Reconnecting New Mexico: Improving Residential Internet Connectivity for Students, Teachers, and Families in Northern New Mexico

An Interactive Qualifying Project Submitted to the Faculty of WORCESTER POLYTECHNIC INSTITUTE in partial fulfillment of the requirements for the Degree of Bachelor of Science by

Frederic Ghonda
Nicholas Hudgins
Tai Kjendal
Rachel McBrine
Drake Tierney

Advisors:
Seth Tuler

Date: December 10, 2020

Submitted to:
Professor Seth Tuler - Worcester Polytechnic Institute
Jennifer Nevarez, John DiRuggiero - Community Learning Network

Sponsoring Agencies:

Santa Fe Project Center
Worcester Polytechnic Institute

Abstract

New Mexico, particularly in northern areas, has one of the lowest rates of residential access to broadband internet in the country. Our goal was to pilot test an internet connectivity survey and create an informational website to assist in ongoing work by state agencies and local organizations to address the lack of broadband internet access. We tested the survey in the Penasco Independent Schools District. We also compiled existing information about access in 7 northern New Mexico counties and 28 programs aimed at improving connectivity in rural and marginalized communities. Our recommendations include taking steps to improve survey response rate and timeliness, gathering supplementary information from teachers, and assessing innovative solutions to improve broadband coverage.

Acknowledgements

We would like to thank these people for their help and support throughout our project:

Our advisor Seth Tuler: For guiding us through all aspects of our project.

Our Liaisons, Jenifer Case Nevarez and John DiRuggiero, and the CLN: For their consistent support of our project and giving us guidance.

Gar Clarke and NMDoIT: For maps and data about New Mexico.

Michael Noll and the Penasco school district: For participating in the New Mexico Connectivity survey.

Table of Contents

List of Tables

List of Figures

Authorship Table

Sect. # or Name	Primary Author	Secondary Author
1	Nick	Drake
2	Hunter	Fred
2.1	Hunter	Fred
2.2	Hunter	-
2.2.1	Hunter	-
2.3	Rachel	-
2.4	Drake	Fred
2.4.1	Rachel	Hunter
2.5	Nick	-
2.5.1	Nick	-
2.5.2	Rachel	Fred
2.5.3	Drake	Fred
2.6	Drake	-
3	Team	
3.1	Drake	-
3.2	Rachel	-
3.2.1	Rachel	-
3.3	Hunter	-
3.3.1	Hunter	Nick
3.3.2	Nick	Hunter
4	Rachel	Drake
4.1	Rachel	-
4.1.1	Rachel	-
4.1.2	Rachel	-
4.1.3	Rachel	-
4.1.4	Rachel	-
4.1.5	Rachel	-
4.2	Fred	-
4.2.1	Fred	-
4.2.2	Fred	-
4.2.3	Nick	-
4.2.4	Rachel	-
4.3	Hunter	Rachel
4.3.1	Hunter	Rachel
4.3.2	Hunter	Nick
4.3.3	Nick	-
5	Nick	Drake
6	Rachel	-
6.1	Rachel	-
6.2	Nick	Drake
6.3	Drake	-
6.4	Nick	Drake
6.5	Hunter	-
7	Fred	-
7.1	Rachel	-
7.2	Fred	-
7.3	Nick	-
Appendix	Hunter	Team

1 Introduction

Across the United States, high-speed internet has become essential for many people by driving entertainment, communication, business, work, and education (Blais, Craig, Pepler, & Connolly, 2007). This increasing reliance on the internet for daily life makes the growing disparity between those who have access to modern technology and internet access, and those who do not, a progressively more substantial barrier. This inequity is known as the digital divide (Merriam-Webster n.d). Minority and rural communities in the United States continue to lag behind the rest of the country in high-speed broadband deployment, and an estimated and 1.2 million Native Americans still lack mobile LTE broadband at speeds of 10 Mbps/3 Mbps (*2018 Broadband Deployment Report*, 2018, p.1). The ever-growing impact of internet connectivity on an individual's life merits serious and careful consideration of this inequity.

Not every U.S. state or territory has equal access to a stable and fast connection. Out of all states and territories, New Mexico is ranked at 49th for broadband access (Cooper, & Tanberk, 2020). Due to the lack of adequate broadband infrastructure, New Mexico has many regions, primarily in the north, that have sub-standard internet connection or even none at all. Individuals of nearly all demographics, especially when they have to contend with additional challenges posed by the COVID-19 pandemic, are affected. Some of the groups so drastically affected by poor quality or a complete absence of internet, both before and during the pandemic, are students and academic professionals due to the nature of their work (Mansfield & Conlon, 2020).

