends on the inputs of labor and capital. It was developed independently by economists Paul Douglas and Charles Cobb in the 1920s. Overall, the Cobb-Douglas production function is a foundational tool in economic theory and empirical analysis, helping to explain the relationship between inputs and outputs in production processes.

The standard Cobb-Douglas production function is expressed in the following form:

$$Q = AL^{\propto}K^{\beta}$$

Where:

- Q represents the quantity of output produced.
- L stands for the quantity of labor input.
- K stands for the quantity of capital input.
- A is a positive constant called the total factor productivity or technological factor, which represents the level of technology, efficiency, and other factors that affect production but are not specifically related to labor or capital.
- α and β are the output elasticities of labor and capital, respectively. They are constants between 0 and 1 that represent the percentage change in output resulting from a 1% change in the respective input. The sum of α and β equals 1 in the standard Cobb-Douglas production function.

Thus, my education production function can be written as the function below:

$$Y = AE^{\alpha}(IR)^{\beta}$$

Where Y is student outcomes (grades)

A is learning ability

E is student effort

R is the amount of resources going into teaching

I is the effectiveness with which these resources are used

(*IR*) is effectively used resources

α and β are elasticities of schooling quality

Q is schooling quality

$$Y_1 = AE_1{}^{\alpha_1}QK^{\beta}$$

Y_1 is student outcomes (grades)

A is the quality of teacher (years of experience, classroom management ability, leadership ability)

E is the student effort

Q is the quality of facilities (Facilities Condition Index)

K is capital (building)

Methodology

The education production function that depicts what is happening in schools is taken to be of the Cobb-Douglas form. Student outcomes Y1 is produced according to the model in equation 1.

$$Y_1 = AE_1^{\alpha_1}(QK)^{\beta} \tag{1}$$

$$Y_2 = AE_2^{\alpha_2}(QK)^{\beta}$$

In this model, students are not assumed to be perfectly homogenous therefore $_i$ represents the different types of students (race).

$$\pi_i = P_i AE_i^{\alpha_i}(QK)^{\beta} - W_i E_i - rK$$

The cost of E=W

The cost of K=r

$$\frac{\delta\pi^i}{\delta E_i} = \alpha^i P_i A {E_i}^{\alpha i-1}(QK)^\beta - W_i = 0$$

π is a profit function

P is price

$$\alpha_i P_i A {E_i}^{\alpha_i-1}(QK)^\beta = W_i$$

*multiply both sides by Ei

$$\alpha_i P_i A {E_i}^{\alpha_i}(QK)^\beta = W_i E_i$$

*substitute equation (1)

$$\alpha_i P_i Y_i = W_i E_i$$

$$E_i = \frac{\alpha_i P_i Y_i}{W_i} \tag{2}$$

$$\frac{\partial\pi_i}{\partial K} = \beta P A {E_i}^{\alpha_i} Q^\beta K^{\beta-1} - r = 0$$

$$\beta P A {E_i}^{\alpha_i} Q^\beta K^{\beta-1} = r$$

*multiply both sides by K

$$\beta P A {E_i}^{\alpha_i} Q^\beta K^\beta = rK$$

*substitute equation 1

$$\beta P Y_1 = rK$$

$$K^* = \frac{\beta P Y_i}{r} \tag{3}$$

*substitute equation (2) and equation (3) into equation (1)

$$Y_i = A {E_i}^{*\alpha_i}(QK^*)^\beta$$

$$Y_i = A\left(\frac{\alpha_i P_i Y_i}{W_i}\right)^{\alpha_i} Q^\beta \left(\frac{\beta P_i Y_i}{r}\right)^\beta$$

$$Y^{*} = A\left(\frac{\alpha_i P_i}{W_i}\right)^{\alpha_i}\left(\frac{\beta P_i}{r}\right)^{\beta} Q^{\beta} {Y_i}^{(\alpha+\beta)}$$

$$Y_1^{\,1-\alpha_i-\beta} = A\left(\frac{\alpha_i}{W_i}\right)^{\alpha_i}\left(\frac{\beta}{r}\right)^{\beta} {P_i}^{\alpha_i+\beta} Q^{\beta}$$

$$Y_i^{\,*} = \left[A\left(\frac{\alpha_i}{W_i}\right)^{\alpha_i}\left(\frac{\beta}{r}\right)^{\beta} {P_i}^{\alpha_i+\beta} Q^{\beta}\right]^{\frac{1}{1-\alpha_i-\beta}}$$

where

$$\frac{1}{1-\alpha_i-\beta} > 0$$

$$(\alpha_i+\beta) < 1$$

$$Y_i = \left[A\left(\frac{\alpha_i}{w_i}\right)^{\alpha_i}\left(\frac{\beta}{r}\right)^{\beta} {P_i}^{\alpha_i+\beta} Q^{\beta}\right]^{\frac{1}{1-\alpha_i-\beta}}$$

A positive β_1 coefficient will explicitly add quality of educational facilities to the basket of policy tools apt to be used to enhance inclusive education, and thus contribute to income equality among socio-economic groups, given that education is an established predictor of future earnings.

$$\frac{\partial Y_i}{\partial Q} > 0$$

Improvements in quality of buildings (Q) will lead to higher performance (Y_i).

$$\frac{\partial\left|Y_i - Y_j\right|}{\partial Q} >< 0$$

where $\left|Y_i - Y_j\right|$is the achievement gap

$$Y_i = \propto_0 + \propto_1 Q + x + e_i$$

$$y_i = \log Y_i$$

$$G_i = \beta_0 + \beta_1 Q + x + e_i$$

where x is the control variable and e_i is the error term

β_1 can be positive or negative which leads to an empirical issue

FCI From the data set is Q

I expect FCI to be positive because high FCI = lower quality building

Quality of building will impact performance

A building with low quality (high FCI) student should lead to lower performance.

