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Influence of High-Speed Internet Infrastructure Availability on Aggregate Academic Outcome Measures for Washington State High Schools

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This is to certify that the doctoral dissertation by

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2025

Abstract

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by

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MS, Southern New Hampshire University, 2020

BS, University of Phoenix, 2015

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

P-20 Education Self-Designed

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Abstract

Limited research has been conducted about the potential influence of high-speed broadband infrastructure availability in rural and urban communities on high school academic outcome measures in Washington state. Guided by Siemens's theory of connectivism and van Dijk's digital divide theory, the purpose of this quasi-experimental, causal-comparative, quantitative study was to determine whether significant differences in high school academic performance, measured by graduation rates and standardized test scores, exist between urban and rural communities with and without access to high-speed broadband internet infrastructure in Washington state. Three research questions were developed to examine differences in graduation rates, 10th-grade English Language Arts and Mathematics scores, and 11th-grade science scores across rural and urban schools with and without broadband availability. Publicly available school-level data from the 2022–2023 academic year were analyzed using separate one-way ANOVAs. The sample included 374 schools for graduation rates, 437 for ELA, 358 for Math, and 421 for science scores. Statistically significant differences in graduation rates were found based on broadband availability ($p = .006$), locale ($p = .041$), and their interaction ($p = .015$), with rural schools and those with broadband access showing higher graduation rates. No significant differences were found for standardized test scores. These results suggest broadband infrastructure may be more closely linked to graduation outcomes than test performance in the state of Washington. Implications for positive social change include informing state-level broadband expansion efforts to improve graduation outcomes, especially in underserved communities, and giving these students better opportunities.

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Dedication

To my loving husband, whose unwavering support and encouragement have been my anchor throughout this journey. Your belief in me, even in my most challenging moments, has been my greatest strength.

To my amazing daughters, whose patience and understanding have been a source of inspiration. Your smiles and love have been the light that guided me through this endeavor.

To my incredible mother, whose wisdom, love, and steadfast belief in me have been a constant source of motivation. Your sacrifices and guidance have shaped who I am and made this achievement possible.

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Chapter 1: Introduction to the Study

Introduction

In the rural Pacific Northwest, as in many rural areas across the United States, high school students face significant challenges related to the availability of broadband infrastructure. This issue is not merely one of convenience; it has profound implications for educational equity and the quality of learning opportunities available to these students. This system of broadband "haves and have-nots," or digital divide, places rural students at a distinct disadvantage, affecting their ability to complete homework and their capacity to acquire the digital literacy skills necessary for success in the 21st-century economy (Hampton et al., 2020). High school students in the rural Pacific Northwest face significant challenges due to limited broadband, which impacts educational equity and learning quality. According to a report from the Washington Student Achievement Council, approximately 17% of K-12 students and 14% of postsecondary students did not have access to high-speed internet at home, and roughly 6% of K-12 students did not have a computer at home (Kwakye et al., 2021).

Despite improvements, nearly 10% of rural households in the U.S. still lack broadband (Center for Public Education, 2023). Researchers have suggested that broadband is crucial for digital literacy, which is essential for equitable participation in education and other life aspects (Arsen et al., 2022; Demir Kaymak & Horzum, 2022; Hampton et al., 2020, 2021, 2023; McCarron & Frydenberg, 2023; Wang & Tahir, 2020). Rural areas often have higher poverty rates and minority populations, with lower broadband adoption among these groups affecting academic outcomes (Center for Public

Education, 2023; Mack et al., 2024; National Center for Education Statistics, 2023; Valentín-Sívico et al., 2023). Research on socioeconomic status and racial effects on internet access is extensive, but more understanding is needed regarding high school academic outcomes in rural areas. Prior studies showed that high-speed internet access improved student achievement (Hampton et al., 2020; Whitacre & Biedny, 2022), and this study aimed to explore these findings in the Pacific Northwest, focusing on location and broadband availability as key factors.

This chapter presents the background of the research on high-speed internet availability and its impact on student success outcomes. It outlines this study's problem and purpose statements, the research questions and associated hypotheses, the theoretical frameworks underpinning this study, and the nature of the study. Additionally, it includes definitions, assumptions, scope and delimitations, limitations, and the potential significance of this study.

Background

Broadband infrastructure, encompassing all components used to provide internet service (Oughton et al., 2023), has historically been inequitably rolled out in the U.S., with rural areas lagging behind urban areas (Hampton et al., 2020, 2021, 2023; Kwakye et al., 2021; National Telecommunications and Information Administration, 1995; Valentín-Sívico et al., 2020, 2022, 2023; van Dijk, 2005, 2020). The dynamics of rural broadband show that while availability refers to infrastructure supply, adoption involves consumer demand, with adoption having a higher impact on economic development (Whitacre & Gallardo, 2022). Rural areas face significant barriers, including fewer

physical cables, cellular towers, and high satellite internet costs (Hampton et al., 2020, 2021, 2023; Kwakye et al., 2021; Valentín-Sívico et al., 2020, 2022, 2023; van Dijk, 2005, 2020).

Broadband, defined as internet with at least 25 Mbps download and 3 Mbps upload speeds (Consumer and Governmental Affairs, 2024), remains limited in many rural areas, leaving them underserved (Valentín-Sívico et al., 2023). This issue is not unique to the U.S.; similar disparities exist globally (Aldashev & Batkeyev, 2021; Cullinan et al., 2021; De Clercq et al., 2023; Grenestam & Nordin, 2018; Mazzuki & Chiwamba, 2024). Historically, infrastructure development has prioritized urban areas, leaving rural areas behind (Aldashev & Batkeyev, 2021; NTIA, 1995). Recent efforts, such as the Consolidated Appropriations Act of 2021, aim to bridge this digital divide, but challenges remain (Rachfal et al., 2021; Valentín-Sívico et al., 2023). Limited broadband availability affects educational equity and learning opportunities, particularly in rural high schools (Caldarulo et al., 2022; Hampton et al., 2020, 2021, 2023).

Researchers use various indicators to measure academic achievement, with qualitative studies focusing on perceptions of effectiveness and quantitative studies evaluating outcomes such as standardized test scores, GPAs, and graduation rates (Arsen et al., 2022; Caldarulo et al., 2022; Cheng & Yang, 2023; Gonzales et al., 2020; Grenestam & Nordin, 2018; Hampton et al., 2020, 2021, 2023; Heilmann et al., 2024; Kwakye et al., 2021; Mazzuki & Chiwamba, 2024; Phutela & Dwivedi, 2020). In Washington State, students are assessed through various standardized tests to ensure they meet grade-appropriate learning outcomes (OSPI, n.d.a; OSPI, n.d.b). High school

academic outcomes often focus on graduation rates and standardized test scores, which are reported to the Department of Education (Heinrich & Darling-Aduana, 2021; OSPI, n.d.b).

Digital literacy skills are crucial for success in the modern world. The National Digital Inclusion Alliance defines digital literacy as the ability to use information and communication technologies effectively (NDIA, n.d.). Researchers have found that students without broadband access lag in digital literacy skills, which are essential for education and the workplace (Arsen et al., 2022; McCarron & Frydenberg, 2023; Reisdorf et al., 2020). Studies show that students who practice digital literacy skills at home perform better than those who do not have such opportunities (Demir Kaymak & Horzum, 2022; Hampton et al., 2020, 2021, 2023; McCarron & Frydenberg, 2023; Wang & Tahir, 2020).

Equity in education and learning opportunities is a significant concern for rural high schools. These schools often face inadequate funding, teacher shortages, and a lack of broadband infrastructure, contributing to educational inequalities (CPE, 2023; Arsen et al., 2022; Bala, 2024; Hampton et al., 2020, 2021, 2023; Mack et al., 2024; Skinner et al., 2024). The National Equity Project emphasizes that educational equity means providing each child with what they need to reach their full potential (National Equity Project, n.d.). Research shows that socioeconomic status, race, gender, and parental education level significantly impact academic outcomes in rural high schools (Hampton et al., 2023; Puente, 2022; Xin et al., 2024). However, few studies have empirically examined the

relationship between community broadband programs and student achievement using community or school-level data (Xin et al., 2024).

The term “rural” lacks a single definition, generally referring to areas with low population and housing density far from metropolitan regions (U.S. Census Bureau, 2020; CPE, 2023). The U.S. Census Bureau and the Office of Management and Budget (OMB) provide common standards, with the Census Bureau using urbanized areas and clusters and the OMB defining metropolitan and micropolitan areas, leaving rural as all other areas (CPE, 2023). In education, the National Center for Education Statistics standards categorize rural areas into rural-fringe, rural-distant, and rural-remote (CPE, 2023).

Interventions to address broadband availability for high school populations vary between rural and urban areas. Providing laptops or tablets has been more successful in urban areas, where students can access free Wi-Fi services more easily (Tomer & George, 2021). Mobile internet devices often fail to connect in rural areas, and rebates or discounted internet programs are ineffective where ISPs are unavailable (Hampton et al., 2020, 2021, 2023; Valentín-Sívico et al., 2023). Community solutions, such as extending hours at community centers, are less effective in rural areas due to distance (CPE, 2023; Valentín-Sívico et al., 2023; Ventimiglia et al., 2024). Rural schools face higher educator shortages and funding challenges due to lower population densities (Aldashev & Batkeyev, 2021; Dunham, 2022; EESI, 2021; Kim & Jang, 2020; Mazzuki & Chiwamba, 2024; Valentín-Sívico et al., 2023).

Understanding the differences between rural and urban communities is crucial for developing effective strategies. Rural communities benefit from the same internet opportunities as urban areas (Gallardo et al., 2020). However, rural teens may experience lower self-esteem due to isolation and lack of internet access (Hampton & Shin, 2023). Rural educators face geographical isolation, a lack of social services, and fewer professional development opportunities (Mazzuki & Chiwamba, 2024). Rural areas also have fewer ISPs and higher poverty rates compared to urban areas (CPE, 2023; Mack et al., 2024; NCES, 2023; Valentín-Sívico et al., 2023; Ventimiglia et al., 2024).

Further research is needed to understand the implications of poor community broadband availability on high school academic outcomes. This gap in research contributes to the lack of empirical information needed to facilitate communication and joint initiatives between educators and federal, state, and local governments and organizations to expand broadband infrastructure to rural communities.

Problem Statement

The specific research problem addressed through this study was that little research has been conducted about the potential influence of high-speed broadband infrastructure availability in rural and urban communities on high school academic outcome measures in Washington state.

Research has extensively explored the links between socioeconomic status, race, gender, and parental education level on rural high school academic outcomes. Puente (2022) used critical race spatial analysis (CRSA) to assess how the pandemic exacerbated rural Latinx students' lack of opportunities due to insufficient internet access, devices,

and school personnel. Hampton et al. (2023) also examined these factors but focused on whether broadband infrastructure availability influenced academic outcomes, controlling for socioeconomic status, race, gender, and parental education level. Xin et al. (2024) noted that while many studies address these demographic factors, few have empirically investigated the impact of community broadband programs on student achievement using community or school-level data.

Existing research on high-speed internet access considered factors like socioeconomic status and race, acknowledging the diverse backgrounds of rural students. Prior studies (Hampton et al., 2020; Whitacre & Biedny, 2022) demonstrated that high-speed internet access improves student achievement, highlighting the need for better internet access in rural areas of the Pacific Northwest. Kwakye et al. (2021) confirmed these regions' lack of high-speed internet. The purpose of this study was to verify if these findings hold true in the Pacific Northwest, focusing on location and home broadband availability as key factors in determining student achievement outcomes. Hampton et al.'s (2020, 2023) research on rural students and internet access served as a foundation for this new investigation.