With many students now required to work from home, a stable connection is now indispensable to proper academic participation and success (Lancker, & Parolin, 2020). However, there are over 134,000 students in New Mexico lacking adequate access to the internet, and many students have resorted to traveling to hotspots (*2019 Broadband Deployment Report*, 2019). Public hotspots are places where people can go and connect to the internet for free. This is not a particularly efficient method and acts more as a temporary "band aid" to the lack of residential internet connectivity. In more rural areas of northern New Mexico, even this is not always an option, as these hotspots can be too far away or provide no shelter from inclement weather.

Solving the problem of inadequate internet, in New Mexico and nationwide, has become a priority for organizations in the United States, such as the FCC, in order to address the digital divide present throughout different regions of the country (*National Broadband Plan*, 2010). Many organizations have tried to gain the funds to improve the infrastructure on national, state, and local levels. Although previous projects have aimed to assist specific counties of New Mexico, the problem remains that there are still many parts of the state lacking adequate broadband access.

Goal

The goal of this project is to help community leaders and policy makers improve internet equity and accessibility in northern counties of New Mexico by identifying relationships between connectivity and demographic data that may pose challenges to broadband access and making policy recommendations. To accomplish this goal, we have completed our list of objectives.

Objectives

1. Characterize the current state of residential internet access and equity in the northern New Mexico counties of Los Alamos, Mora, Rio Arriba, Sandoval, San Juan, San Miguel, Santa Fe, and Taos New Mexico and specifically in the town of Peñasco with existing data.
2. Deploy a pilot survey to assess the condition of internet access and equity in the school district of Peñasco Independent Schools.
3. Identify successful strategies and technologies used in other broadband improvement programs and outline potential appropriate solutions for our target counties based on observed needs.

2 Background

This chapter provides context for our project with research and data regarding the digital divide in the United States as a whole, and in New Mexico. In this chapter, we highlight how New Mexico is struggling to provide adequate internet resources, and how that affects education. We also discuss various efforts to advance broadband adoption in New Mexico, detailing the efforts of various government and third party organizations to build and improve internet infrastructure in the area.

2.1 Problems with Investment and Implementation

The problem of the digital divide is one that has existed in this country for some time. As different internet providers took off and technology improved, much of rural America did not receive significant investment in DSL (digital subscriber line) technology.

DSL provides access to high capacity bandwidth by transferring data over telephone lines. In 2003, cities with populations exceeding 100,000, had DSL available to 56% of people. But in cities with populations lower than 100,000, only 5% had DSL available to them (Malecki, 2003), placing less urban areas at a disadvantage. Most of these less populated areas were small urban communities representative of a large proportion of rural areas across America, which have had comparatively worse internet connectivity and access ever since (Malecki, 2003). The remaining effects of this initial inequity in high speed internet is reflected in contemporary broadband adoption.

As of early 2019, just 63% of U.S. adults in rural communities had broadband service at home, compared to 75% in urban areas and 79% in suburban areas (Pew Research Center, 2020). Rural areas typically have a low population density, which increases the cost of implementing fiber optic cables to cover the larger space. Many providers do not consider the resulting profit to be worth the necessary investment (Prieger, 2013). As time passes, providers become more unwilling to implement plans in the area, because in some cases they must build infrastructure from scratch, rather than improving or updating existing structures and services.

Even in areas which do have the infrastructure necessary to connect residents to the internet, the available infrastructure is often unable to support speeds available in more urban areas, or even those that meet FCC standards. When a person connects to the internet, their device sends information through a point of presence (POP), which represents an access point or physical connection allowing networks and devices to communicate. In 2003, urban communities across the U.S had a total of 1,395 POPs, while rural communities had a total of 316 (Malecki, 2003). Although this information is dated, it shows rural areas were falling behind early on. This situation remains an issue because distance affects the traffic at a POP (Kasiviswanathan & Eidenbenz & Yan, 2011). Traffic is the amount of data that is traveling on the same path. When data is moving from one place to another it will typically travel the quickest path to that place. Since rural areas do not have as many POPs as urban and suburban regions, there are fewer routes through which data can travel, resulting in more traffic and high latency–the time necessary for a signal to travel and return–for your device (Kasiviswanathan & Eidenbenz & Yan, 2011).

The distances between these points is a consequence of the lack of investment in internet infrastructure in rural areas. This dispersal necessitates the use of more material to create connections and the installation of more POPs in order to provide users speeds comparable to those in more urban areas. Providers who engage in this process rather than providing internet to areas with greater population density would see a lower return on investment. This disincentivization has resulted in internet connection being disproportionately slower and less available in rural areas.

Additionally, environmental factors make installation and maintenance more difficult and expensive. Deploying large equipment and vehicles across New Mexico's mountainous terrain is time consuming and requires more caution. For example, the town of Peñasco, NM sits in a valley at the bottom of a mountain called Jicarita peak. The difficulty of installing infrastructure across the mountain to improve internet access to this town has disincentivized internet providers from doing so. Peñasco currently has two internet providers and no broadband access (BroadbandNow, 2020 a). This type of situation is not uncommon and can be exacerbated by climate. New Mexico's arid climate can reach extremely high temperatures during the day and drop sharply at night. Extreme climates make it more difficult for workers to safely perform installation or maintenance. All of this is an obstacle to obtaining broadband access on par with that of the rest of the country for rural areas.