Data Collection and Management

Four major data points were used in this study. The first component is the condition of the building as measured by the FCI. The FCI is a metric for measuring a campus adequacy and suitability of facilities. It is calculated by dividing the cost of remedying deficiencies by current replacement value (CRV). The higher the FCI, the poorer the condition of the facility. The scale below is presented by the International Facility Management Association:

- Good: 0 to 5% FCI.
- Fair: 5% to 10% FCI.
- Poor: 10% to 30% FCI.
- Critical: greater than 30% FCI

This tool is primarily used in the United States in government, education, housing, transportation, and other organizations that operate and maintain multiple properties. The purpose of FCI is to provide a means for assessing the building's condition and allowing decision makers to understand building renewal funding needs

(Facility Condition Index, 2022). The FCI data used in this study is from 2021 and was prepared by a group of architects, engineers, and industry professionals.

The second set of variables comes from the STAAR test. STAAR is a standardized academic achievement test designed to measure the extent to which students have learned and are able to apply the knowledge and skills defined in the state-mandated curriculum standards, the Texas Essential Knowledge, and Skills (TEKS). Every STAAR question is directly aligned to the TEKS currently implemented for the grade and subject or course being assessed. STAAR fulfills the requirements of the federal Every Student Succeeds Act (ESSA), which requires that all students be assessed in specific grades and subjects throughout their academic careers. The STAAR results for the school year 2021-2022 were used in this study. STAAR scores used in this analysis include:

- Elementary School – all grades mathematics
- Middle School – all grades mathematics
- High School - all grades mathematics

The third component is the sub-groups of students as identified by the Texas Education Agency (TEA). The student groups identified by the TEA in the annual TAPR are special education, gifted and talented education, career and technical education, at-risk, military connected, Title I, migrant, immigrant, homeless, foster care, emergent bilingual, section 504, and Economically Disadvantaged. Race/ethnic groups are defined by the TEA data as African American, Hispanic, White, American Indian, Asian, Pacific Islander, and two or more races.

The fourth component is the average income of the parents and guardians of the students in the study. Research has confirmed that lower-income students perform worse in school as measured by academic tests. Children from low-income families often start school already behind their peers who come from more affluent families. Workman (2021) found students in states with higher income inequality had lower average mathematics achievement.

A formal data request was submitted to the school district office of research. The office provided the results of the Facility Condition Assessment which shows the FCI for all schools in the school district in 2022. The office also provided links to publicly available STAAR results. The definitions and sources for all variables used in the analysis are listed in Table 1.

Table 1

List of Variables

Variable	Definition	Source
FCI	The Facility Condition Index (FCI) is a standard tool used by architects, engineers, and facility planners to compare the condition of school facilities and determine whether it is more economical to fully modernize an existing school or to replace it. This is a nationally recognized standard that has been adopted by the National Association of College and University Business Officers (www.nacubo.org) and the Association of Higher Education Facilities Officers (www.appa.org). The index is computed as a ratio of the total cost to remedy identified deficiencies to the current replacement value (CRV) of the building. The higher the FCI, the poorer the condition of the facility. The scale below is presented by the International Facility Management Association: Good: 0 to 5% FCI Fair: 5% to 10% FCI	National Center for Education Statistics https://nces.ed.gov/pubs2003/fim/ch_3.asp

	Poor: 10% to 30% FCI Critical: greater than 30% FCI	
Scores	All grades mathematics, All grades ELA/reading, All grades Both subjects, etc. They are expressed in percentage by type of students (African American, Hispanic, White, Asian). 2019 and 2021	Texas Education Agency Texas Academic Performance Report (TAPR)
Year built	YEAR BUILT means, with respect to any mortgaged real property securing an underlying mortgage loan, the year when construction of the property was principally completed.	Law Insider
Average income	The average income in the homes in the same zip code as the school	Income by Zip Code
Maintenance costs	Cost of maintenance at that school for the school year 2021-2022	Maintenance records
Performance Gap (African American vs Asian)	Abs (Score African American-Score Asian)	Computed
Performance Gap (African American vs Hispanic)	Abs (Score African American-Score Hispanic)	Computed
Performance Gap (African American vs White)	Abs (Score African American-Score White)	Computed
Performance Gap (Asian vs Hispanic)	Abs (Score Asian-Score Hispanic)	Computed

Performance Gap (Asian vs White)	Abs (Score Asian-Score White)	Computed
Performance Gap (Hispanic vs White)	Abs (Score Hispanic-Score White)	Computed
Performance Standard Deviation	Standard deviation of scores across the four socio-economic groups (i.e., African American, Asian, Hispanic, and White)	Computed
The dataset contains numerous socio-economic groups. I report only information related to racial groups, with more available information, for a better comparison.		

Data Analysis Steps

From the original data, I constructed new variables that reflected educational achievements gaps. These variables included the cross-sectional standard deviations in educational performance across different types of students, and absolute 2-by-2 gaps in scores from different types of students as shown in Table 2 below.

Table 2

Educational achievement gaps

	A) African American	B) Hispanic	C) White	D) Asian
A) African American				
B) Hispanic	|A-B|			
C) White	|A-C|	|B-C|		
D) Asian	|A-D|	|B-D|	|C-D|	

C(n,r)=C(4,2)=6

Validation Measures

The Texas Education Agency (TEA) contracted with the Human Resources Research Organization (HumRRO) to provide an independent evaluation of the validity and reliability of the State of Texas Assessments of Academic Readiness (STAAR) scores. The independent evaluation is intended to support HB 743, which states that before an assessment may be administered, "the assessment instrument must, on the basis of empirical evidence, be determined to be valid and reliable by an entity that is independent of the agency and of any other entity that developed the assessment instrument" (Texas Education Code, 2017, para. 23).

CHAPTER IV

RESULTS

Introduction

The purpose of this study was to examine the relationship between the condition of public school facilities in Texas and the mathematical achievement gap, while controlling for the effects of the demographic variables of student sub-groups, and average income. Data were taken from the 2021-2022 STAAR exam and the 2021 facility condition assessment.

Presentation of the Data

There was a total of 77 schools used in this analysis representing 51 elementary schools, 15 middle schools, and 11 high schools. Table 3 shows the FCI by school types. The mean FCI was 32.545 with a standard deviation of 14.551. The minimum FCI was 0 and the maximum was 59. The FCI of 0 reflects newly constructed buildings at the elementary and middle school levels. The oldest elementary school is 54 years old and the newest high school is 13 years old. The age of the building and level of maintenance explain the variation between the minimum and maximum values. Results are summarized in Table 3.