Purpose of the Study

The purpose of this quantitative study was to determine if significant differences exist in aggregate measures of academic performance in high schools, as measured by graduation rate and standardized test data, for urban and rural communities with and without high-speed broadband internet infrastructure availability in Washington state. The independent variables were the school locale type (rural/urban school locale

classification (R/U)) and the availability of high-speed broadband internet infrastructure within the community (Y/N). The dependent variables are high school graduation rate, grade 10 Smarter Balance assessment score averages (by high school), and grade 11 Washington Comprehensive Assessment of Science score averages (by high school). I analyzed publicly available secondary data, including school-level academic performance records (graduation rates and standardized assessment data) for high schools from the 2022–2023 school year, alongside data on the availability of broadband infrastructure from existing surveys and public databases.

Research Questions and Hypotheses

RQ1: Is there a statistically significant difference in graduation rates for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state?

$H_0$1: There is no statistically significant difference in graduation rates for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state.

$H_1$1: There is a statistically significant difference in graduation rates for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state.

RQ2: Is there a statistically significant difference in 10th-grade standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state?

$H_0$2: There is no statistically significant difference in 10th-grade standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state.

$H_1$2: There is a statistically significant difference in 10th-grade standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state.

RQ3: Is there a statistically significant difference in 11th-grade standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state?

$H_0$3: There is no statistically significant difference in 11th-grade standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state.

$H_1$3: There is a statistically significant difference in 11th-grade standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state.

Theoretical Framework for the Study

The research was grounded in Siemens's (2004) theory of connectivism and van Dijk's (2005) digital divide theory. The term "digital divide" was first introduced in a 1995 NTIA report. These theories emphasize the importance of equal access to technology for continuous growth and learning. Siemens (2004) argued that traditional learning theories like behaviorism, cognitivism, and constructivism are outdated in the digital age. He proposed that the mind should be viewed as a network that adapts to its

environment (Siemens, 2006). Connectivism integrates concepts from the network, chaos, complexity, and self-organization theories, highlighting the importance of diverse opinions, connecting specialized information sources, and maintaining connections for ongoing learning (Bell, 2011; Foroughi, 2015; Siemens, 2004).

Pick and Sarkar (2016) described the digital divide theory as comprising four foundational theories, including van Dijk's theory of digital technology access and societal impacts. Van Dijk (2005) argued that inequalities in technology access persist throughout accessing and using technology. The digital divide theory identifies personal and positional characteristics influencing technology access, such as age, gender, education, and household (van Dijk, 2005). Van Dijk (2020) identified three eras of the digital divide: physical access (1995-2003), skills and usage (2004-present), and outcomes (2012-present). Both theories highlight the need for equal access to technology to facilitate growth and learning. Students in rural areas often lack high-speed internet, limiting their educational opportunities and perpetuating the digital divide throughout their lives (De Clercq et al., 2023). Concepts from both theories will inform the research.

Nature of the Study

This quasi-experimental, causal-comparative study employed a quantitative research design using secondary data to examine the extent to which differences exist in high school graduation rates and standardized test scores based on broadband infrastructure availability and school locale type (rural or urban). Although a two-way MANOVA was originally planned to assess the main effects and potential interactions between the independent variables for all three dependent variables simultaneously, the

assumptions of multivariate normality and homogeneity of variance-covariance matrices were violated in the final dataset when all data points for all variables were accounted for. As a result, the analysis approach was revised to use one-way ANOVAs to evaluate the main and interaction effects for each dependent variable individually, allowing independent, complete samples to be used for each analysis. The independent variables were school locale type (rural/urban classification) and the availability of high-speed broadband internet infrastructure within the community (yes/no). The dependent variables were high school graduation rates, grade 10 Smarter Balanced assessment score averages (ELA and Math), and grade 11 Washington Comprehensive Assessment of Science (WCAS) score averages, aggregated at the school level.

This study was not designed to establish causal relationships but rather to identify and describe the extent of differences between groups. The revised methodology remains aligned with the study's purpose, research questions, and hypotheses by evaluating whether statistically significant differences exist in educational outcomes across rural and urban high schools with and without broadband infrastructure, using publicly available state and federal data.

Definitions

Availability of high-speed broadband internet infrastructure (Y/N): Areas with high school populations where at least 85% of households have broadband service availability are identified as "yes." High school populations with less than 85% coverage will be classified as "no" (see EESI, 2021).

Broadband internet infrastructure: The physical and organizational structures needed to provide high-speed internet access, including fiber-optic cables, coaxial cables, wireless networks, and satellite systems that transmit data at high speeds over long distances. According to the Federal Communications Commission (FCC,2022), broadband is defined as having minimum download speeds of 25 Mbps and minimum upload speeds of 3 Mbps.

Graduation Rate: High school graduation rates are typically defined as the percentage of students who complete their high school education and receive a diploma within a specified period, usually four years (see OSPI, n.d.a).

School Locale Classification: The National Center for Education Statistics (NCES) classifies geographic locations into four main categories: city, suburban, town, and rural. Each category is subdivided based on population size and proximity to larger areas (NCES, 2024b). The NCES Locale framework utilizes urban area criteria defined by the Census Bureau and extends these standard urban and rural classifications to provide additional detail (US Census Bureau, 2023). The NCES classifications and corresponding two-digit locale codes can be determined using the Locale Lookup map tool (NCES, 2024b).

School Locale Type (Rural/Urban): Any school with a school locale classification category of town-distant (32) to rural-remote (43) was classified as rural. All other schools were classified as urban (see NCES, 2024b).

Smarter Balance Assessment: The Washington State Smarter Balanced Assessment is a comprehensive testing system designed to measure student proficiency in

English Language Arts (ELA) and Mathematics. It includes interim assessments administered throughout the year and a summative assessment at the school year's end. The summative assessment consists of a computer-adaptive test and a performance task, providing educators with standards-aligned tools and resources to support teaching and learning (OSPI, 2023b).

Washington Comprehensive Assessment of Science: The Washington Comprehensive Assessment of Science (WCAS) measures the proficiency of Washington students based on the 2013 K-12 Science Learning Standards, which align with the Next Generation Science Standards (NGSS). The WCAS is administered to students in grades 5, 8, and 11 to fulfill the federal Every Student Succeeds Act (ESSA) requirement for science testing at the elementary, middle, and high school levels (OSPI, 2023a).

Assumptions

It was assumed that broadband infrastructure is not uniformly reliable across the Pacific Northwest, with rural areas significantly lagging behind urban regions regarding broadband availability (Hampton et al., 2020; Valentín-Sívico et al., 2023). This disparity in broadband availability was believed to have profound implications for educational equity and the quality of learning opportunities available to high school students in these areas. Rural regions' lack of high-speed internet access was assumed to place students at a distinct disadvantage, affecting their ability to complete homework and develop essential digital literacy skills necessary for success in the 21st-century economy (Hampton et al., 2020; Kwakye et al., 2021).

The existence of a digital divide, characterized by the gap between those with and without access to high-speed internet, was assumed to exacerbate educational inequalities. Students in rural areas are particularly disadvantaged compared to their urban counterparts due to limited broadband availability (Hampton et al., 2020; Valentín-Sívico et al., 2023). Despite recent policy efforts, such as the Consolidated Appropriations Act of 2021, aimed at bridging this digital divide, it was assumed that significant challenges remain in ensuring equitable broadband availability for all students (Rachfal et al., 2021; Valentín-Sívico et al., 2023).

Examining community and school-level data was crucial to understanding the full impact of broadband availability on student achievement. This approach allowed for a comprehensive analysis of how broadband infrastructure influences educational outcomes, particularly in rural high schools (Xin et al., 2024). By addressing these disparities, it was assumed that policymakers and educators could work towards providing equitable learning opportunities for all students, regardless of their geographic location (Hampton et al., 2020; Valentín-Sívico et al., 2023).

Scope and Delimitations

The scope of this quantitative study was to determine if significant differences exist in aggregate measures of academic performance in high schools, specifically graduation rates and standardized test scores, for urban and rural communities with and without high-speed broadband internet infrastructure availability in Washington state. I analyzed school-level data from Washington state high schools, focusing on the 2022-2023 academic year. The research was driven by three quantitative research questions

and their associated hypotheses, examining the main effects and potential interactions between the availability of broadband infrastructure and school locale type (rural or urban) on high school graduation rates and standardized test scores.

This study was geographically focused on high schools in Washington state, which may limit the generalizability of the findings to other states or regions. The research relied on secondary, publicly available data from the 2022–2023 school year, including academic performance records and broadband access data. The accuracy and completeness of the existing data sources constrained the study. The independent variables in this study were the school locale type (rural or urban) and the availability of high-speed broadband internet infrastructure within the community. The dependent variables were high school graduation rates and standardized test scores, specifically the grade 10 Smarter Balance assessment scores and grade 11 Washington Comprehensive Assessment of Science scores. The study employed a quasi-experimental, causal-comparative design to explore differences in educational outcomes based on broadband availability and school locale. The original plan to analyze all three dependent variables simultaneously was revised due to violations of key statistical assumptions, including multivariate normality and homogeneity of variance-covariance matrices. Consequently, separate one-way ANOVAs were conducted for each dependent variable using complete and independent samples. Census sampling was used, meaning all public high schools in Washington state with available data were included in the study. The population consisted of 753 public high schools, and the final sample sizes were as follows: 374 schools for graduation rate data, 437 for 10th-grade SBAC ELA scores, 358 for 10th-

grade SBAC Math scores, and 421 for 11th-grade WCAS Science scores. The study was based on data from the 2022–2023 academic year, which may not reflect current conditions or changes that have occurred since the data were collected. Ethical considerations were also addressed, as the study used archival data, ensuring anonymity and masking identifiable information. No primary data collection or educational interventions were conducted. By defining these delimitations, the study aimed to provide a focused and manageable investigation into the relationship between broadband availability and academic performance in Washington state high schools.

Limitations

This study presents several limitations that may affect the generalizability, validity, and reliability of its findings. First, the research was geographically confined to high schools in Washington State, which may limit the applicability of the results to other states or regions with different broadband infrastructure, demographic characteristics, or educational policies. Additionally, the study focused exclusively on high school academic outcomes; therefore, the findings cannot be generalized to elementary or middle school populations.

The use of secondary, publicly available data from the 2022–2023 academic year introduces limitations related to the data's accuracy, completeness, and consistency. Because the data reflect a specific point in time, they may not capture current conditions or recent changes in broadband access or educational performance. Furthermore, broadband availability was measured at the school level, which may not accurately reflect individual student access at home, potentially limiting the precision of the findings.

The study employed a quasi-experimental, causal-comparative design, which allows for identifying associations but does not establish causality. As such, observed differences in academic outcomes cannot be definitively attributed to broadband access or school locale. Additionally, the study did not control for other potentially influential variables such as socioeconomic status, school funding, or teacher quality, which may also impact student achievement.

Another limitation of this study is that each dependent variable was analyzed using a separate one-way ANOVA, resulting in different sample sizes and potentially different sets of schools included in each analysis. Because the samples were not identical across the three analyses, direct comparisons between outcomes should be interpreted with caution. This approach was necessary to preserve complete data for each variable; however, it may limit the generalizability of findings across all the measured outcomes.