2.2 Internet Delivery Methods

The strides in the progress of internet technology made in past decades have vastly improved the availability of an internet connection across the country, still some challenges remain. There are many connection options for customers with different needs, although obstacles to accessibility, such as cost and location, sometimes leave these needs unmet. A variety of features of these connection types determine which options are available for different populations.

2.2.1 Types of Internet

A crucial part of the rapid advancement internet technology has seen in the past decades is providing people with a wide range of connection types and technologies. The first commercially available internet technology was dial-up in the early 90s. It was named for the fact that users dialed a number to turn on the service, and utilized existing telephone lines to transfer data at 56 Kbps (*Best Dial-up Internet*, n.d.). The service is easy to set up, and only requires a telephone connection, which most homes had by then. Since then, the needs of consumers have far surpassed what dial-up can provide in terms of speed and reliability.

Digital Subscriber Line (DSL) was developed and distributed in the early 2000s, and was a significant improvement over dial-up internet. Like dial-up, DSL connections used telephone lines, and therefore was widely available in the US. Unlike dial-up, DSL stayed "on" and transmitted data at a higher frequency; keeping phone lines open (Cooper, 2020 b). It is able to transfer data at much higher speeds: 5-25 Mbps download, 1-10 Mbps upload (Cooper, 2020 b), making it the first broadband technology. However, latency increases over longer connections, and the asymmetric allocation of bandwidth makes uploading content slower. Even so, DSL greatly improved residential internet.

Cable broadband was introduced around the same time as DSL. It provides internet via the cable infrastructure, and delivers even greater speeds of around 20-200 Mbps. It is also widely available in the US, and has very low latency compared to DSL. However, speeds can fluctuate based on usage in the area, and the limited number of providers means there are fewer plans to choose from (Cooper, 2020 a).

Mobile wireless allows smartphones to connect to the internet wirelessly over a cellular connection. When 3G service was launched in 2001, and 4G in 2010 (*The History of the Internet*, n.d.), users could connect to high-speed internet outside the range of WiFi. Mobile broadband has a very large coverage area, even in rural regions. However, low data caps limit how much users can do, and access to new cellular technology usually requires buying a new device.

Satellite internet uses a satellite connection to deliver internet to remote areas. Coverage is available nearly everywhere, making them a popular choice in remote regions without a wired infrastructure. However, satellite signals have high latency and "fade" across inclement weather (*Pros And Cons Of Satellite Internet*, n.d.). Additionally, plans have restrictive data caps, are more expensive than fiber, have expensive installation fees, and locks customers in long-term contracts (Schafer, 2019). Even so, satellite internet is a better option for remote areas, even though providers do not always accommodate the needs of families in these regions.

Fixed wireless internet is an alternative to satellite internet. It provides low latency connections with speeds comparable to DSL, and towers have a wide coverage area (*Fixed Wireless Internet Providers*, n.d.). Despite offering lower speeds, plans and installation fees are cheaper than satellite, for similar service. Like with satellite technology, performance "fades" in bad weather or across blocking terrain, and towers require a line of sight to the customer (Cooper, 2020 d). Overall, fixed wireless is a good option for remote customers who do not want to pay for satellite internet.

Long range WiFi or signal repeaters are devices that extend the WiFi signal of a home or business. They are often used at construction sites to provide internet where there is currently no infrastructure, or residences with detached buildings. Modern radios can extend a WiFi signal for several miles, but require a direct line of sight for the best signal, which can be an issue in regions with variable elevation. It should be noted that WiFi alone does not provide internet, but rather distributes internet from a connected source.

WiFi also became available in the early 2000s, and was quickly introduced at many restaurants, stores, and offices for the public to use freely (*The History of the Internet*, n.d.). Recently, WiFi has also become available on public transportation, such as trains, buses, and planes. These services provide a way for the public to use WiFi outside their home, but are only a temporary fix for homes that do not have good internet of their own.

Mesh networks are an alternative solution to WiFi. A mesh network consists of nodes that communicate with each other. Networks act like a "mesh" or "web" of WiFi extenders or radios, which cross connect to make stable connections. The technology used is inexpensive and can be used to distribute internet across towns, or large buildings. Performance depends on the density of the nodes, the quality of the equipment used, and if significant blockage present (metal buildings, terrain). It only requires a handful of devices to be connected to the internet, which then distribute the internet connection to all devices in the network.