Table 3

Summary of FCI by School Type

	Obs	Mean	Std Dev	Min	Max
Elementary	51	32.98	16.194	0	58
Middle	15	28.2	10.213	0	40
High	11	36.455	10.28	17	59
All	77	32.545	14.551	0	59

Table 4 presents the results of the STAAR test scores by school type and race/ethnicity. In the “All” summary, it can be seen that Asian and White students are outperformed by Hispanic and African American students.

Table 4

Average Test Scores by Types of Schools and Race/ethnicity for all Grades Mathematics

	Elementary	Middle	High	All
African American	74.46	60	66.43	70.8
Hispanic	75.15	58.95	64.63	70.76
White	77.57	66.5	70.45	74.43
Asian	87.17	79.12	81.46	84.74

Table 5 shows the average standard deviation of test scores by school.

Table 5

Average Standard Deviations Across Student Types

	All Grades Mathematics
Elementary	8.2
High	9.31
Middle	8.35
Grand Total	8.39

By using the absolute value of the difference between race/ethnic groups, the academic gap across groups can be identified. This has led to six dependent variables as presented in Table 2. Closing the academic gap through investment in facilities could result in the closing of the achievement gap. Higher quality elementary and middle schools (Good: 0 to 5% FCI) are compared to lower quality schools (greater than 30% FCI). Higher quality high schools (Poor: 10% to 30% FCI) are compared to lower quality schools (greater than 30% FCI).

Table 6

Summary of Achievement Gap at Elementary Schools

			Good	Critical
ES	All Grades Mathematics	Achievement gap between African American and Hispanic	5.5	7.548387
ES	All Grades Mathematics	Achievement gap between African American and White	11.66667	8.55
ES	All Grades Mathematics	Achievement gap between African American and Asian	10.83333	12.52381
ES	All Grades Mathematics	Achievement gap between Hispanic and White	12.16667	5.85
ES	All Grades Mathematics	Achievement gap between White and Asian	8.333333	12.28571
ES	All Grades Mathematics	Achievement gap between Hispanic and Asian	14.5	11.22222

In elementary schools the achievement gap in mathematics was smaller in the schools of higher quality 56% of the time (10/18).

Table 7

Summary of Achievement Gap at Middle Schools

			Good	Critical
MS	All Grades Mathematics	Achievement gap between African American and Hispanic	5	4.166667
MS	All Grades Mathematics	Achievement gap between African American and White	3	7
MS	All Grades Mathematics	Achievement gap between African American and Asian	16	20.6
MS	All Grades Mathematics	Achievement gap between Hispanic and White	8	7.833333
MS	All Grades Mathematics	Achievement gap between White and Asian	21	19.6
MS	All Grades Mathematics	Achievement gap between Hispanic and Asian	13	12.4

In middle schools the achievement gap in mathematics was smaller in the schools of higher quality 60% of the time (15/30).

Table 8

Summary of Achievement Gap at Elementary School

			Poor	Critical
HS	All Grades Mathematics	Achievement gap between African American and Hispanic	7.727273	7.875
HS	All Grades Mathematics	Achievement gap between African American and White	16.25	16.6
HS	All Grades Mathematics	Achievement gap between African American and Asian	19.875	24.6
HS	All Grades Mathematics	Achievement gap between Hispanic and White	10.625	12
HS	All Grades Mathematics	Achievement gap between White and Asian	20.75	23.6
HS	All Grades Mathematics	Achievement gap between Hispanic and Asian	13.125	12.8

In high schools the achievement gap in mathematics was smaller in the schools of higher quality 83% of the time (5/6).

Empirical Results

Logarithmic transformation is a useful technique for transforming a highly skewed variable into a more normalized dataset. Logarithmic transformation was applied to academic scores, facility condition index and average income to reshape the distribution of these features into a form that more closely resembles a normal distribution.

The coefficient of log facility condition index is the elasticity of the racial group, African American, Hispanic, White, and Asian, with respect to facility condition index. It explains the change in the test scores related to a change in facility condition index by 1%.

Table 9

Descriptive Statistics for Elementary Schools

Variable	Obs	Mean	Std. dev.	Min	Max
Racial groups test scores					
African American	51	76.35294	8.96398	58	100
Hispanic	51	76.41176	9.19386	57	96
White	38	76.89474	11.29168	45	100
Asian	39	87.10256	8.04852	67	100
Log of racial groups test scores					
log of African American	51	4.328819	0.114836	4.060443	4.60517
log of Hispanic	51	4.328757	0.124061	4.043051	4.564348
log of White	38	4.330795	0.1594367	3.806662	4.60517
log of Asian	39	4.46275	0.0954136	4.204693	4.60517
Academic gaps					
Achievement gap between African American and Hispanic	51	0.0970579	0.0720039	0	0.3029495
Achievement gap between African American and White	38	0.1329753	0.1008168	0.0219789	0.5108256
Achievement gap between African American and Asian	39	0.1522172	0.0882437	0	0.3285041
Achievement gap between Hispanic and White	38	0.108266	0.1058567	0	0.5500463
Achievement gap between White and Asian	39	0.1509696	0.1160084	0	0.3997994
Achievement gap between Hispanic and Asian	34	0.1646377	0.1632658	0	0.6931472
Facility Condition Index	51	32.98039	16.19443	0	58
Average Income	51	120254.9	38508.53	12764	175816

There were 51 elementary schools included in the elementary analysis, seen in Table 9. African American and Hispanic students were represented at all campuses. White students were represented at 38 campuses and Asian students were represented at 39 campuses.

Table 10

Descriptive Statistics for Middle Schools

Variable	Obs	Mean	Std. dev.	Min	Max
Racial groups test scores					
African American	15	66.73333	6.584252	56	78
Hispanic	15	63.6	8.982523	50	77
White	15	69.8	10.48264	45	82
Asian	14	81.35714	12.83389	40	93
Log of racial groups test scores					
log of African American	15	4.196236	0.0974835	4.025352	4.356709
log of Hispanic	15	4.143244	0.1419609	3.912023	4.343805
log of White	15	4.23331	0.1692781	3.806662	4.406719
log of Asian	14	4.382241	0.2076192	3.688879	4.532599
Academic gaps					
Achievement gap between African American and Hispanic	15	0.081399	0.0614435	0	0.2311117
Academic gap between African American and White	15	0.09879	0.0888131	0	0.3364722
Achievement gap between African American and Asian	14	0.2302796	0.0862984	0.0892311	0.3429448
Achievement gap between Hispanic and White	15	0.1171815	0.087785	0	0.266268
Achievement gap between White and Asian	14	0.2720423	0.1141289	0.1221027	0.4605249
Achievement gap between Hispanic and Asian	14	0.175493	0.1124183	0.0372714	0.5108256
Facility Condition Index	15	28.2	10.21344	0	40
Average Income	15	132257.3	34677.25	69707	175816

There were 15 middle schools included in the middle school analysis as seen in Table 10. African American, Hispanic, and White students were represented at all campuses. Asian students were represented at 14 campuses.