Lastly, while using archival data ensured anonymity and protected individual privacy, it also restricted the ability to account for student-level experiences, perceptions, or contextual factors that may influence academic performance. Despite these limitations, the study offers a focused and transparent examination of the relationship between broadband availability and academic outcomes in Washington State high schools.

Significance

This study was significant as it addressed the scarcity of information regarding the availability of broadband infrastructure in rural areas and its influence on high school students' academic outcomes. By providing valuable data and locale-based evidence, this research could facilitate improved communication and joint initiatives between educators

and federal, state, and local governments and organizations, promoting equitable broadband infrastructure access in rural communities.

This study may provide positive social change by clarifying and providing evidence about how inequitable broadband infrastructure availability affects rural students' educational experiences, opportunities, and academic outcomes. This information may allow decision-makers to consult empirically derived data for communications and joint initiatives that inform educational planning and infrastructure expansion needs. By understanding how the lack of availability of broadband infrastructure influences student academic outcomes, it is anticipated that providing devices and improving broadband services could level the educational playing field for students in rural locations.

Summary

In the rural Pacific Northwest, high school students face significant challenges due to limited broadband infrastructure, which impacts educational equity and the quality of learning opportunities. Approximately 17% of K-12 students and 14% of postsecondary students in Washington state lack high-speed internet at home, with 6% of K-12 students lacking a computer (Kwakye et al., 2021). Despite improvements, nearly 10% of rural U.S. households still lack broadband (Center for Public Education, 2023). Broadband is crucial for digital literacy and essential for equitable participation in education and other life aspects (Arsen et al., 2022; Demir Kaymak & Horzum, 2022; Hampton et al., 2020, 2021, 2023; McCarron & Frydenberg, 2023; Wang & Tahir, 2020). Rural areas often have higher poverty rates and minority populations, with lower

broadband adoption affecting academic outcomes (CPE, 2023; Mack et al., 2024; NCES, 2023; Valentín-Sívico et al., 2023). This study explores the influence of broadband availability on student achievement in the Pacific Northwest.

Broadband infrastructure has historically been inequitably rolled out in the U.S., with rural areas lagging behind urban areas (Hampton et al., 2020, 2021, 2023; Kwakye et al., 2021; NTIA, 1995; Valentín-Sívico, 2020, 2022, 2023; van Dijk, 2005). Rural areas face significant barriers, including fewer physical cables, cellular towers, and high satellite internet costs (Hampton et al., 2020, 2021, 2023; Kwakye et al., 2021; Valentín-Sívico, 2020, 2022, 2023; van Dijk, 2005). Limited broadband availability affects educational equity and learning opportunities, particularly in rural high schools (Caldarulo et al., 2022; Hampton et al., 2020, 2021, 2023). Researchers use various indicators to measure academic achievement, with digital literacy skills being crucial for success in the modern world (Arsen et al., 2022; Caldarulo et al., 2022; Cheng & Yang, 2023; Gonzales et al., 2020; Grenestam & Nordin, 2018; Hampton et al., 2020, 2021, 2023; Heilmann et al., 2024; Kwakye et al., 2021; Mazzuki & Chiwamba, 2024; Phutela & Dwivedi, 2020). Providing equitable education and learning opportunities is a significant concern for rural high schools, which often face inadequate funding, teacher shortages, and a lack of broadband infrastructure (Arsen et al., 2022; Bala, 2024; CPE, 2023; Hampton et al., 2020, 2021, 2023; Mack et al., 2024; Skinner et al., 2024).

The specific research problem addressed in this study was the lack of research on the potential influence of high-speed broadband infrastructure availability on high school academic outcomes in Washington state. Existing research has extensively explored the

links between socioeconomic status, race, gender, and parental education level on rural high school academic outcomes (Hampton et al., 2023; Puente, 2022; Xin et al., 2024). The aim of the study was to verify if previous findings on high-speed internet access improving student achievement hold true in the Pacific Northwest (Hampton et al., 2020; Whitacre & Biedny, 2022). The purpose of this quantitative study was to determine if significant differences exist in aggregate measures of academic performance in high schools, as measured by graduation rate and standardized test data, for urban and rural communities with and without high-speed broadband internet infrastructure availability in Washington state.

The study was driven by three quantitative research questions and their associated hypotheses. It focuses on graduation rates and standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure. Additionally, the research is based on Siemens's (2003) connectivism theory and van Dijk's (2005) digital divide theory, both addressing the need for equal access to facilitate growth and learning. These theories underscore the need for equitable access and availability to high-speed internet for rural students to connect and excel in education (De Clercq et al., 2023; Foroughi, 2015; Kotzee, 2021; Pick & Sarkar, 2016; Sanders & Scanlon, 2021; Siemens, 2004). The nature of the study was described as a quasi-experimental, causal-comparative design using secondary data. Although a two-way MANOVA was initially planned, assumption violations led to the use of separate one-way ANOVAs for each dependent variable. Census sampling was employed, and the final sample sizes ranged from 358 to 437 schools, depending on the outcome measure.

Key terms such as broadband internet infrastructure, graduation rate, school locale classification, and specific assessments (Smarter Balance Assessment and Washington Comprehensive Assessment of Science) were defined.

It is assumed that broadband infrastructure is not uniformly available or reliable across the rural Pacific Northwest, with rural areas significantly lagging behind urban regions (Hampton et al., 2020; Valentín-Sívico et al., 2023). The existence of a digital divide is assumed to exacerbate educational inequalities, and examining community and school-level data is crucial for understanding the impact of broadband availability on student achievement (Xin et al., 2024).

The study focused on high schools in Washington state, analyzing school-level data from the 2022-2023 academic year. It examined the effects and potential interactions between broadband infrastructure availability and school locale type on high school graduation rates and standardized test scores. Geographically confined to Washington state, the study relied on secondary data from a specific point in time and employed a quasi-experimental design that does not establish cause-and-effect relationships. It focused on specific variables and used archival data, ensuring anonymity but not accounting for individual student experiences.

This study addressed the scarcity of information regarding broadband infrastructure in rural areas and its influence on high school students' academic outcomes. The research could facilitate improved communication and joint initiatives between educators and governments by providing valuable data and evidence, promoting equitable broadband infrastructure access and availability in rural communities. Positive

social change may result from clarifying how inequitable broadband infrastructure availability affects rural students' educational experiences and outcomes.

As I transition to the literature review, I will explore the existing body of research on broadband infrastructure, educational equity, and academic outcomes. This review will provide a comprehensive understanding of the current knowledge landscape, identify gaps in the literature, and establish the context for this study's contributions.

Chapter 2: Literature Review

Introduction

The research problem addressed through this study is that little research has been conducted about the potential influence of high-speed broadband infrastructure availability in rural and urban communities on high school academic outcome measures in Washington state. The purpose of this quantitative study was to determine if significant differences exist in aggregate measures of academic performance in high schools, as measured by graduation rate and standardized test data, for urban and rural communities with and without high-speed broadband internet infrastructure availability in Washington state. Although there has been significant research on the effects of socioeconomic status and race on high-speed internet access across the country (Demir-Kaymak & Horzum, 2022; Phutela & Dwivedi, 2022; Puente, 2022), a better understanding is needed in rural areas related to high school academic outcomes. Little research has been conducted about the influence of the availability of high-speed broadband infrastructure, or the lack thereof, on high school academic outcomes based on community location, specifically in rural areas, without regard to socioeconomic status, parental education attainment, or race. Existing research about access to high-speed internet services considers other factors, such as socioeconomic status and race. Still, students in rural areas come from diverse backgrounds.

My systematic literature review was focused on three key concepts: the availability of broadband infrastructure, high school academic outcomes, and household type, mainly focusing on rural household types. The dynamics of rural broadband

infrastructure, broadband deployment, the differences between high and low-speed internet access, and the reported implications when communities lack the availability of broadband internet infrastructure are examined. Commonly accepted metrics used as academic achievement indicators by researchers, the importance of digital literacy skills, and equity in educational and learning opportunities are discussed in a literature review on high school academic outcomes. Finally, I evaluate similarities and differences between rural and urban communities, specifically regarding secondary education outcomes.

Literature Search Strategy

I searched a variety of databases to find current literature. These databases included Education Source, ERIC, SAGE Journals, Science Direct, Taylor and Francis Online, Academic Search Complete, and Google Scholar from the Walden University Library. I also utilized the Western Washington University Library databases Access Washington, Education Research Complete, PsycINFO, Social Sciences Databases, and Teacher Reference Center. My initial searches were conducted with the search terms *broadband*, *mobile broadband*, *infrastructure access and availability*, *homework gap*, *rural students*, *digital skills*, *digital inequalities*, *broadband planning*, *web technologies*, *learning theory*, *digital age*, *connectivism*, *academic performance*, and *digital divide*, separately and in combinations, with no date limiters on the results.

As I started to find relevant sources, I separated them into categories for further review. The first category reflected sources within the past 3–5 years that directly relate to this study. The second category included sources outside the past 5 years, which may

be used to determine if other studies had since referenced that work in subsequent publications. The third category had sources within the timeframe but only slightly related to this study, which may be used for citation mining in the areas where they correlate with this study. My research into current literature continues with database search alerts and repeatedly checking for new citations of the sources listed in my literature section in new research.

Theoretical Foundation

The basis of this research is founded on Siemens's (2004) theory of connectivism and van Dijk's (2005) digital divide theory. The term "digital divide" was initially coined in a 1995 National Telecommunications and Information Administration (NTIA) report. Together, these two theories address the needs of individuals to have equal access to connect with others to facilitate continued growth and learning. Concepts from both theories informed my research.

Originally published in electronic format, Siemens (2004) concluded that the accepted learning theories of behaviorism, cognitivism, and constructivism were developed before the advent of technology in education and, therefore, may no longer be applicable learning theories for a digital age. Siemens (2006) proposed a shift in how the mind is viewed. Instead of viewing the mind as a black box, computer, or reality, as had been the case previously, Siemens stated, "Our mind is a network…an ecology. It adapts to the environment" (p. 27). Connectivism combines the concepts of network, chaos, complexity, and self-organization theories (Foroughi, 2015; Siemens, 2004). Connectivism's basic principles are the following: Learning and knowledge rest in the

diversity of opinion; learning is a process of connecting specialized information sources, and the currency of knowledge is essential; learning may reside in non-human appliances; the capacity to know more is more critical than what is already known; a core skill is an ability to see connections between ideas and concepts; nurturing and maintaining connections is needed to facilitate continual learning; and decision making is a learning process, which includes choosing what to learn (Bell, 2011; Foroughi, 2015).

Pick and Sarkar (2016) stated that the digital divide theory is made up of four foundational theories: adoption-diffusion theory (ADT), van Dijk's theory of digital technology access and societal impacts, unified theory of acceptance and use of technology (UTAUT), and spatially aware technology utilization model (SATUM). Specifically, van Dijk's (2005) theory is that "inequalities in access are perpetuated throughout the entire process of accessing and using technology in society" (Pick & Sarkar, 2016, p. 3890). The digital divide theory recognizes specific positional characteristics influencing the level of technology access. These include personal attributes, such as age, gender, intelligence, and health, as well as positional characteristics like labor, education, household, and nation (van Dijk, 2005). After 25 years of research on the digital divide theory, van Dijk (2020) concluded that there were three distinct eras of the digital divide: the first-level divide, which focused on physical access between 1995 and 2003; the second-level divide, which focused on skills and usage between 2004 to present; and the third-level divide, which focused on outcomes from 2012 to present.