Broadband over power lines (BPL) is an internet service that utilizes the existing power infrastructure to deliver high-speed internet. Its speeds are comparable to cable, and plans are usually cheaper. However, implementation in the US is not currently available due to the use of step down transformers (requiring repeaters on every transformer), and wireless interference (Cooper, 2016). It is a viable solution for rural areas, but limitations prevent it from becoming popular in the US.

Fiber-optic internet provides the best high-speed internet to businesses and consumers. Fiber connections use pulses of light through glass strands to send data at 70% the speed of light (*What Is Fiber Internet?*, n.d.). This results in extremely low latency, and bandwidths up to 1,000 Mbps. The main types of implementation are fiber to the premises (FTTP or FTTH), and fiber to the node (FTTN). FTTP brings fiber directly to a home or business, and is more expensive to install. FTTN runs fiber to a central location or provider, and copper cables are used to connect individual buildings. FTTN is less expensive, with minimal increase in latency. A drawback of fiber is that it relies on new infrastructure, and installing fiber-optic networks are a costly expenditure for internet providers (Cooper, 2020 c). For more information on types of internet, see Appendix B.1 - B.4.

2.3 The Digital Divide in New Mexico

New Mexico faces many challenges to broadband access in many of its communities. A major factor contributing to the digital divide in New Mexico is the large proportion of rural communities. With around 24% of New Mexico's population living in rural communities (*2019 Broadband Deployment Report*, 2019), implementing statewide internet is an expensive challenge for internet providers. For example, Colfax County (on the border of New Mexico and Colorado), only has a 16.1% broadband adoption rate, while the national average is 47.3% in rural areas of the United States. Colfax is not alone; similar broadband adoption rates exist in other New Mexico counties such as Socorro and Hidalgo (Cooper, & Tanberk, 2020). The state also has an average speed of 54 Mbps compared to the national 133 Mbps and as a result, New Mexico is ranked second worst in the country for internet access (Cooper, & Tanberk, 2020).

While the internet speed average for New Mexico is 54 Mbps, many areas—especially rural ones and those in northern regions—fall below the FCC standard for broadband (25 Mbps download, 3 Mbps upload). This inequality is further illustrated in the 2019 FCC broadband report (Table 1), which shows the discrepancy in average internet speed between urban and rural areas. Two million New Mexico citizens were surveyed in this report with half a million residing in rural areas and 1.5 million coming from urban areas. Of those two million surveyed, 83% (1.74 million) said they had access to broadband that met FCC standards. The remaining 17% already represents a significant divide in access. Furthermore, of those who live in rural areas, only 48% have access to internet that meets FCC standards (*2019 Broadband Deployment Report*, 2019).

Table 1. Deployment (Millions) of Fixed 25 Mbps/3 Mbps; Mobile LTE with a minimum Advertised Speed of 5 Mbps/1 Mbps; and Mobile LTE with a median Speed of 10 Mbps/3 Mbps by State (*2019 Broadband Deployment Report*, 2019).

	Pop. Evaluated	Fixed 25 Mbps/3 Mbps		Mobile LTE 5 Mbps/1 Mbps		Pop. Evaluated	Mobile LTE 10 Mbps/ 3 Mbps	
		Pop.	% of Pop.	Pop.	% of Pop.		Pop.	% of Pop.
New Mexico	2.088	1.741	83.4%	2.078	99.5%	1.856	0.895	48.2%
Rural Areas	0.502	0.237	47.3%	0.492	98.0%	0.376	0.075	19.8%
Urban Areas	1.586	1.504	94.8%	1.586	100%	1.480	0.821	55.4%

Table 1: The above information illustrates remaining inequities in connectivity between urban and rural communities.

2.4 Effects on Education

Currently, students in New Mexico are heavily impacted by the lack of reliable internet. According to the Community Learning Network (CLN), over 25% of students in New Mexico do not have a reliable internet connection (*CommUNITY Connectivity*, 2020). The onset of the COVID-19 pandemic in early 2020 makes reliable internet a main concern for people who may not have had internet access in the first place, and now must participate in remote learning. Studies show that up to a quarter of students in New Mexico did not have reliable access to the internet prior to the pandemic (Da, 2020), and the CLN estimates 134,000 in our target area. If student needs are not met, the learning gap caused by social and income inequality could put the education and future of these students at risk.

2.4.1 The Homework Gap and Availability of Education Technology

Although providing families, students, and teachers with a stable and reliable internet connection is key in addressing the digital divide in the United States, having access to education technology can be just as important to its efficacy. Education technology is the combined use of computer hardware and software for learning purposes, often being school-issued laptops (Lathan, 2020). This combination of lacking internet connection and absence of education technology results in what is known as a "homework gap" (Auxier & Anderson, 2020).