Table 11

Descriptive Statistics for High Schools

Variable	Obs	Mean	Std. dev.	Min	Max
Racial groups test scores					
African American	11	55.09091	18.60352	36	100
Hispanic	11	53.18182	13.12873	37	74
White	8	63.375	17.40228	33	89
Asian	8	76.5	9.928314	61	93
Log of racial groups test scores					
log of African American	11	3.963754	0.3067925	3.583519	4.60517
log of Hispanic	11	3.946505	0.2437049	3.610918	4.304065
log of White	8	4.110892	0.3082892	3.496508	4.488636
log of Asian	8	4.329883	0.1304494	4.110874	4.532599
Academic gaps					
Achievement gap between African American and Hispanic	11	0.1364187	0.1126372	0.0152675	0.3398678
Achievement gap between African American and White	8	0.2809118	0.1825618	0.0303053	0.5810299
Achievement gap between African American and Asian	8	0.3095929	0.1890949	0.0333364	0.556288
Achievement gap between Hispanic and White	8	0.1896723	0.1498035	0.0150379	0.4855078
Achievement gap between White and Asian	8	0.3338056	0.1376547	0.1410786	0.5306283
Achievement gap between Hispanic and Asian	8	0.218991	0.2155034	0.0439631	0.6143663
Facility Condition Index	11	36.45455	10.27972	17	59
Average Income	11	116223	45933.79	12764	175816

There were 11 high schools included in the analysis as seen in Table 11. African American and Hispanic students were represented at all campuses. White and Asian students were represented at 8 campuses.

Analysis of Scores

Four linear regression models were estimated using Ordinary Least Squares (OLS) to analyze the achievement scores of students across different racial groups as seen in Tables 12-14. These models incorporate interaction terms to investigate whether the combined effect of two independent variables on student scores deviates from a simple additive relationship.

In Tables 12-14, the dependent variable is test score by ethnic group. In reg1, a linear regression analysis was performed where log of facility condition index is the independent variable. In reg2, log of average income is introduced as a control variable to check the robustness of the model. Control variables are used to establish a correlational or causal relationship between the variables of interest and helps to avoid research bias. In reg3, log of facility condition index x middle school test scores, log of facility condition index x elementary school test scores, and log of facility condition index x high school test scores are the independent variables. In reg4, log of average income is used as a control variable. The interaction terms in the regression model were created by multiplying the log of facility condition index and test scores by type, elementary, middle, and high, together. Interaction terms allow for determination of whether the relationship between the dependent and the independent variable changes depending on the value of another independent variable.

In reg1 and reg2, the average aggregate test score across all schools in the study is analyzed. In reg3 and reg4 the types of school are disaggregated to determine the impact on the different types of schools.

Table 12

Analysis of African American Test Scores

	reg1		reg2		reg3		reg4	
	b	se	b	se	b	se	b	se
log of FCI	-0.011	0.036	-0.006	0.036				
log of average income			0.075	0.05			0.059	0.038
log of FCI x middle school test scores					-0.028	0.031	-0.026	0.03
log of FCI x elementary school test scores					0.011	0.028	0.015	0.028
log of FCI x high school test scores					-0.093***	0.03	-0.087***	0.03
_cons	4.290***	0.126	3.398***	0.604	4.295***	0.096	3.595***	0.462
N	73		73		73		73	
r2	0.001		0.033		0.44		0.459	

*, **, *** denote statistical significance at 10%, 5%, and 1%.

In Table 12, the coefficients of reg1 and reg2 are negative as expected however they are not statistically significant. The variable log of facility condition index x high school test scores appears to be a significant predictor in both reg3 and reg4 models, while log of facility condition index and log of average income do not appear to be significant in any models. The findings indicate that quality of building is important in high schools for African American students.

Table 13

Analysis of Hispanic Test Scores

	reg1		reg2		reg3		reg4	
	b	se	b	se	b	se	b	se
log of FCI	-0.035	0.037	-0.031	0.037				
log of average income			0.053	0.051			0.04	0.038
log of FCI x middle school test scores					-0.065**	0.03	-0.063**	0.03
log of FCI x elementary school test scores					-0.012	0.027	-0.01	0.027
log of FCI x high school test scores					-0.120***	0.029	-0.116***	0.029
_cons	4.358***	0.128	3.722***	0.62	4.371***	0.094	3.893***	0.455
N	73		73		73		73	
r2	0.013		0.028		0.489		0.497	

*, **, *** denote statistical significance at 10%, 5%, and 1%.

In Table 13, the coefficients of reg1 and reg2 are negative as expected however they are not statistically significant. The variables log of facility condition index x middle school test scores and log of facility condition index x high school test scores consistently shows a significant negative relationship with the dependent variable in both reg3 and reg4. The explanatory power of the models, as indicated by r2, is significantly higher for reg3 and reg4 compared to reg1 and reg2, which could suggest that the variables included in the latter two models have a stronger association with the dependent variable. The findings indicate that quality of building is important in high schools and middle schools for Hispanic students.

Table 14

Analysis of White Test Scores

	reg1		reg2		reg3		reg4	
	b	se	b	se	b	se	b	se
log of FCI	0.065*	0.037	0.065*	0.037				
log of average income			0.067	0.053			0.041	0.05
log of FCI x middle school test scores					0.056	0.037	0.055	0.037
log of FCI x elementary school test scores					0.085**	0.035	0.084**	0.035
log of FCI x high school test scores					0.017	0.038	0.019	0.038
_cons	4.058***	0.127	3.274***	0.639	4.051***	0.117	3.565***	0.599
N	57		57		57		57	
r2	0.052		0.079		0.229		0.239	

*, **, *** denote statistical significance at 10%, 5%, and 1%.