Utilizing a theoretical framework grounded in connectivism, Kotzee (2021) concluded that the lack of teacher bandwidth within online learning environments could be supplemented with student collaboration. In the context of online learning, the "teacher bandwidth problem" refers to the limited capacity of teachers who can provide individualized attention to many students. Kotzee's study underscores the importance of student collaboration in online learning environments. It highlights the critical need for high-speed internet availability and access to ensure that all students, including those in rural areas, can fully participate and benefit from these collaborative learning opportunities.

Applying the digital divide theory, Sanders and Scanlon (2021) researched the role of technology and the importance of access to high-speed internet. They concluded that rural residents are among the groups on the lacking side of the digital divide. They contended that this reality of individual characteristics "perpetuates social, economic, and political disparities" (p. 130). They reviewed recent state and local policies addressing the digital divide in the United States and provided tools for expanding their work to further locations.

The theories of connectivism and the digital divide highlight the importance of equitable access to digital networks for fostering ongoing learning and personal development. Students in predominantly rural high schools often face limited access to high-speed internet at home, which restricts their ability to engage with educational content, collaborate with peers, and participate fully in digital learning environments. This lack of connectivity places them at a disadvantage compared to their urban

counterparts and contributes to persistent educational inequities. Rural communities remain disproportionately affected by the digital divide, which continues to be systematically reinforced across generations (De Clercq et al., 2023).

Gates (2025) emphasizes that the digital divide presents significant barriers for students, making it more challenging to complete assignments, participate in remote learning, and access essential educational resources. These challenges are especially acute in low-income and marginalized communities, where limited digital access exacerbates existing disparities and hinders academic success.

Guided by these frameworks, my research draws on concepts from both theories to explore how digital inequities shape educational outcomes. As McCosker and Tucker (2025) note, “We emphasize the need to shift attention from individual digital skills to collective digital capabilities, emphasizing sociotechnical functions embedded in networks of shared resources and practices.” This approach aligns with connectivism, which views learning as a networked process involving interactions among people, technologies, and information systems. By recognizing the role of sociotechnical networks in education, we can better inform policies and practices that promote inclusive and equitable access to digital learning opportunities.

Literature Review Related to Key Variables and Concepts

Availability of Broadband Infrastructure

Broadcast infrastructure refers to all electrical and non-electrical aspects that provide broadband internet service (Oughton et al., 2023). As the NTIA (1995) discussed in 1995, there has not been an equitable rollout of communications and digital

technologies across the United States. Sizable portions of the country's population do not enjoy the same availability of broadband services that more densely populated areas benefit from daily (Hampton et al., 2020, 2021, 2023; Kwakye et al., 2021; Valentín-Sívico, 2020, 2022, 2023; van Dijk, 2005). These differences in the availability of broadband infrastructure contribute to the conversation of the digital divide, rural broadband infrastructure, broadband deployment, and the availability of access to high-speed internet in the homes of rural households.

Dynamics of Rural Broadband

In a brief for the Southern Rural Development Center, Whitacre and Gallardo (2022) investigated the relationship between broadband availability and adoption. The researchers stated that availability refers to the infrastructure supply, and adoption refers to consumer demand, including cost and benefits perceptions. They concluded that both availability and adoption are important considerations; however, adoption appears to have a higher influence on economic development. This finding is contrary to other studies, in which researchers have suggested that socioeconomic status, gender, race, and other factors are less impactful than the availability of broadband infrastructure (Dunham, 2022; Gallardo et al., 2020; Hampton et al., 2020, 2021, 2023; Schmit & Severson, 2021). Turner Lee (2024) described those without the availability of broadband infrastructure as digitally invisible and suffering from substantial, documented, systematic barriers.

Broadband infrastructure is less developed in rural areas of the United States than in urban areas (Hampton et al., 2020, 2021, 2023; Kwakye et al., 2021; Valentín-Sívico,

2020, 2022, 2023; van Dijk, 2005). Broadband infrastructure can be provided by cables or lines, underground or above ground, via cellular towers, or satellite. The barriers to the availability of broadband infrastructure in rural areas include the lack of physical cables or lines run in less populated areas, the lower number of cellular towers in rural areas, and the still low accessibility to and unaffordable prices of high-speed satellite internet services. According to the National Center for Education Statistics (NCES, 2023), 11% of students living in rural areas of the United States are without broadband infrastructure availability. This difference in the availability of infrastructure between rural and urban America is commonly called the digital divide (Oughton et al., 2023; Pick & Sarkar, 2016; Sanders & Scanlon, 2021; van Dijk, 2005).

High-Speed Versus Low-Speed Internet

Internet availability does not mean the same thing as broadband availability. Broadband internet is high-speed internet, defined as having a download speed of at least 25 megabits per second (Mbps) and a 3 Mbps upload speed (Consumer and Governmental Affairs, 2024). Valentín-Sívico et al. (2023) addressed the difference between underserved and unserved communities. Unserved communities are defined as not having at least 10 Mbps upload and 1 Mbps download speed, while underserved communities are above the 10/1 Mbps level but not the 25/3 Mbps level of broadband. As mentioned, there are several ways to provide broadband infrastructure. Within each of those ways, internet service providers (ISPs) sometimes offer high- and low-speed internet services. Above or underground cable, wireless towers, and satellite services may be implemented in rural areas; however, if the cables lack the capabilities required, the

towers are too widely spread or not powerful enough, or the satellites are not in a direct line of sight, availability to high-speed internet will be limited (Consumer and Governmental Affairs, 2024; Skinner et al., 2024; Tomer et al., 2020; Tomer & George, 2021). Although there may be the availability of ISPs in rural areas, residents in much of the rural United States remain underserved (Valentín-Sívico et al., 2023).

Rural availability of broadband infrastructure is not a United States problem alone (Cullinan et al., 2021). Studies from across Europe, Asia, Canada, Australia, Africa, and South America have shown disparities in the deployment of broadband infrastructure in rural areas (Aldashev & Batkeyev, 2021; Cullinan et al., 2021; De Clercq et al., 2023; Grenestam & Nordin, 2018; Mazzuki & Chiwamba, 2024). Although the issue of equitable broadband deployment across the globe may be the same, the reasons and solutions will differ.

According to the Environmental and Energy Study Institute (EESI) (2021), up to 42 million Americans are without broadband availability. EESI estimated that only 66.8% of rural households could access the latest 100/10 Mbps broadband standard speed. In comparison, 97.8% of urban households had access. The reasons indicated for these differences in service levels between rural and urban households include a low return on investment for internet service providers in sparsely populated areas, a lack of competition or one option provider, high service costs or affordability, and the higher likelihood of lower socioeconomic status in rural populations. Gonzales et al. (2020) agreed with the effect of rural socioeconomic status on broadband availability and the ability to maintain services once accessed initially and maintain equipment. Kelley and

Sisneros (2020) contended that policymakers should focus equally on availability, affordability, and device access.

Broadband Deployment

Broadband deployment in the United States has followed a similar pattern to its innovative predecessors, such as transportation and telecommunications. Railways, major highways, paved roads, and public transit started on the East Coast of the United States in major population centers. They spread westward to join other large population centers, only expanding into smaller rural areas out of necessity or after the urban areas were completed. Telecommunications systems were well established in urban metropolitan areas many years before phone companies began running lines to more remote, rural areas of the United States (National Telecommunications and Information Administration, 1995). As with these previous deployments, more densely populated areas of the United States have benefited from a more extensive and rapid rollout of broadband infrastructure (Aldashev & Batkeyev, 2021). The review of rural broadband development literature conducted by Mack et al. (2024) found that the goal of connecting rural areas with adequate broadband infrastructure continues to be a challenge with many implications. The Consolidated Appropriations Act of 2021 provided numerous funding opportunities to address the bridging of the digital divide; however, the data used to distinguish between unserved and underserved was a barrier to the effectiveness of the purpose (Rachfal et al., 2021; Valentín-Sívico et al., 2023).

Implications of Varying Availability

High schools with student populations affected by these broadband infrastructure availability deficiencies show implications for educational equity and the quality of learning opportunities for their students. The availability of broadband infrastructure in a high school is not defined solely by the availability at the high school location but also by the availability of broadband infrastructure to the high school's student population outside of the high school (Caldarulo et al., 2022). Within Washington State, most high school populations comprise a combination of rural and urban residents (Kwakye et al., 2021). This ratio can influence the overall availability of broadband infrastructure for the high school population. Educational equity and the quality of learning opportunities for high school student populations are reduced when the availability of broadband infrastructure is limited (Hampton et al., 2020, 2021, 2023).

High School Academic Outcomes

Academic Outcomes Metrics

Researchers use various indicators to express academic achievement. Many qualitative researchers examine the perceptions of educators, administrators, or students about the effectiveness of interventions, programs, and perceived learning as indicators of academic achievement (Arsen et al., 2022; Gonzales et al., 2020; Heilmann et al., 2024; Mazzuki & Chiwamba, 2024; Phutela & Dwivedi, 2020). Quantitative researchers frequently evaluate standardized test scores, grade point averages, completion rates, continuation to higher education, or school ratings as academic achievement indicators (Caldarulo et al., 2022; Cheng & Yang, 2023; Grenestam & Nordin, 2018; Hampton et

al., 2020, 2021, 2023; Kwakye et al., 2021). Quantitative and qualitative researchers examine various aspects of education from various perspectives, and the researchers evaluate the data they collect in other ways; however, their results usually attempt to assess the academic outcomes of their subjects.

In the state of Washington, students are expected to have achieved a grade-appropriate level in reading comprehension, literacy, communication, writing, mathematics, social and life sciences, history, civics, cultural studies, art, and health and fitness. They should also have instruction in digital literacy, analytical, logical, and problem-solving skills (OSPI, n.d.a). To ensure these learning outcomes are being upheld, the Washington State Office of the Superintendent of Public Instruction requires the Smarter Balanced Assessment in grades 3-8 and grade 10 to evaluate English language arts and mathematics, the Washington Comprehensive Assessment of Science in grades 5, 8, and 11, and other OSPI developed tests to be administered per a state testing timeline in arts, educational technology, health and physical education, and social studies (OSPI, n.d.b).

When education researchers focus on the high school level, as I will in this study, two standard academic outcome variables are school completion or graduation rates and standardized testing scores. As Heinrich and Darling-Aduana (2021) discussed, high school graduation rates have been a core academic achievement outcome since they were required to be reported by schools under No Child Left Behind and later by Every Student Succeeds Act. Additionally, assessment data or standardized test scores must be reported to the Department of Education (ED); however, each state has the autonomy to

determine which assessments they will use and require for graduation as long as they have been approved by the ED (OSPI, n.d.b). In this study, I will focus on these variables in the state of Washington at the high school level: graduation rate, Smarter Balanced Assessment grade 10 data, and Washington Comprehensive Assessment of Science grade 11 data.

Digital Literacy Skills

The National Digital Inclusion Alliance ([NDIA], n.d.) defines digital literacy as "the ability to use information and communication technologies to find, evaluate, create, and communicate digital information, requiring both cognitive and technical skills." Arsen et al. (2022) indicated the need for local communities to be prepared to provide digital literacy education to community members when broadband infrastructure services are newly introduced. They recommend coordinating local schools or community centers to offer digital literacy skills training. Reisdorf et al. (2020) agreed that the availability of devices and broadband infrastructure alone is not a solution without acquiring the digital literacy skills required to use them effectively.