The "homework gap" is a term that describes a problem that 15 percent or more of school-age children are facing in the U.S. For these students, after the school day ends, they are unable to complete their homework due to their lack of broadband access and/or access to education technology (Auxier & Anderson, 2020). Those affected by the homework gap are primarily those in homes with inadequate internet access, but households that do have internet service are affected as well. In an interview with the chief information officer for public schools in Cincinnati, Sarah Trimble Oliver says that "[the students] have access, but it is too slow. Or [the students] have a computer in the home, but it is shared amongst five or six family members, so actually getting time on that Internet-enabled computer is difficult to complete homework" (Meyer, 2016). Additionally, in Austin, Texas, a survey regarding the homework gap was completed by over 350 participants in the most underprivileged zip codes of the area. When the participants were asked if their children are unable to complete their homework due to a lack of access to a computer, 20 percent of them said that they agree. Similarly, when they were asked if their children's computer skills are not good enough to complete their homework, 24 percent of them said that they agree (Santillana et al., 2020). The results from these two questions show that having access to a computer, and more importantly, understanding how to use it, are important for students to be able to complete their homework away from school.

Additionally, it has become apparent that the homework gap disproportionately affects different demographics. For African American, Hispanic, and lower-income households, the homework gap is much more pronounced. According to a Pew Research Center analysis of 2015 U.S. Census Bureau data, 35% of households with an annual income below $30,000 a year do not have a reliable internet connection at home. Comparatively, just 6% of households earning $75,000 a year or more lack a high-speed internet connection (Auxier & Anderson, 2020). With a 29% difference between these two figures, it is apparent that there is a deficit of broadband access for lower-income families. Furthermore, the same analysis revealed that African American and Hispanic teens are more likely to be impacted by the homework gap as well. When the students were asked if they are unable to complete their homework because of a lack of a reliable computer or internet connection, 25% of African American students while 17% of White students said they often or sometimes do. And when the students were asked if they have access to a home computer, 18% of Hispanic teens said they did not have one compared to the 9% of White teens who said the same (Anderson & Perrin, 2020).

2.5 Organizations' Effects on Broadband Availability

Over the past decade, federal and state organizations (including those in New Mexico) have made it a priority to address the growing gaps in internet access across the country. On the national level, the Federal Communications Commission (FCC) regulates interstate telecommunications and implementation, including broadband infrastructure and internet constraints. On the state level, The New Mexico Department of Information Technology (NMDoIT) and the Community Learning Network (CLN) are organizations working to address the digital divide in New Mexico. The CLN aims to improve the conditions of and resources available to communities through education and cultural development. The NMDoIT provides IT services and aims to provide cost-effective services to residents.

2.5.1 The Federal Communications Commission

In 2010, the FCC established the *National Broadband Plan*, which detailed several objectives with the goals of stimulating economic growth, increasing job creation, and improving education and health care by increasing availability of broadband internet (*National Broadband Plan*, 2010). The major objectives listed in their Broadband Action Agenda include advancement of broadband infrastructure and progression, accelerating broadband access and adoption, advancing national purposes such as education and healthcare, fostering competition to drive innovation, and advancing public safety communications networks (*National Broadband Plan*, 2010). Subtasks consist of connecting rural America, low-income Americans, schools and libraries, and Native American communities. In the report, there are several steps outlined that the FCC view as crucial to aid in reaching these objectives. Firstly, the FCC recommends reevaluating funding and contributions with the Universal Service Fund (USF), and the Connect America Fund (CAF), to effectively deploy broadband in high-cost areas. Secondly, they propose special plans for schools, libraries, and low-income areas to make broadband more accommodating for residents of high cost areas. Finally, the FCC formed a team to coordinate efforts with tribal communities and to ensure that their concerns are taken into account.

In their annual Deployment Report, the FCC found that as of 2016, 92.3% of Americans have access to some form of internet that meets the FCC standards. While this marks an important step to closing the digital divide, there are still inequities in relevant factors such as quality, speed, and affordability. The FCC continues to provide research, insight, and funding towards improving broadband access in hopes of further addressing this disparity. They are still working towards the goal of 100 percent connectivity - and higher quality connectivity - in America, and their work to do so provides useful baselines and statistics for future efforts.

2.5.2 New Mexico Department of Information Technology

The New Mexico Department of Information Technology (NMDoIT) was created in 2007 to provide New Mexico's government with the appropriate technological foundation to allow it to better address the needs of its citizens and to increase accountability and efficiency in information technology. Their main priorities include evaluating and developing strategies for implementing effective internet solutions for the state. "The vision for DoIT as a whole is to improve efficiency and effectiveness in the delivery of state services, and to be the trusted leader in delivering enterprise information technology services and solutions that enable state government to better service New Mexico's residents" (*Annual Rate Committee Meeting Public Notice and Agenda*, n.d).