In Table 14, log of facility condition index is significantly significant but positive in reg1 and reg2. log of facility condition index x elementary school test scores is statistically significant but positive in the last two models. The findings indicate that quality of building is not important for White students.

Table 15

Analysis of Asian Test Scores

	reg1		reg2		reg3		reg4	
	b	se	b	se	b	se	b	se
log of FCI	0.002	0.027	0.003	0.026	-0.01	0.028		
log of average income			0.067*	0.037			0.061*	0.036
log of FCI x middle school test scores					0.022*	0.013	0.012	0.025
log of FCI x elementary school test scores					-0.017	0.018	-0.023	0.028
log of FCI x high school test scores					0	-	-0.011	0.028
_cons	4.421***	0.092	3.632***	0.447	4.423***	0.087	3.709***	0.43
N	57		57		57		57	
r2	0		0.057		0.13		0.176	

*, **, *** denote statistical significance at 10%, 5%, and 1%.

In Table 15, several variables were statistically significant but positive including log of facility condition index in reg2, log of facility condition index x middle school test scores in reg3, and log of average income in reg4. The findings indicate that quality of building is not important for Asian students.

Dispersion Measures

In Tables12-15 the impact of facility condition index across different types of schools was observed. In Tables 16-21 the data is disaggregated to determine if facility condition index has an impact on the achievement gaps across the different types of school. A negative coefficient means that the gap is closing with a decrease in facility condition index. In Table 16 the regression results for six different models are presented. Each model represents a different model of the impact of facility condition index on achievement gaps. A linear regression analysis is performed using academic gap as the dependent variable. In this model, the regression model includes a constant term (_cons).

Table 16

FCI and Achievement Dispersion by School Type

	Achievement gap between African American and		Achievement gap between African American and White		Achievement gap between African American and Asian		Achievement gap between Hispanic and White		Achievement gap between Hispanic and Asian		Achievement gap between White and Asian	
	b	se	b	se	b	se	b	se	b	se	b	se
log of FCI x middle school test scores	0.015	0.016	-0.045*	0.023	0.038*	0.023	-0.055**	0.022	0.064**	0.025	-0.062*	0.033
log of FCI x elementary school test scores	0.02	0.014	-0.037*	0.022	0.015	0.021	-0.059***	0.02	0.031	0.023	-0.064**	0.031
log of FCI x high school test scores	0.031**	0.015	0.007	0.023	0.059**	0.023	-0.032	0.022	0.080***	0.025	-0.046	0.033
_cons	0.029	0.049	0.255***	0.072	0.103	0.07	0.302***	0.067	0.052	0.078	0.382***	0.104
N	73		57		57		57		57		52	
r2	0.077		0.24		0.245		0.187		0.288		0.092	

*, **, *** denote statistical significance at 10%, 5%, and 1%.

The achievement gap between African American and Hispanic students increased in high school. The achievement gap between African American and White students decreased in elementary school and middle school. The achievement gap between African American and Asian students increased in middle school and high school. The achievement gap between Hispanic and White students decreased in elementary school and middle school. The achievement gap between Hispanic and Asian students increased in middle school and high school. The achievement gap between White and Asian students decreased in elementary school and middle school. In general, it was observed that different factors had varying levels of significance across different models, which might suggest that the impact of these factors on facility condition index and achievement dispersion is conditional upon the type of school.

In Table 17, the regression results for six different models are presented with log of average income used as a control variable. Each model represents a different model of the impact of facility condition index on achievement gaps. In this model, the regression model does not include a constant term.

Table 17

FCI and Achievement Dispersion by School Type Without Constant Terms

	Achievement gap between African American and Hispanic		Achievement gap between African American and White		Achievement gap between African American and Asian		Achievement gap between Hispanic and White		Achievement gap between Hispanic and Asian		Achievement gap between White and Asian	
	b	se	b	se	b	se	b	se	b	se	b	se
log of FCI x middle school test scores	0.019	0.015	-0.038	0.023	0.045*	0.023	-0.042*	0.022	0.067***	0.025	-0.058*	se
log of FCI x elementary school test scores	0.023*	0.014	-0.031	0.022	0.021	0.021	-0.047**	0.021	0.034	0.023	-0.061*	0.033
log of FCI x high school test scores	0.034**	0.015	0.014	0.023	0.066***	0.022	-0.019	0.022	0.083***	0.025	-0.04	0.031
log of average income	0.001	0.004	0.020***	0.006	0.007	0.006	0.022***	0.006	0.004	0.007	0.031***	0.033
N	73		57		57		57		57		52	0.009
r2	0.648		0.674		0.784		0.598		0.776		0.597	

*, **, *** denote statistical significance at 10%, 5%, and 1%.

In all models, log of average income is consistently significant and positive in the gap between African American and White, the gap between Hispanic and White, and the gap between Hispanic and Asian models, indicating a strong relationship with the dependent variable in these contexts. Log of facility condition index x high school test scores shows a significant positive effect in the gap between the gap between African American and Asian and gap between Hispanic and Asian models. Interestingly, the impact at elementary schools and middle schools have both positive and negative associations in different models, suggesting their effect might vary depending on the school type or specific context. The impact on the achievement gap between Hispanic and White and the achievement gap between White and Asian is consistent in Table 16 and Table 17.

Skewness-Kurtosis Test

Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point. Positive skew indicates a distribution with an asymmetric tail extending towards more positive values. Negative skew indicates a tail that extends towards more negative values. In other words, skewness shows the amount and direction of skew, the departure from horizontal symmetry. The skewness value can be positive or negative, or even undefined. If skewness is 0, the data are perfectly symmetrical, although it is quite unlikely for real-world data. As a general rule of thumb:

- If skewness is less than -1 or greater than 1, the distribution is highly skewed.
- If skewness is between -1 and -0.5 or between 0.5 and 1, the distribution is moderately skewed.
- If skewness is between -0.5 and 0.5, the distribution is approximately symmetric.

Because actual datasets are rarely evenly distributed, a test of skew helps developers create better, more accurate models. Skewness disregards model assumptions or lowers the importance of a dataset feature.