Digital literacy skills are an essential aspect of one's everyday life to be successful in the modern world. Despite this, researchers have shown that students lacking the availability of broadband infrastructure lag behind their peers in digital literacy skills. McCarron and Frydenberg (2023) found that although individuals born after 1997 are commonly assumed to be digital natives, they are not as digitally literate in the areas required for education and the workplace as expected. McCarron and Frydenberg explained that these individuals may have extensive experience in social

media and mobile devices; however, they lack concrete experience in file management, cloud computing, digital business communications, academic writing, and media literacy. Considering this lack of digital literacy skills among young adults, it is not surprising that students without the availability of broadband infrastructure have fewer digital literacy skills than their already under-skilled peers.

Digital literacy skills cannot be taught or reinforced in the home in rural areas with little to no availability of broadband infrastructure. Although studies have shown that students completing projects and assignments at school designed to teach digital literacy skills show higher skill levels than students without those in-school opportunities, students who continue to practice and utilize those skills at home show higher levels of digital literacy skills than their peers without the ability to do so (Demir Kaymak & Horzum, 2022; Hampton et al., 2020, 2021, 2023; McCarron & Frydenberg, 2023; Wang & Tahir, 2020; Yang et al., 2025). Because of this, undergraduate courses in basic digital literacy skills are becoming more common in higher education programs and, in some cases, are included in the general education requirements (Cullinan et al., 2021; McCarron & Frydenberg, 2023; Reisdorf et al., 2020; Yang et al., 2025). Additionally, Hampton et al. (2023) stated that students without the availability of broadband infrastructure are also less likely to be interested in pursuing higher education.

Equity in Education & Learning Opportunities

High schools in or serving rural communities are reported to be left out of research and policy initiatives, which may decrease their learning opportunities and equity in education (Center for Public Education [CPE], 2023). The National Equity

Project (n.d.) states, “Educational equity means that each child receives what they need to develop to their full academic and social potential.” According to the CPE, inadequate funding, the need for more high-quality curriculum and services, persistent educator shortages, a lack of policy and research support, and the lack of availability to broadband infrastructure at home, causing a homework gap, contribute to the unequal learning opportunities faced by students in rural communities.

Arsen et al. (2022), Bala (2024), Hampton et al. (2020, 2021, 2023), Mack et al. (2024), and Skinner et al. (2024) agreed with the need for increased research and policy support of broadband educational equity in rural communities. Inadequate funding, persistent teacher shortages, and the lack of availability of broadband infrastructure were also discussed as causes of educational inequalities in numerous other studies (See Bala, 2024; Caldarulo et al., 2022; Gonzales et al., 2020; Hampton et al., 2020, 2021, 2023; Kelley & Sisneros, 2020; Kim & Jang, 2020; Miller & Liu, 2021; NCES, 2023; Nowicki, 2022; Reisdorf et al., 2020; Van de Werfhorst et al., 2022; Varghese & Balarama, 2025; Wang et al., 2024). Although many researchers agree there are inequities in educational and learning opportunities for rural high schools, their research variables and conclusions about the affecting factors differ.

The links between socioeconomic status, race, gender, and parental education level of rural high school academic outcomes have been extensively studied. Puente (2022) utilized critical race spatial analysis (CRSA) as a framework to evaluate rural Latinx students’ lack of opportunities during the pandemic due to a lack of access to the internet, devices, and school personnel. Hampton et al. (2023) also studied the

relationship of race in rural populations, as well as socioeconomic status, gender, and parental education level. Contrary to Puente's research, however, Hampton and colleagues sought to determine if academic outcomes were affected by the availability of broadband infrastructure, controlling for socioeconomic status, race, gender, and parental education level. Xin et al. (2024) agreed that many researchers focus on socioeconomic status, race, gender, and parental education level; however, "few studies on community broadband program impacts have empirically examined their relationship with student achievement using community or school-level data" (p. 3). The importance of the availability of broadband infrastructure and high school academic outcomes have been discussed. Now, I will explore the literature about how place, or household type, factors into the equation.

Household Type

Rural, Defined

There is not one set definition of the term "rural" (U.S. Census Bureau, 2020). Generally, rural areas have a low population and housing density far from metropolitan areas (CPE, 2023). The variation in the definition of the term rural requires researchers and academics to clearly outline their standards when writing about topics and phenomena regarding rural populations. According to the U.S. Census Bureau, the two most common standards used are their definitions and the Office of Management and Budget's (OMB) Metropolitan and Micropolitan Statistical Areas. The U.S. Census Bureau utilizes urbanized areas, areas containing 50,000 people or more, and urban clusters, with 2,500 to 50,000 people; however, they do not use the term rural. The OMB

defines metropolitan as having at least 50,000 people, and micropolitan, having 10,000 to 50,000 people, by county, also leaves rural as all others not explicitly defined. In education, however, many researchers will use the NCES standards to represent rural areas, with three categories of rural-fringe, rural-distant, and rural-remote, based on the U.S. Census Bureau's non-urban classification (CPE, 2023).

Similarities and Differences of Rural and Urban High Schools

Solutions and interventions to address a lack of broadband availability for high school populations are not one-size-fits-all for all communities and household types. One common intervention is providing all students with laptops or tablets. This intervention has shown much greater success in urban areas than rural areas, where even students without home internet access are more likely to be close enough to freely accessible Wi-Fi services (Tomer & George, 2021). Other schools or districts have attempted to provide students with mobile internet devices at low to no cost; however, in rural areas, those devices can have trouble connecting or not connect at all compared to their wide high-speed network coverage in metropolitan areas (Hampton et al. 2020, 2021, 2023). Similarly, rebates and discounted internet programs are not beneficial for households that do not have an ISP available to use in rural areas where the infrastructure may not be in place (Valentín-Sívico et al., 2023).

Even when communities come together to find a solution, the results can differ in rural and urban areas. In a metropolitan area, a community center can extend its hours and open a computer lab for students in the community to access high-speed internet and have a place to work on homework and school projects (CPE, 2023; Valentín-Sívico et

al., 2023; Ventimiglia et al., 2024). The same type of community center could still be too far for many students to benefit from its services in a rural area. Rural schools also suffer from higher educator shortages due to the economic factors plaguing rural communities (Aldashev & Batkeyev, 2021; Dunham, 2022; EESI, 2021; Mazzuki & Chiwamba, 2024; Valentín-Sívico et al., 2023). When the majority of school funding is decided on enrollment, the lower population of rural communities directly impacts the inadequate funding and the need for higher-quality curricula and services in rural schools (Kim & Jang, 2020; Mazzuki & Chiwamba, 2024; Valentín-Sívico et al., 2023).

Understanding the differences between rural and urban communities is essential to developing effective strategies and interventions. Gallardo et al. (2020) concluded that rural communities benefited when provided with the same internet benefits and opportunities as urban communities. In a study on rural teen self-esteem, Hampton & Shin (2023) concluded that lower self-esteem, caused by disconnection and feelings of isolation, may be higher in rural communities due to a lack of internet availability. Mazzuki and Chiwamba (2024) discussed geographical isolation, lack of social services, and lack of professional development opportunities available for rural educators. Compared to their urban counterparts, rural communities have few ISPs to choose from when they have broadband availability (CPE, 2023; Valentín-Sívico et al., 2023; Ventimiglia et al., 2024). Another characteristic of rural communities is the increased population at or below the poverty level (CPE, 2023; Mack et al., 2024; NCES, 2023; Valentín-Sívico et al., 2023).

Summary and Conclusions

My review of the literature revealed the following major themes. The availability of broadband infrastructure in rural areas is increasing; however, it is not at a pace to keep up with the needs of the rural communities it serves (Hampton et al., 2020, 2021, 2023; Kwakye et al., 2021; Valentín-Sívico, 2020, 2022, 2023; van Dijk, 2005). Although broadband standards are consistent, evaluating the availability of broadband infrastructure has been challenging for researchers and policymakers (EESI, 2021; Hampton et al., 2020, 2021, 2023; Kwakye et al., 2021; Valentín-Sívico, 2020, 2022, 2023; van Dijk, 2005). Academic outcomes may be influenced by digital literacy skills and broadband availability (Arsen et al., 2022; Demir Kaymak & Horzum, 2022; Hampton et al., 2020, 2021, 2023; McCarron & Frydenberg, 2023; Wang & Tahir, 2020). Educational equity and digital inclusion are interrelated issues. Additionally, rural communities face different challenges and experience different opportunities from urban communities (See Bala, 2024; Caldarulo et al., 2022; Gonzales et al., 2020; Hampton et al., 2020, 2021, 2023; Kelley & Sisneros, 2020; Kim & Jang, 2020; Miller & Liu, 2021; NCES, 2023; Nowicki, 2022; Reisdorf et al., 2020; Van de Werfhorst et al., 2022; Varghese & Balarama, 2025; Wang et al., 2024).

Notably, the review of the research indicated that these themes overlap and relate to each other. Although there have been documented increases in the availability of broadband infrastructure in rural communities in the United States, nearly 10% of rural households still have no broadband infrastructure available (CPE, 2023). Census track data has been shown to be an ineffective measure for determining the location area of

service availability; however, that was the standard used until 2021 (EESI, 2021; Hampton et al., 2020, 2021, 2023; Kwakye et al., 2021; Valentín-Sívico, 2020, 2022, 2023). Broadband availability is reported to be an essential component in attaining digital literacy skills, and researchers have stated that digital literacy skills are critical for participating equitably and inclusively in all aspects of life, including education (Arsen et al., 2022; Demir Kaymak & Horzum, 2022; Hampton et al., 2020, 2021, 2023; McCarron & Frydenberg, 2023; Wang & Tahir, 2020; Yang et al., 2025). Studies on rural populations have indicated that there are higher proportions of poverty and minorities, broadband adoption is reported to be lower among lower-income and minority households, and researchers have demonstrated a correlation between socioeconomic status and race and academic outcomes (CPE, 2023; Mack et al., 2024; NCES, 2023; Valentín-Sívico et al., 2023).

In the rural Pacific Northwest, as in many rural areas across the United States, high school students face significant challenges related to the availability of broadband infrastructure. This issue is not merely one of convenience; it has profound implications for educational equity and the quality of learning opportunities available to these students. According to Whitacre and Biedny (2022), the Broadband Deployment Accuracy and Technological Availability (DATA) Act of 2020 hopes to improve upon the current FCC reporting of the state of high-speed broadband access nationally; however, the availability of data across different areas is still unreliable. This system of broadband “haves and have-nots,” or digital divide, places rural students at a distinct disadvantage, affecting their ability to complete homework and their capacity to acquire

the digital literacy skills necessary for success in the 21st-century economy (Hampton et al., 2020). In the rural Pacific Northwest, the problem is particularly acute. According to a Washington Student Achievement Council report, approximately 17% of K-12 students and 14% of postsecondary students did not have access to high-speed internet at home. Roughly 6% of K-12 students did not have a computer at home (Kwakye et al., 2021).