The NMDoIT provides organizations with services such as email, internet, application maintenance and design, provision of equipment and networks, hosting, storage, telecommunication, network improvements, and technical training. They help match their clients with these and other specific services based on the client's needs. The NMDoIT "looks at its role in terms of changing the IT workforce of the State and in terms of more decentralized and componentized technology solutions across the State" (Lujan, E. and Sanchez, M. R., 2018). Their efforts have made them a major player in the efforts to gain adequate internet access for northern New Mexico.

2.5.3 Community Learning Network

Since 2014, an objective of the Community Learning Network (CLN) has been to provide a sufficient source of broadband internet to residents and students in rural regions of New Mexico. According to their research, over 25% of students in New Mexico do not have a reliable internet connection (*CommUNITY Connectivity*, 2020). Collaborative efforts by the CLN to address this problem include membership in the Homework Gap Team and cooperation with the Information Technology Disaster Resource Center (ITDRC), the Internet Society, the National Digital Inclusion Alliance (NDIA), and more. Together, these organizations work to provide affordable broadband internet, internet-enabled devices, digital literacy training, technical support, and applications for self-sufficiency.

The CLN provides several services and solutions to the broadband problem in New Mexico. First, the CLN has joined with ITDRC to provide mobile and fixed hotspots or "HomeworkHubs" to temporarily aid in remote learning. These are free wireless access points where students, teachers, and families can go to work remotely. To better direct these emergency efforts, CLN also researches and polls regions to determine where these Homework Hubs should be placed to maximize availability and convenience to the greatest number of people. Second, they collaborate with other organizations to investigate and address the overarching, general issue of the digital divide so they may provide governments and stakeholders with information and suggestions on how to best improve connectivity in New Mexico. Third, the CLN provides resources for the community to learn and become involved in the process of improving the state of their internet connectivity. They are a vital resource to this problem, as they have years of research and experience with residents and have made significant improvements and contributions to the many of these regions in New Mexico.

2.6 Summary

The digital divide, the growing inequality between those who have reliable access to adequate computers and internet connectivity and those who do not, has had a drastic effect on New Mexico and its residence. As evidenced in previous sections, there are many factors that contribute to low broadband adoption, particularly in rural areas. Often these areas lack the infrastructure to support the kind of connection needed to keep up with much of the US and many residents in rural areas represent lower-income households, making investments here less profitable than in urban areas.

Existing analysis shows that broadband infrastructure is crucial to the economic and educational development of a community, as well as many other facets of its wellbeing (*Broadband Deployment Report*, 2019). A large portion of those affected are students, especially in the conditions of a pandemic. With students unable to access stable internet connection, their education is at a severe disadvantage. Many rural communities, such as those in New Mexico, rely on the efforts of public and private organizations to gain adequate and affordable options for their communities. The CLN and NMDoIT are dedicated to redeveloping internet access in areas with poor internet connectivity, but they require tools and support to achieve these goals.

3 Methodology

This chapter describes our plan for investigating internet access in northern New Mexico through research, student and teacher surveys, and collaboration with schools and sponsors. We generated solutions and recommendations based on our findings and presented our project and findings on a website.

Goal

The goal of this project is to help community leaders and policy makers improve internet equity and accessibility in northern counties of New Mexico by identifying relationships between connectivity and demographic data that may pose challenges to broadband access and making policy recommendations. To accomplish this goal, we have completed our list of objectives.

Objectives

1. Characterize the current state of residential internet access and equity in the northern New Mexico counties of Los Alamos, Mora, Rio Arriba, Sandoval, San Juan, San Miguel, Santa Fe, and Taos New Mexico and specifically in the town of Peñasco with existing data.
2. Deploy a pilot survey to assess the condition of internet access and equity in the school district of Peñasco Independent Schools.
3. Identify successful strategies and technologies used in other broadband programs and outline potential appropriate solutions for Peñasco based on observed needs.

3.1 Objective 1: Characterize Residential Internet in New Mexico, Target Counties, and Peñasco

The purpose of this objective is to determine which school districts need improvement, and which districts currently have adequate public broadband access. As we described in the background, some areas are significantly lacking in broadband internet coverage. We answer the question: What are the average, median, mode, range and distribution type of internet speed in the different regions of New Mexico, and how do they compare to the rest of the state?

Our initial approach was to use information and statistics from internet service providers (ISPs) including Xfinity, CenturyLink, and Spectrum—three major providers in New Mexico. They provide speed, cost, and locational availability of various plans on their websites. We used usage statistics available online from organizations involved in the evaluation and betterment of internet access in New Mexico such as BroadbandNow and the Fiber Broadband Association. We then characterized how much of the infrastructure is inadequate to provide connectivity consistent with standards set by the FCC, as well as determine the prices for residents in our target regions. We expanded and improved upon this existing data utilized mapping software and data provided by the NMDoIT and CLN to reach our goal.