Kurtosis is a measure of whether the data are heavy-tailed or light-tailed relative to a normal distribution. That is, data sets with high kurtosis tend to have heavy tails, or outliers. Data sets with low kurtosis tend to have light tails, or lack of outliers. A uniform distribution would be the extreme case.

These tests help to understand which variables might require transformations or different analytical approaches that do not assume normality, particularly useful in advanced modeling and hypothesis testing. Low p-values ($p < 0.05$) indicate that the distribution is not normal.

In Table 18. the results for the Skewness-Kurtosis Test are presented.

Table 18

Skewness-Kurtosis Test

				Joint test	
Variable	Obs	Pr(skewness)	Pr(kurtosis)	Adj chi2(2)	Prob>chi2
laa	76	0.9332	0.6621	0.2	0.9058
lhis	76	0.6569	0.4333	0.83	0.66
lwh	61	0.019	0.1555	6.84	0.0326
las	61	0.1028	0.4041	3.52	0.1719
gaahis	76	0.0007	0.4855	10.06	0.0065
gaawh	61	0.0381	0.9192	4.4	0.1108
gaaas	61	0.804	0.3308	1.04	0.5941
ghiswh	61	0.0311	0.4081	5.19	0.0745
ghisas	61	0.46	0.5349	0.96	0.6184
gwhas	59	0	0.0025	19.59	0.0001
stdev_o	76	0	0.0012	23.9	0
stdev_g	63	0.0061	0.1681	8.24	0.0163
mad	76	0	0.0013	23.52	0
mape	76	0	0.0008	24.75	0

Table 18 shows that the scores of African American and Hispanic students and the gap between African American and Asian students are highly skewed. The Kurtosis test shows that the gap between White and Asian students is the only variable with a low p-value indicating that the distribution is not normal.

Bootstrapping

Bootstrapping is a statistical procedure that resamples a single dataset to create many simulated samples. After the method was first introduced to statistical sciences in 1979 and computer technologies were updated, the procedure became widespread because it provides methodological reasoning for inferential statistics (Choi, 2016). This process allows one to calculate standard errors, construct confidence intervals, and perform hypothesis testing for numerous types of sample statistics. Bootstrap methods are alternative approaches to traditional hypothesis testing and are notable for being easier to understand and valid for more conditions. Bootstrapping uses samples to draw inferences about populations. To accomplish this goal, the procedure treats the single sample that a study obtains as only one of many random samples that the study could have collected.

Table19 presents results from a linear regression analysis using academic gap as the dependent variable and log of facility condition index x elementary school test scores, log of facility condition index x middle school test scores, log of facility condition index x high school test scores, and log of average income (control) as independent variables using bootstrapped standard errors.

Table 19

FCI and Achievement Dispersion by School Type Using Bootstrapped Standard Errors with Lavinc

	Achievement gap between African American and Hispanic		Achievement gap between African American and White		Achievement gap between African American and Asian		Achievement gap between Hispanic and White		Achievement gap between Hispanic and Asian		Achievement gap between White and Asian	
	b	se	b	se	b	se	b	se	b	se	b	se
log of FCI x middle school test scores	0.015	0.012	-0.044	0.037	0.039***	0.015	-0.054	0.033	0.065***	0.019	-0.061	0.054
log of FCI x elementary school test scores	0.019	0.012	-0.037	0.034	0.015	0.014	-0.058*	0.031	0.031*	0.017	-0.064	0.048
log of FCI x high school test scores	0.029*	0.017	0.006	0.037	0.057***	0.022	-0.036	0.034	0.079***	0.022	-0.046	0.055
log of average income	-0.021	0.023	-0.029	0.045	-0.040**	0.02	-0.073*	0.043	-0.019	0.041	-0.003	0.094
_cons	0.274	0.275	0.599	0.545	0.570**	0.238	1.153**	0.516	0.27	0.484	0.413	1.113
N	73		57		57		57		57		52	
r2	0.092		0.253		0.272		0.284		0.292		0.092	

*, **, *** denote statistical significance at 10%, 5%, and 1%.

In Table 19, the only significant relationship as a result of bootstrapping was the reduction of the achievement gap between Hispanic and White students.

Quantile regression is used to analyze the conditional quantiles of the dependent variable, such as the median or other percentiles, rather than the mean. Quantiles are points in a dataset that divide the data into intervals with equal probabilities. They are used as a tool to understand the dispersion or spread of the data. Table 20 presents the results of a model where various quantiles (q10, q30, q50, q70, q90) are being used as dependent variables for different regression models.