Although there has been significant research on the effects of socioeconomic status and race on high-speed internet access across the country (Demir-Kaymak & Horzum, 2022; Phutela & Dwivedi, 2022; Puente, 2022), a better understanding is needed in rural areas related to high school academic outcomes. Little research has been conducted about the influence of the availability of high-speed broadband infrastructure, or the lack thereof, on high school academic outcomes based on community location, specifically in rural areas, without regard to socioeconomic status, parental education attainment, or race. Existing research about access to high-speed internet services considers other factors like socioeconomic status and race. Still, students in rural areas come from diverse backgrounds. Prior research (Hampton et al., 2020; Whitacre & Biedny, 2022) showed that high-speed internet access improved student achievement. Kwakye et al. (2021) confirmed the lack of high-speed internet access in rural parts of the Pacific Northwest. This study aims to see if the results hold true in the Pacific Northwest, focusing specifically on location and the availability of broadband infrastructure as key factors in student achievement outcomes.

My literature review was focused on three key concepts: the availability of broadband infrastructure, high school academic outcomes, and household type, mainly

focusing on rural household types. In the next chapter, I will outline the research methodology used to examine the effects of broadband availability and household locale (rural or urban) on high school graduation rates and standardized test scores. Due to data limitations and assumption violations, separate one-way ANOVAs were conducted for each dependent variable using secondary school-level data.

Chapter 3: Research Method

Introduction

The purpose of this quantitative study was to determine if significant differences existed in aggregate measures of academic performance in high schools, as measured by graduation rate and standardized test data, for urban and rural communities with and without high-speed broadband internet infrastructure availability in Washington state. I analyzed school-level data from Washington state high schools. My study was not designed to detect cause-and-effect relationships but rather the extent to which any differences may exist. This chapter includes descriptions of the research design and rationale, methodology, data analysis plan, threats to validity, and chapter summary.

Research Design and Rationale

This study employed a quasi-experimental, causal-comparative, ex post facto design using secondary data to examine differences in academic outcomes among high schools in Washington state based on broadband infrastructure availability and school locale. The research was guided by three quantitative research questions and associated hypotheses.

The independent variables were school locale type (rural vs. urban) and the availability of high-speed broadband internet infrastructure (yes vs. no). The dependent variables were high school graduation rate, Grade 10 Smarter Balanced assessment score averages (ELA and Math), and Grade 11 Washington Comprehensive Assessment of Science (WCAS) score averages.

Initially, a two-way multivariate analysis of variance (MANOVA) was planned to assess the main effects and interaction between the independent variables across multiple dependent variables simultaneously. However, assumption testing revealed violations of multivariate normality and homogeneity of covariance matrices, which rendered the MANOVA approach inappropriate (Tabachnick & Fidell, 2019). Therefore, separate one-way ANOVAs were conducted for each dependent variable using secondary school-level data.

Methodology

This study analyzed secondary, publicly available data, including school-level academic performance records (graduation rates and standardized assessment data) for Washington state high schools from the 2022–2023 school year. These data were examined alongside broadband infrastructure availability data from the 2023 American Community Survey (ACS) and other public databases.

Population

The target population for this study consisted of all public high schools in Washington state. As of the 2022–2023 academic year, there were approximately 753 high schools across 271 school districts. All schools in the state report graduation rates and standardized assessment outcomes to the Washington State Office of the Superintendent of Public Instruction (OSPI), making these data publicly accessible and suitable for analysis.

Sampling and Sampling Procedures

A power analysis was conducted using G*Power 3.1 to determine the minimum sample size required for a two-way MANOVA, assuming a medium effect size ($f^2 = 0.25$), an alpha level of 0.05, and a power level of 0.80. This analysis indicated that a minimum of 180 schools (45 per group across four groups) would be needed to detect statistically significant effects. However, when considering all variables in a single multivariate analysis, the final sample size per group fell short of this threshold. Additionally, assumption testing revealed violations of multivariate normality and homogeneity of covariance matrices, indicating that the data were not suitable for MANOVA. These limitations led to a revision of the analytical approach, resulting in the use of separate one-way ANOVAs for each dependent variable.

To support the revised analytical approach, a second power analysis was conducted for one-way ANOVA using G*Power 3.1, with the same parameters: medium effect size ($f^2 = 0.25$), alpha level of 0.05, and power level of 0.80. This analysis confirmed that a minimum of 180 schools (45 per group across four groups) were required to detect statistically significant effects. While the overall sample size exceeded this threshold, the individual group sizes within each analysis did not consistently meet the minimum requirement. This limitation may have reduced the statistical power of some comparisons and should be considered when interpreting the results.

A census sampling strategy was used. This approach included all high schools in Washington state for which complete data were available, ensuring comprehensive representation across the population. Schools were included in the sample if they had

publicly available data for graduation rates or standardized assessments, broadband availability data for their geographic area accessible via ACS, and if they could be classified as either rural or urban using NCES locale codes. Schools were excluded if they lacked data for all three research question variables or if their locale classification or broadband data were unavailable.

Initially, schools were categorized into four groups based on the two independent variables: rural schools with broadband (NCES Locale Code 32–43 and ≥85% broadband availability), rural schools without broadband (<85%), urban schools with broadband (NCES Locale Code 11–31 and ≥85%), and urban schools without broadband (<85%). Each group was intended to include a minimum of 45 schools to meet power requirements. However, when conducting a complete case analysis, which was limited to schools with data available for all three dependent variables, the sample sizes within some groups fell below this threshold. This imbalance contributed to violations of key assumptions for a two-way MANOVA, including multivariate normality and homogeneity of covariance matrices. To address these issues, the analytical approach was revised to use separate one-way ANOVAs for each dependent variable, allowing for larger and more complete samples in each individual analysis.

Procedures for Data Collection

This study utilized archival data that were publicly available from reputable government sources. Academic performance data, including graduation rates, Smarter Balanced Assessment scores, and Washington Comprehensive Assessment of Science scores, were downloaded directly from the Washington State Office of Superintendent of

Public Instruction (OSPI) Data Portal. These datasets are maintained by OSPI, the official state education agency responsible for collecting and reporting school-level performance data (Office of Superintendent of Public Instruction, n.d.).

Broadband availability data were obtained from the American Community Survey (ACS), which is administered by the U.S. Census Bureau. The ACS provides detailed estimates of infrastructure and demographic characteristics across geographic regions. Data were accessed via the Census Bureau's website, which offers downloadable tables and documentation without requiring formal permission (US Census Bureau, n.d.).

Archival Data Use

Both OSPI and ACS are recognized as authoritative sources. OSPI's data are used for statewide educational accountability and policymaking, while ACS data are widely employed in research and government planning due to their methodological rigor and comprehensive coverage. The reputability and transparency of these sources ensured the reliability of the data used in this study.

Because the data were from the 2022–2023 academic year and the 2023 American Community Survey Data, it was considered archival data. Academic outcome data were directly downloaded via links to Excel spreadsheets from the publicly available data on the Washington State Office of the Superintendent of Public Instruction Data Portal (n.d.). The Washington OSPI Data Portal includes, in its publicly accessible databases and codebooks, the variables identified for this study: graduation rates by high school, Smarter Balanced standardized assessment scores by high school, and Washington Comprehensive Assessment of Science scores by high school. No requests for or

permission to obtain these data elements are required from the Washington OSPI, and the data is readily available to download on their website.

Additionally, the American Community Survey is publicly accessible data, requiring no permission from or prior requests to the Bureau (US Census Bureau, 2024). The availability of broadband infrastructure within the geographic study area was available for the academic year of the study through the United States Census Bureau website (US Census Bureau, n.d.). The codebooks for the ACS data can be found on the Census.gov Public Use Microdata Sample (PUMS) documentation page (US Census Bureau, 2024).

Instrumentation and Operationalization of Constructs

This study examined three primary constructs: school locale, broadband availability, and academic outcomes. Each construct was defined using publicly available school-level data from reputable sources, with variables selected to represent each construct as accurately as possible. School Locale Classification was determined using the National Center for Education Statistics (NCES) locale codes, which categorize schools based on geographic and population characteristics. Schools with NCES locale codes ranging from 32 to 43 were classified as rural, while those with codes from 11 to 31 were classified as urban (NCES, 2024, b). For the purposes of analysis, locale was treated as a binary variable, with rural schools coded as 1 and urban schools coded as 0. For example, a school with an NCES code of 33 was classified as rural.

Broadband availability was operationalized using broadband service level (BSL) coverage data from the American Community Survey (ACS). Schools located in areas

where 85% or more of the population had availability to broadband were classified as having broadband availability, while those below this threshold were classified as lacking broadband. This variable was also treated as binary, with broadband availability coded as 1 and no availability coded as 0. For instance, a school with 87% broadband coverage was classified as having broadband (U.S. Census Bureau, 2024).

Academic outcomes included graduation rates and standardized assessment scores. Graduation rates were defined as the percentage of students graduating within four years, as reported by the Washington State Office of Superintendent of Public Instruction (OSPI). Standardized assessment outcomes included Smarter Balanced Assessment scores and Washington Comprehensive Assessment of Science (WCAS) scores, both reported as the percentage of students meeting the standard. These scores were used as reported by OSPI, without further manipulation. For example, a school with a Smarter Balanced English Language Arts score of 82.35% was recorded as such (Office of Superintendent of Public Instruction, n.d.).

Data Analysis Plan

The research questions and associated hypotheses were as follows:

RQ1: Is there a statistically significant difference in graduation rates for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state?

$H_0$1: There is no statistically significant difference in graduation rates for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state.

$H_1$1: There is a statistically significant difference in graduation rates for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state.

RQ2: Is there a statistically significant difference in 10th-grade standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state?

$H_0$2: There is no statistically significant difference in 10th-grade standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state.

$H_1$2: There is a statistically significant difference in 10th-grade standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state.

RQ3: Is there a statistically significant difference in 11th-grade standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state?

$H_0$3: There is no statistically significant difference in 11th-grade standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state.

$H_1$3: There is a statistically significant difference in 11th-grade standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state.

The data were analyzed using IBM SPSS Statistics version 30.0.0.0 software. The first dependent variable represented the associated high school graduation rate. The second and third dependent variables represented the average high school test scores from 10th and 11th-grade standardized assessments. All data were obtained from publicly available state or federal sources, including the Washington Office of Superintendent of Public Instruction Data Portal and the United States Census Bureau American Community Survey Data Tables. None of the data obtained required permission from the Washington OSPI or the US Census Bureau.

Due to the initial expectation of correlation among the three dependent variables, graduation rates, 10th-grade assessment scores, and 11th-grade assessment scores, a two-way MANOVA was originally planned to analyze the data. However, assumption testing revealed violations of key MANOVA requirements, including multivariate normality and homogeneity of covariance matrices. As a result, the analytical strategy was revised. Rather than proceeding with the initial MANOVA, instead separate one-way ANOVAs were conducted for each dependent variable to examine the effects of school locale and broadband availability independently. This adjustment ensured that the analyses remained statistically valid and appropriately aligned with the characteristics of the data.

The validity of the data I collected was considered high due to several factors. Because all the data collected came from government agencies, it can be assumed that rigorous, standardized data collection and reporting methodologies have been followed (US Department of Health and Human Services, 2020). Additionally, government agencies operate under strict transparency and accountability guidelines. Another

important aspect is the nonpartisan nature of government data. Typically, government data aims to provide an unbiased view of various metrics, which helps maintain the credibility and trustworthiness of the data (NCES, 2024c).