3.2 Objective 2: Deployment of New Mexico Connectivity Survey for Students, Teachers, and Guardians

Our next step in characterizing broadband access was to launch the New Mexico Connectivity survey created by John DiRuggiero which we helped to refine. The survey is intended for students, teachers, and students' guardians with questions assessing the state of their need surrounding internet connection, device availability, and technical skills. Speed is assessed by providing a link to an online service that measures a device's download speed, upload speed, latency, and retransmission. It then asks the respondent to enter these values in the designated fields. The survey was deployed as a pilot program in the Peñasco Independent Schools district. This district was chosen due to its expressed interest in participating in a test run of this survey in order for us to assess their needs regarding connectivity.

3.2.1 Connectivity Survey Deployment

The first step in deploying the survey, after receiving proper approval from our sponsors and the New Mexico Public Education Department (NMPED), was to reach out to acting superintendent Michael Noll and send him an instructional video we created to help respondents complete the survey. This video is designed to instruct any respondent on taking the survey, and provides the viewer with step-by-step instructions on how to complete the connectivity survey questions. We held two open sessions through Zoom for teachers to ask us questions if they had any. Though we did not receive any questions, providing ample opportunities for clarification is an important part of ensuring the quality of data from the survey. The full set of questions are listed in Appendix C.

3.3 Objective 3: Identifying Possible Solutions through Past Success

Based on our research on internet access in New Mexico, we considered different internet technologies to help leaders decide which potential solutions will best serve the different communities. We also investigated existing policies and guidelines that can be incorporated to allow for greater development of internet access and equity in New Mexico.

3.3.1 Options for Internet Technology

We gathered data on the different common technologies that show promise as potential solutions, as well as some alternative ones, and listed the pros and cons of each to see how they fit the needs of underserved communities in northern New Mexico. To do this, we searched for information from internet providers in New Mexico, as well as literature from other research. We compiled data about cost of implementation, cost to consumer, reliability, typical speeds, and availability in New Mexico from online resources.

3.3.2 Previous Programs

In order to outline potential solutions for our target counties in northern New Mexico, we identified successful strategies and solutions that were implemented in previous broadband improvement programs. Our first step to completing this objective was to gather information on a variety of different broadband improvement programs from a range of locations. When investigating these programs, we were looking for common themes amongst them. The three main themes that we wanted to document were:

1. Is the location of the project rural or urban?
2. What demographic is being affected by the lack of internet access or technology? (ethnicity, income, etc.)
3. What kind of solution was developed to address the digital divide?

We then compared and contrasted the themes from each program to determine if there are any ties between rurality, affected demographic, and the chosen solution.

4 Findings

This chapter presents our findings regarding broadband development in the state of New Mexico, the eight counties making up our target area, and the town of Peñasco. Information gathered on recent conditions in these areas and their school districts will be presented to contextualize the data gathered from the New Mexico Connectivity Survey. These will be considered together to identify correlations and draw conclusions which will inform our recommendations for these areas. These recommendations will discuss potential solutions to expand broadband access in these areas and ways in which the surveying process may be improved.

4.1 Current State of Connectivity

There are a multitude of factors that have contributed to the current state of internet connectivity in New Mexico. While broadband access has certainly increased in past years, there are still obstacles that prevent many residents from having a subscription to a broadband internet service. Understanding the state of New Mexico's connectivity today in different levels of political division is key to understanding where the greatest problems lie so they may be addressed as quickly and effectively as possible.

4.1.1 Statewide Conditions

As of 2020, just 66.5% of New Mexico has access to wired broadband internet as defined by the FCC, placing it at 49th in U.S. state broadband access ranking. In 2019, just 72.3% of households had a broadband subscription (U.S. Census Bureau QuickFacts, 2019). 78.5% have access to some form of connection with speeds of 100mbps or higher, but only 12.5% have access to a wired low-cost plan