Table 20

FCI and Achievement Dispersion by School Type Using Quantile Regression

	Achievement gap between African American and Hispanic		Achievement gap between African American and White		Achievement gap between African American and Asian		Achievement gap between Hispanic and White		Achievement gap between Hispanic and Asian		Achievement gap between White and Asian	
	b	se	b	se	b	se	b	se	b	se	b	se
q10												
log of FCI x middle school test scores	0	0.017	-0.003	0.013	0.032	0.023	-0.049*	0.026	0.044***	0.011	0.016	0.033
log of FCI x elementary school test scores	0.006	0.014	0.005	0.013	0.005	0.018	-0.044*	0.024	0.009	0.011	-0.005	0.035
log of FCI x high school test scores	0.007	0.015	0.002	0.028	0.003	0.04	-0.046*	0.025	0.044*	0.023	0.005	0.032
_cons	0	0.051	0.022	0.045	0.022	0.063	0.169*	0.085	-0.006	0.038	0.028	0.116
q30												
log of FCI x middle school test scores	0.006	0.005	-0.006	0.016	0.052*	0.026	-0.037**	0.018	0.027*	0.016	-0.019	0.032
log of FCI x elementary school test scores	0.006	0.006	-0.003	0.017	0.026	0.023	-0.036***	0.01	0.001	0.014	-0.025	0.034
log of FCI x high school test scores	0.012	0.011	0.04	0.037	0.044	0.041	-0.019	0.015	0.056**	0.026	-0.023	0.038
_cons	0.021	0.017	0.071	0.054	0.007	0.084	0.171***	0.037	0.071	0.048	0.167	0.115
q50												
log of FCI x middle school test scores	0.01	0.02	-0.008	0.058	0.015	0.016	-0.017	0.036	0.06	0.05	-0.019	0.03
log of FCI x elementary school test scores	0.02	0.023	-0.004	0.056	-0.001	0.019	-0.026	0.032	0.021	0.052	-0.03	0.025
log of FCI x high school test scores	0.027	0.023	0.032	0.077	0.058*	0.029	-0.003	0.035	0.093**	0.04	-0.038	0.031
_cons	0.025	0.076	0.127	0.202	0.149**	0.066	0.168	0.116	0.057	0.161	0.238**	0.098
q70												
log of FCI x middle school test scores	0.022***	0.008	-0.093	0.064	0.052***	0.018	-0.057	0.063	0.087**	0.033	-0.083	0.074
log of FCI x elementary school test scores	0.032***	0.008	-0.07	0.065	0.018	0.019	-0.064	0.058	0.056*	0.029	-0.084	0.066
log of FCI x high school test scores	0.036**	0.018	-0.022	0.085	0.072***	0.026	-0.029	0.065	0.102***	0.021	-0.05	0.082
_cons	0.023	0.027	0.423*	0.236	0.136***	0.047	0.339	0.207	0.032	0.099	0.481*	0.245
q90												
log of FCI x middle school test scores	0.035	0.051	-0.096	0.074	0.062	0.05	-0.111	0.079	0.075	0.06	-0.158	0.206
log of FCI x elementary school test scores	0.042	0.045	-0.104	0.07	0.042	0.048	-0.126*	0.075	0.041	0.05	-0.129	0.169
log of FCI x high school test scores	0.069	0.049	-0.001	0.08	0.115**	0.045	-0.043	0.09	0.094	0.057	-0.047	0.183
_cons	0.048	0.171	0.583**	0.262	0.142	0.165	0.637**	0.26	0.197	0.202	0.771	0.631
N	73		57		57		57		57		52	

*, **, *** denote statistical significance at 10%, 5%, and 1%.

In Table 20, once again a correlation is observed between facility condition index and closing the gap between Hispanic and White students specifically in q10, q30, and q90. The q70 quantile provides significant predictors across multiple models, suggesting it might be an influential quantile in the relationship being studied.

Table 21 presents results from the quantile regression using log of average income as a control variable.

Table 21:

FCI and Achievement Dispersion by School Type Using Quantile Regression with Lavinc

	Achievement gap between African American and Hispanic		Achievement gap between African American and White		Achievement gap between African American and Asian		Achievement gap between Hispanic and White		Achievement gap between Hispanic and Asian		Achievement gap between White and Asian	
	b	se	b	se	b	se	b	se	b	se	b	se
q10												
log of FCI x middle school test scores	0.004	0.012	-0.006	0.011	0.046	0.042	-0.015	0.042	0.045***	0.015	0.037	0.051
log of FCI x elementary school test scores	0.007	0.012	0.005	0.011	0.016	0.04	-0.014	0.038	0.005	0.013	0.017	0.048
log of FCI x high school test scores	0.011	0.011	0.001	0.021	0.013	0.042	-0.014	0.044	0.043***	0.016	0.032	0.051
log of average income	-0.048***	0.015	-0.022	0.03	-0.069*	0.037	-0.041	0.044	-0.019	0.042	0.009	0.063
_cons	0.551***	0.166	0.286	0.355	0.799	0.5	0.545	0.521	0.22	0.48	-0.151	0.712
q30												
log of FCI x middle school test scores	0.006	0.007	-0.006	0.015	0.054*	0.031	-0.038	0.035	0.027*	0.015	-0.02	0.03
log of FCI x elementary school test scores	0.006	0.006	-0.004	0.013	0.02	0.029	-0.039	0.033	0.003	0.017	-0.027	0.026
log of FCI x high school test scores	0.013	0.01	0.041	0.029	0.043	0.03	-0.018	0.041	0.056*	0.03	-0.024	0.041
log of average income	-0.031**	0.014	-0.016	0.049	-0.083	0.067	-0.031	0.054	0.005	0.063	0.016	0.064
_cons	0.387**	0.169	0.268	0.563	0.987	0.826	0.546	0.626	0.005	0.748	-0.024	0.784
q50												
log of FCI x middle school test scores	0.012	0.012	-0.009	0.048	0.016	0.022	-0.03	0.044	0.053***	0.019	-0.018	0.069
log of FCI x elementary school test scores	0.015	0.01	-0.001	0.043	-0.001	0.022	-0.025	0.042	0.012	0.024	-0.03	0.063
log of FCI x high school test scores	0.018	0.013	0.033	0.049	0.031	0.037	-0.002	0.047	0.084***	0.023	-0.037	0.076
log of average income	-0.058*	0.029	-0.043	0.043	-0.054	0.049	-0.108**	0.045	-0.07	0.086	-0.019	0.123
_cons	0.700**	0.348	0.636	0.478	0.795	0.589	1.442**	0.597	0.89	1.012	0.468	1.513
q70												
log of FCI x middle school test scores	0.014	0.011	-0.083	0.071	0.051***	0.017	-0.014	0.062	0.082***	0.023	-0.06	0.112
log of FCI x elementary school test scores	0.021*	0.012	-0.062	0.065	0.014	0.015	-0.024	0.058	0.054**	0.022	-0.062	0.101
log of FCI x high school test scores	0.024	0.018	-0.034	0.072	0.059*	0.03	0.007	0.062	0.097***	0.024	-0.032	0.114
log of average income	-0.02	0.022	-0.031	0.129	-0.036	0.052	-0.111***	0.039	-0.062	0.076	0.007	0.17
_cons	0.296	0.247	0.761	1.424	0.57	0.615	1.508***	0.522	0.77	0.901	0.327	1.948
q90												
log of FCI x middle school test scores	0.032	0.064	-0.086	0.065	0.062	0.038	-0.105	0.067	0.066	0.064	-0.136	0.183
log of FCI x elementary school test scores	0.033	0.054	-0.094	0.07	0.041	0.037	-0.123*	0.062	0.031	0.063	-0.108	0.183
log of FCI x high school test scores	0.068	0.058	0.001	0.073	0.115**	0.044	-0.092	0.066	0.061	0.069	-0.043	0.193
log of average income	-0.016	0.031	-0.125	0.126	-0.005	0.061	-0.081*	0.044	-0.035	0.067	-0.153	0.21
_cons	0.245	0.317	2.032	1.38	0.199	0.715	1.582**	0.633	0.647	0.839	2.539	2.485
N	73		57		57		57		57		52	

*, **, *** denote statistical significance at 10%, 5%, and 1%.