Additionally, government data is often subject to regular audits and reviews to ensure accuracy and completeness. Furthermore, making data and methodologies publicly available allows for independent verification and analysis, further enhancing the data's credibility (US Department of Health and Human Services, 2020). However, according to Somasundaram (2023), it is still important to remain critical and consider potential limitations such as human error and methodological differences between agencies.

This methodology aligns with my study purpose, research questions, and hypotheses by determining whether significant differences exist between the graduation rates and standardized assessment data of rural and urban high schools with and without the availability of broadband infrastructure in their community locations using secondary state and federal data. My study did not include primary data collection activities or the implementation of any educational intervention; rather, it examined potentially related variables indicative of academic outcomes.

Threats to Validity

Because the reporting of data to public entities is delayed, my study was based on a snapshot of one specific point in time, which is now 2-3 years old. Many factors may have changed since the time of the data collection that was used in this study; however, the information provided by the results was still useful. Another threat to validity was the

assumption of the reliability of the data. While the data came from reliable government agencies, those agencies can only control for a certain level of accuracy in the data reported to them.

Ethical Procedures

My research was not anticipated to pose any danger to participants because I used archival data, and no specific students, teachers, or schools were identified. This research was conducted without the involvement of students or teachers, and all personal information was removed before analysis to ensure anonymity. I reported all data in aggregate form using charts and tables. All school-level identifiable information was masked in my reporting. This study's results are expected to be shared with educational leaders after dissertation approval.

Summary

This quantitative study examined whether significant differences exist in academic performance among high schools in Washington state based on school locale (urban vs. rural) and the availability of high-speed broadband internet infrastructure. Academic performance was measured using graduation rates and standardized assessment scores from the 2022–2023 school year. The study employed a quasi-experimental, causal-comparative, ex post facto design using secondary data from publicly available sources, including the Washington State Office of Superintendent of Public Instruction and the American Community Survey.

Initially, a two-way multivariate analysis of variance (MANOVA) was planned to assess the effects of the two independent variables—school locale and broadband

availability—on three dependent variables: graduation rates, 10th-grade standardized assessment scores, and 11th-grade science assessment scores. However, assumption testing revealed violations of multivariate normality and homogeneity of covariance matrices, rendering the MANOVA approach inappropriate. As a result, separate one-way ANOVAs were conducted for each dependent variable. A second power analysis confirmed that a total sample size of 180 schools was sufficient to detect statistically significant effects under the revised design. However, the number of schools within individual groups did not consistently meet the minimum threshold of 45 per group, indicating that some analyses may have been underpowered. Despite this limitation, the large overall sample size and the robustness of ANOVA to unequal group sizes supported the decision to proceed with the analyses.

A census sampling strategy was used, including all 753 public high schools in Washington state for which complete data were available. Data were analyzed using IBM SPSS Statistics software, with an alpha level of .05 to determine statistical significance. All data were reported in aggregate form, and no identifiable information was included in the analysis, ensuring ethical standards were maintained.

This methodology aligned with the study's purpose and research questions by enabling the examination of differences in academic outcomes across school types and broadband access levels. The use of archival data allowed for a broad, unbiased analysis of existing conditions without the need for direct intervention or primary data collection.

Chapter 4 presents the results of the statistical analyses conducted for each of the three research questions. Findings from the separate one-way ANOVAs are reported,

including descriptive statistics, test results, and interpretations of significant differences in academic performance based on school locale and broadband availability.

Chapter 4: Results

Introduction

The purpose of this quantitative study was to determine if significant differences exist in aggregate measures of academic performance in high schools, as measured by graduation rate and standardized test data, for urban and rural communities with and without high-speed broadband internet infrastructure availability in Washington state. The independent variables were school locale and broadband availability, and the dependent variables were graduation rate, 10th-grade Smarter Balanced ELA and Math scores, and 11th-grade WCAS Science scores.

This chapter presents the results of the statistical analyses conducted to address the three research questions and associated hypotheses. It begins with a description of the sample and data collection process, followed by the results of the separate ANOVAs conducted for each dependent variable. The chapter concludes with a summary of findings and a transition to Chapter 5.

Data Collection

Descriptive and demographic data were collected from publicly available sources for high schools across Washington state for the 2022–2023 academic year. The sample included schools classified by locale (rural or urban) and by the presence or absence of broadband infrastructure (≥85% coverage). Initial analysis plans included a two-way MANOVA; however, due to extreme group size disparities, particularly in the urban schools without broadband infrastructure, the assumptions for MANOVA were violated. Consequently, separate one-way ANOVAs were conducted for each dependent variable.

Results

Descriptive Statistics

Descriptive statistics were calculated for each dependent variable: graduation rate, 10th-grade SBAC ELA and Math scores, and 11th-grade WCAS Science scores, based on broadband availability (≥85%) and school locale (rural vs. urban). The results are summarized in Table 1.

Table 1

Descriptive Statistics

	Broadband Availability ≥ 85%	Rural /Urban	Mean Percentage	Standard Deviation	N
Graduation Rate	No	Rural	79.61%	0.14	42
4-Year		Urban	59.17%	0.29	3
	Yes	Rural	81.13%	0.15	85
		Urban	82.89%	0.15	244
SBAC ELA Percent Met					
Standard	No	Rural	54.96%	0.13	58
10th Grade		Urban	45.27%	0.22	4
	Yes	Rural	54.30%	0.18	109
		Urban	56.46%	0.19	266
SBAC Math Percent Met					
Standard	No	Rural	26.63%	0.14	43
10th Grade		Urban	24.73%	0.18	3
	Yes	Rural	29.29%	0.14	83
		Urban	30.29%	0.18	229
WCAS Science Percent Met					
Standard	No	Rural	39.14%	0.14	56
11th Grade		Urban	29.70%	0.17	3
	Yes	Rural	39.82%	0.16	108
		Urban	38.35%	0.17	254

RQ1: Is there a statistically significant difference in graduation rates for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state?

Prior to conducting the ANOVA, several assumptions were tested. The assumption of normality was assessed using Shapiro-Wilk tests, which indicated that

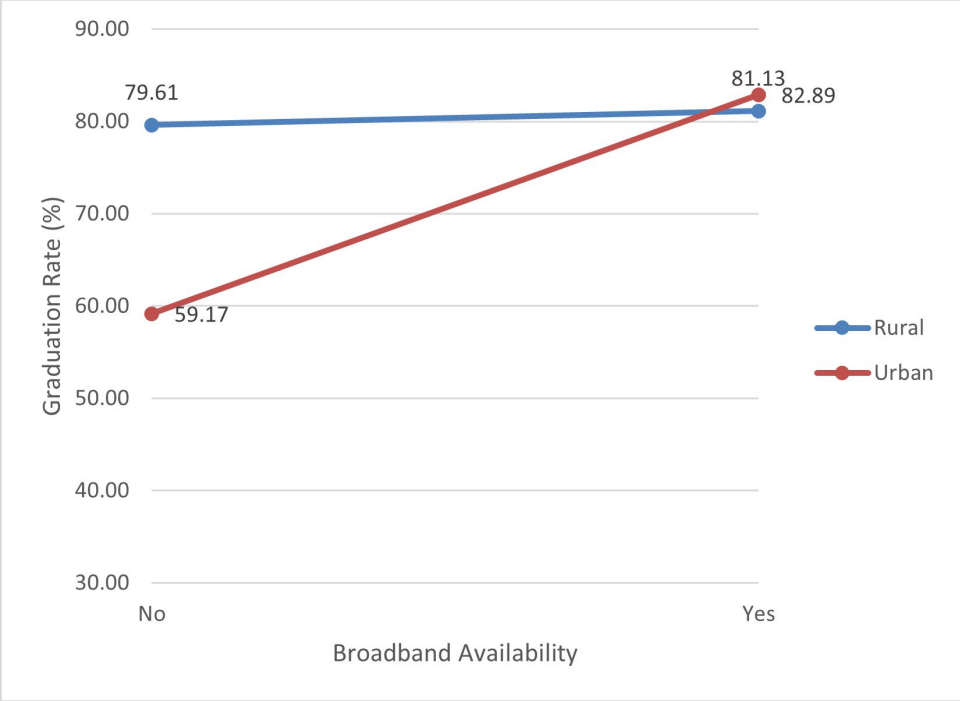
graduation rates were approximately normally distributed within each group. Levene's test for homogeneity of variances was not significant ($p > .05$), suggesting that the assumption of equal variances was met. Independence of observations was assumed based on the study design.

A one-way ANOVA revealed a statistically significant main effect of broadband availability on graduation rates, $F(1, 370) = 7.67$, $p = .006$, with a small effect size ($\eta^2 = .020$). Schools in communities with broadband had higher graduation rates (M = 82.0%, SE = 0.9%) than those without broadband (M = 69.4%, SE = 4.5%). The 95% confidence interval for the mean difference ranged from 3.7% to 21.6%.

There was also a statistically significant main effect of school locale, $F(1, 370) = 4.20$, $p = .041$, with rural schools (M = 80.4%, SE = 1.4%) outperforming urban schools (M = 71.0%, SE = 4.3%). The interaction between broadband availability and locale was statistically significant, $F(1, 370) = 5.94$, $p = .015$, indicating that the effect of broadband availability on graduation rates differed by locale, as illustrated in Figure 1.

Figure 1

Interaction Effect of Broadband Availability and Locale on Graduation Rate



Based on these findings, the null hypothesis was rejected. There is a statistically significant difference in graduation rates based on broadband availability and school locale.

RQ2: Is there a statistically significant difference in 10th-grade standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state?

Assumptions were tested prior to my analysis. Shapiro-Wilk tests indicated that SBAC ELA and Math scores were approximately normally distributed across groups, and Levene's test for homogeneity of variances was non-significant for both ELA and Math

scores ($p > .05$), which supported the assumption of equal variances. Independence of observations was assumed.

For SBAC ELA scores, the ANOVA revealed no statistically significant differences based on broadband availability, $F(1, 433) = 1.20$, $p = .273$, or school locale, $F(1, 433) = 0.62$, $p = .433$. The interaction effect was also not significant, $F(1, 433) = 1.52$, $p = .218$. For SBAC Math scores, no statistically significant differences were found based on broadband availability, $F(1, 354) = 0.68$, $p = .409$, or locale, $F(1, 354) = 0.008$, $p = .927$. The interaction effect was not significant, $F(1, 354) = 0.085$, $p = .771$. Based on these results, the analysis failed to reject the null hypothesis. There is no statistically significant difference in 10th-grade assessment outcomes based on broadband availability or school locale.

RQ3: Is there a statistically significant difference in 11th-grade standardized assessment data for high schools in rural and urban communities with and without high-speed broadband internet infrastructure availability in Washington state?

Assumptions testing indicated that WCAS Science scores were approximately normally distributed across groups, as assessed by Shapiro-Wilk tests. Levene's test for homogeneity of variances was non-significant ($p > .05$), indicating that the assumption of equal variances was met. Independence of observations was assumed. The ANOVA results showed no statistically significant differences for broadband availability, $F(1, 417) = 0.88$, $p = .349$, school locale, $F(1, 417) = 1.20$, $p = .274$, or their interaction, $F(1, 417) = 0.64$, $p = .424$. Based on these findings, the analysis failed to reject the null

hypothesis. There is no statistically significant difference in 11th-grade science assessment outcomes based on broadband availability or school locale.