In q50, q70, and q90, a significant reduction of the achievement gap between Hispanic and White students is observed.

Summary

This chapter described the statistical analysis procedures used in this study, the results of the findings, and an analysis of those findings. Sections of this chapter included: (a) presentation of the data, including descriptive statistics for the study variables and (b) data analysis using multiple regression analyses. The interpretations from the statistical results of this study are discussed in Chapter V.

CHAPTER V

DISCUSSION, SUMMARY AND CONCLUSIONS

Introduction

The purpose of this study was to examine the impact that school facility conditions had on closing the academic achievement gap in mathematics. The following research question guided this study: How can an investment strategy that focuses on improving the quality of school facilities lead to a reduction in the mathematics achievement gap in the United States? The study was conducted with data from elementary, middle, and high school students in Fort Bend ISD. The variables used in the study were Facility condition index, the results of the STAAR test, racial sub-groups, and average income. This chapter examines the findings, offers a discussion of the findings, and a conclusion based on those findings. This chapter concludes with some recommendations for further study.

The study was noteworthy and contributed to the existing knowledge and understanding of the topic, because, at the time, there have been few published theory-driven, data-based studies in the last five to seven years that identified improving the condition of facilities as a strategy to close the academic achievement gap in mathematics. Existing data were used. The findings support the use of improving the condition of facilities as a strategy to close the academic achievement gap in mathematics.

Summary of Results

The tests results of elementary, middle, and high school students in Fort Bend ISD who participated in the State of Texas Assessments of Academic Readiness (STAAR) exam in school year 2021-2022 were used to examine the relationship between school building condition and student achievement. The students represented 51 elementary schools, 15 middle schools, and 11 high schools. The theoretical model derived from Bishop and Wossman (2004) was also used in the study. This study addressed the impact of facility condition on the achievement gap in mathematics. The building condition (FCI) was calculated by a team consisting of architects, engineers, and industry professionals in 2021. The student population was sub-divided by race as defined by the TEA. The academic gap studied was the difference in the average score of the students in one sub-group compared to another sub-group. Average income data was obtained from the internet at the Income by Zip Code website.

All school buildings in Fort Bend ISD were used in this study. The school buildings were assigned to a category that consisted of good, fair, poor, or critical, based on the FCI score. The academic gap between the two sub-groups of lower quality facilities was compared to the academic gap of higher quality facilities. This study focused on the mathematics score on the STAAR exam.

Conclusions

Four linear regression models were estimated using Ordinary Least Squares (OLS) to analyze the achievement scores of students across different racial groups. The study found the impact of facility condition index on racial groups across different types of schools. The findings indicated that quality of building was important in high schools for African American students and the quality of building was important in high schools and middle schools for Hispanic students. The results also indicated that the quality of building is not important for White or Asian students.

Next, the data was disaggregated to determine whether facility condition index had an impact on the achievement gaps across the different types of school. The regression results for six different models representing the academic gap between sub-groups, were analyzed. The impact on the achievement gap between Hispanic and White and the achievement gap between White and Asian were consistent. The results showed that different factors had varying levels of significance across different models, which might suggest that the impact of these factors on facility condition index and achievement dispersion was conditional upon the type of school.

A test for Skewness revealed that the scores of African American and Hispanic students, and the gap between African American and Asian students were highly skewed. The Kurtosis test showed that the gap between White and Asian students was the only variable with a low p-value indicating that the distribution is not normal.

Bootstrapping was used to resample the dataset. Bootstrapping identified a significant relationship in the reduction of the achievement gap between African American and Asian students. There was also a reduction of the achievement gap between Hispanic and Asian students.

Quantile regression was employed to analyze the conditional quantiles of the Facility Condition Index (FCI). Various quantiles (q10, q30, q50, q70, q90) were used as dependent variables in different regression models to investigate whether there was a correlation between the condition of school facilities and the achievement gap across various student groups. The analysis revealed a correlation between the FCI and the closing of the achievement gap between African American and Asian students at the q30, q50, q70, and q90 quantiles. Similarly, a correlation was observed between Hispanic and Asian students at the q10, q30, q50, and q70 quantiles. Notably, the q70 quantile emerged as a significant predictor across multiple models, suggesting that it may be a particularly influential quantile in understanding the relationship between facility conditions and educational outcomes among different racial groups. This finding underscores the importance of considering facility quality in efforts to close educational achievement gaps.

Discussion

Multiple statistical analyses were conducted in this study. The first analysis conducted was OLS. One of the assumptions that must hold in order for the OLS estimation method to be reliable is a normal distribution of the dependent variable. Within the data set, I cannot assume that the dependent variable is normally distributed. To validate that the dependent variable is normally distributed, the bootstrapping method was utilized. Bootstrapping leads to a more robust standard error. The skewness test identified that most of the dependent variables were not normally distributed. Quantile regression does not need the assumption that the dependent variable is normally distributed. Some of the results were confirmed from OLS and quantile regression which suggests a stable relationship across quantiles.

The initial OLS results aligned with previous studies that showed Asian and White students score higher than African American and Hispanic students on standardized tests. Further tests found that as the quality of building improved, the gap between Hispanic students and Asian students was reduced. This research concludes that improvements in school facilities can lead to a reduction in the mathematics achievement gap.

Recommendations for Further Research

The following recommendations for further studies are offered.

1. Conduct a study of school districts of varying size to determine how small districts to compare large ones.

2. Conduct a study where female students are compared to male students to see if the condition of the building impacts students of different sexes differently.

3. Conduct a study to see which component of FCI has the greatest impact on closing the student achievement gap. Results could help decision makers prioritize repairs.

4. Conduct a study to see if the results are replicated across other subjects. While math was the focus in this study, the results for Science or English could be different.

5. Conduct a study utilizing private schools and charter schools' data to see if the condition of school facilities impacts them in the same way as in this public-school study.

6. Conduct this study in school districts that have concentrated demographics such as race, socioeconomic background, average income.

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Nov. 2018	K12 Facilities Forum

PUBLICATIONS

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