Summary

In summary, the analysis revealed statistically significant differences in graduation rates based on both broadband availability and school locale, with rural schools and those with broadband infrastructure showing higher graduation rates. However, no significant differences were found in standardized assessment scores (SBAC ELA, SBAC Math, WCAS Science) based on either independent variable or their interaction. These findings suggest that while broadband infrastructure may be associated with improved graduation outcomes, its impact on standardized test performance is less clear. Chapter 5 will explore these findings in greater depth and discuss implications for policy and practice.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of this quantitative study was to determine whether statistically significant differences exist in aggregate measures of academic performance, specifically high school graduation rates and standardized test scores, based on school locale (rural vs. urban) and the availability of high-speed broadband internet infrastructure in Washington state. Using a quasi-experimental, causal-comparative design, the study analyzed publicly available secondary data from the 2022–2023 school year, including school-level graduation rates and standardized assessment scores (grade 10 Smarter Balanced ELA and Math, and grade 11 WCAS Science), alongside broadband infrastructure data.

Although a two-way MANOVA was initially planned, violations of key assumptions necessitated a shift to one-way ANOVAs to examine the main and interaction effects of the independent variables, school locale and broadband availability, on each dependent variable individually. This revised approach remained aligned with the study's purpose and research questions by enabling a valid comparison of academic outcomes across rural and urban schools with varying levels of broadband access.

The analysis revealed statistically significant differences in graduation rates based on both broadband availability and school locale, with rural schools and those in communities with broadband infrastructure showing higher graduation rates. A significant interaction effect also indicated that the impact of broadband availability differed by locale. However, no significant differences were found in standardized

assessment scores (SBAC ELA, SBAC Math, WCAS Science) based on either independent variable or their interaction. These findings suggest that while the availability of broadband infrastructure may be associated with improved graduation outcomes, its influence on standardized test performance is less evident.

Interpretation of the Findings

The findings of this study both confirm and extend existing knowledge about the relationship between broadband infrastructure availability, school locale, and academic outcomes. Consistent with the prior research of Hampton et al. (2020, 2021, 2023) and Whitacre & Biedny (2022), this study found that high schools in communities with broadband infrastructure had significantly higher graduation rates than those without. This supports the assertion that digital access contributes to improved educational outcomes, particularly in rural areas where infrastructure is often lacking. Additionally, the significant effect of school locale on graduation rates, with rural schools outperforming urban schools, adds to the existing literature. While many studies have emphasized the disadvantages faced by rural students due to limited broadband access (Kwakye et al., 2021; Sanders & Scanlon, 2021), my finding suggests that when broadband is available, rural schools may leverage it effectively to support student success. This extends the work of Gallardo et al. (2020), who found that rural communities benefit when provided with the same digital opportunities as urban communities. However, the lack of statistically significant differences in standardized assessment scores (SBAC ELA, SBAC Math, WCAS Science) based on broadband availability or school locale contrasts with earlier studies that linked digital access to

improved academic performance metrics (Hampton et al., 2020; Puente, 2022). This discrepancy may be due to the nature of standardized testing, which captures a narrower range of academic behaviors and may be less sensitive to the indirect benefits of broadband availability, such as increased engagement, homework completion, or digital literacy development.

From a theoretical perspective, the findings align with van Dijk's (2005, 2020) digital divide theory, particularly the third-level divide, which focuses on outcomes. The significant differences in graduation rates suggest that broadband availability contributes to positive educational outcomes, reinforcing the idea that digital inequities translate into achievement gaps. However, the absence of significant differences in standardized test scores may reflect the persistence of second-level divides, specifically differences in digital skills and usage, even when infrastructure is present.

Siemens's (2004) theory of connectivism is also evident in interpreting these results. Graduation rates may reflect broader learning networks and sustained engagement, which are supported by digital connectivity. In contrast, standardized assessments may not fully capture the networked learning processes emphasized by connectivism, such as collaboration, access to diverse information sources, and self-directed learning. The findings suggest that while broadband infrastructure supports the ecological learning environments described by Siemens, its impact may be more visible in long-term outcomes like graduation than in discrete testing events.

Overall, this study confirms the importance of broadband infrastructure in supporting educational equity, particularly in rural settings, and extends the literature by

highlighting the differential impact on graduation versus standardized testing outcomes. These results underscore the need for nuanced policy approaches that address not only access but also digital literacy, usage, and support systems to fully realize the benefits of connectivity in education.

Limitations of the Study

Several limitations emerged during the execution of this study that may affect the generalizability, validity, and reliability of the findings. First, the generalizability of my study was limited because the study utilized publicly available secondary data from high schools in Washington state during the 2022–2023 academic year. As such, the findings may not be generalized to other states or regions with different broadband infrastructure, educational policies, or demographic compositions. Additionally, the classification of school locale as either rural or urban was based on standardized federal definitions, which may not fully capture the nuances of geographic and community contexts. Trustworthiness and validity limitations were also a concern based on the use of secondary data because of the lack of control over how the data were originally collected, coded, and reported. Moreover, while federal and state databases from which the data were obtained are generally considered reputable, there remains the potential for inconsistencies or reporting errors that can affect the internal validity of the study.

Equally important, the initial plan to use a two-way MANOVA was revised due to violations of statistical assumptions, which limited the ability to assess multivariate relationships among the dependent variables. The use of separate one-way ANOVAs allowed for valid analysis of individual academic outcomes; however, this approach

restricted the ability to examine combined effects across performance measures. Additionally, because the study relied on aggregate school-level data rather than individual student-level data, the reliability of findings may be influenced by variations in school reporting practices and sample sizes. For example, some subgroups, such as urban schools without broadband, had very small sample sizes, which may reduce the stability of statistical estimates and increase the risk of Type II errors. Although the total sample size was sufficient to support the revised analyses, the number of cases within individual groups did not consistently meet the minimum threshold for adequate statistical power. This limitation was considered when interpreting the results.

Lastly, measurement limitations may have contributed to the study results. Broadband availability was operationalized as a binary variable (≥85% availability vs. <85%), which may oversimplify the complex nature of digital accessibility and availability. This threshold does not account for variations in speed, affordability, or actual usage, which are essential components of digital equity. Similarly, standardized test scores were used as variables for academic achievement, but they may not fully reflect students' learning experiences or competencies.

Recommendations

Building on the strengths and limitations of this study, several recommendations for future research may help deepen understanding of the relationship between broadband infrastructure and academic outcomes in high schools. Six specific recommendations are outlined here for future research in Washington state.

Use Student-Level Data

This study relied on aggregate school-level data, which limited the ability to describe individual differences related to student accessibility and availability of broadband, usage and digital literacy proficiencies, and academic performance. Future research should consider using individual-level data to explore how broadband availability affects students differently based on personal or household characteristics, such as socioeconomic status, race, or parental education level. This would allow for more precise modeling of digital inequities and their impact on learning.

Digital Literacy and Digital Usage Variables

While this study focused on broadband availability, it did not assess how students use digital resources or their level of digital literacy. As highlighted in the literature, access alone does not guarantee effective use of digital resources (McCarron & Frydenberg, 2023; Reisdorf et al., 2020). Future studies should include measures of digital literacy skills and patterns of technology use to better understand the mechanisms through which broadband access influences academic outcomes.

Explore Longitudinal Effects

This study captured a single academic year (2022–2023), limiting the ability to assess long-term trends or changes over time. Longitudinal research could examine how sustained availability to broadband infrastructure affects academic trajectories, graduation rates, and post-secondary enrollment. Such studies would help determine whether the benefits of broadband availability accumulate over time.

Examine More Academic Outcomes

Standardized test scores and graduation rates are important indicators, but they may not fully capture the breadth of student learning and engagement. Future research could explore additional outcomes such as attendance, homework completion, course grades, or participation in digital learning environments. These measures may be more sensitive to the effects of broadband availability, especially in rural settings.

Investigate Contextual Factors in Rural and Urban Settings

My literature review emphasized that rural and urban communities face distinct challenges related to broadband deployment and educational equity. Future studies should explore contextual factors, such as school funding, teacher availability, and community support, that may moderate the relationship between broadband access and academic performance. Mixed-methods approaches could be particularly valuable in capturing these nuances.

Refine Broadband Availability Metrics

This study used a binary threshold (≥85% availability) to classify broadband access, which may oversimplify the complexity of infrastructure and service quality. Future research should consider more granular measures, including actual speeds, affordability, and reliability of service, to better reflect the lived experiences of students and families. These recommendations are grounded in the current study's scope and findings and reflect gaps identified in the literature. By addressing these areas, future research may contribute to more targeted and equitable policy interventions aimed at closing the digital divide and improving educational outcomes for all students.

Implications

This study contributes to the growing body of research on digital equity and educational outcomes by highlighting the relationship between broadband infrastructure availability and high school graduation rates in Washington state. While the findings do not establish causality, they offer compelling information about the relationship between broadband infrastructure availability and its influence on high school graduation rates. These findings offer several implications for positive social change at multiple levels. Improved access to broadband infrastructure in rural communities may enhance students' ability to complete assignments, engage in digital learning, and develop essential digital literacy skills. As noted in the literature (e.g., McCarron & Frydenberg, 2023; Hampton et al., 2020), students with reliable internet access are better positioned to succeed academically and pursue postsecondary opportunities. Families benefit when students are able to access educational resources from home, reducing the burden of travel or reliance on public Wi-Fi.

School districts and educational organizations can use these findings to advocate for infrastructure investments and digital inclusion initiatives. The significant association between broadband availability and graduation rates suggests that schools in underserved areas may benefit from targeted support, such as mobile hotspots, community Wi-Fi hubs, or partnerships with internet service providers. These efforts can help close the homework gap and promote equitable learning environments. At the policy level, the study reinforces the importance of broadband deployment in rural areas as a matter of educational equity. Policymakers may consider prioritizing funding and legislation that

supports broadband expansion in underserved communities, aligning with recommendations from national reports and initiatives (e.g., NTIA, FCC, EESI). The findings support calls for more accurate mapping of broadband availability and for policies that address not only infrastructure but also affordability and digital literacy training.

Methodologically, this study demonstrates the challenges of using multivariate techniques with secondary data, particularly when assumptions are violated. The shift to one-way ANOVAs allowed for valid analysis but limited the ability to explore complex interactions. Future studies may benefit from mixed-methods designs or longitudinal approaches to better capture the nuances of digital access and academic performance. Theoretically, the findings align with van Dijk's digital divide theory, particularly the third-level divide focused on outcomes. The results also support Siemens's connectivism framework, suggesting that access to digital networks contributes to sustained learning and academic success, especially in rural contexts.

Educators, administrators, and district leaders should consider assessing and addressing digital access gaps within their student populations, especially in rural areas, advocating for infrastructure improvements and collaborating with local governments and service providers, integrating digital literacy instruction into curricula to ensure students can effectively use available technology, and more thoroughly monitor academic outcomes in relation to digital access to inform ongoing initiatives. The recommendations for practice are grounded in the study's findings and the literature and may offer actionable insights for improvement in educational equity.

Conclusion

This study demonstrates that the availability of high-speed broadband infrastructure is significantly associated with higher high school graduation rates in Washington state, particularly in rural communities. While standardized test scores did not show the same relationship, the findings underscore the critical role of broadband availability in supporting long-term educational outcomes. As rural and underserved areas continue to face barriers to connectivity, targeted infrastructure investments and digital inclusion efforts remain essential for promoting educational equity and closing the digital divide.

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