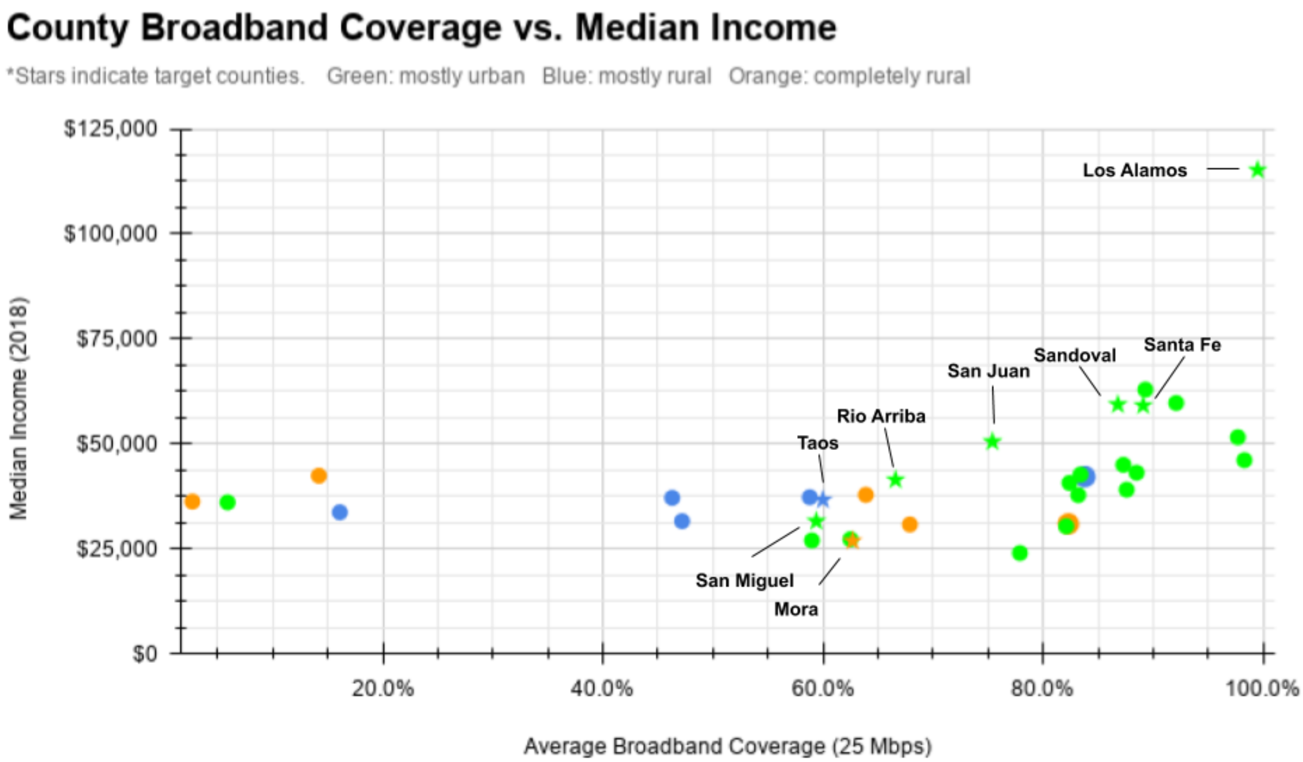
(BroadbandNow, 2020 b). However, with a poverty rate of 18.2% and median household income of $48,059 as of 2018, this leaves significant opportunity for price to become a barrier to attainment of a broadband subscription for many residents.

Many ISPs also place limits on the amount of data a subscriber can use in a given period of time, or “data caps", on some of their plans (BroadbandNow, 2020 b). In some cases this means subscribers are no longer able to connect to the internet, but in others they are charged separately for all data use over the set limit. Not all providers are available in every part of the state, and some areas receive coverage from very few. If a given area only receives service from companies with high starting prices, there is a higher chance that options for low income households will be substantially limited. Right now there are many for whom broadband internet has become a necessity to ensure the quality of their child’s education. At the time of writing, New Mexico Schools are conducting classes completely remotely due to the recent rise in COVID-19 cases across the country (KRQE, 2020). In a time where so many families are suffering financially, cost can be even more of a preventative factor.

4.1.2 Broadband in the Eight Northern New Mexico Counties

Our focus area includes the counties of Los Alamos, Mora, Rio Arriba, Sandoval, San Juan, San Miguel, Santa Fe, and Taos. There is considerable variation among these areas in numerous categories. Broadband access in these counties ranges from 61.6% coverage to 99.5%. Data for these eight counties is presented in Appendix E.

The counties with the four highest rates of broadband access (Los Alamos, Santa Fe, Sandoval, and San Juan) also have the highest median incomes. While internet coverage does not align perfectly with income, there is a clear positive correlation between the two (Figure 1). Income tends to be lower in rural areas (U.S. Census Bureau, 2016), and these areas tend to have poor coverage more frequently than mostly urban areas, as illustrated in Figure 2, suggesting that higher income may improve likelihood of a given area having widespread broadband access.



BroadbandNow. (2020, September 1). *Internet Access in New Mexico: Stats & Figures*. https://broadbandnow.com/New-Mexico.

U.S. Census Bureau QuickFacts. (2019). 2019 Population Estimate. U.S. Census Bureau. https://www.census.gov/quickfacts/fact/table/NM/PST045219 (Accessed on November 30, 2020)

Figure 1. Relationship between county broadband coverage and median income (BroadbandNow, 2020).

While rurality itself does not condemn a given area to poor broadband connection, it is clear that a disproportionate amount of rural areas are represented in those with poor broadband access. Figure 2 shows that the majority of rural counties (10 out of 12) have less than 75% coverage,, while the majority of urban counties (17 out of 22) have 75% coverage or greater.

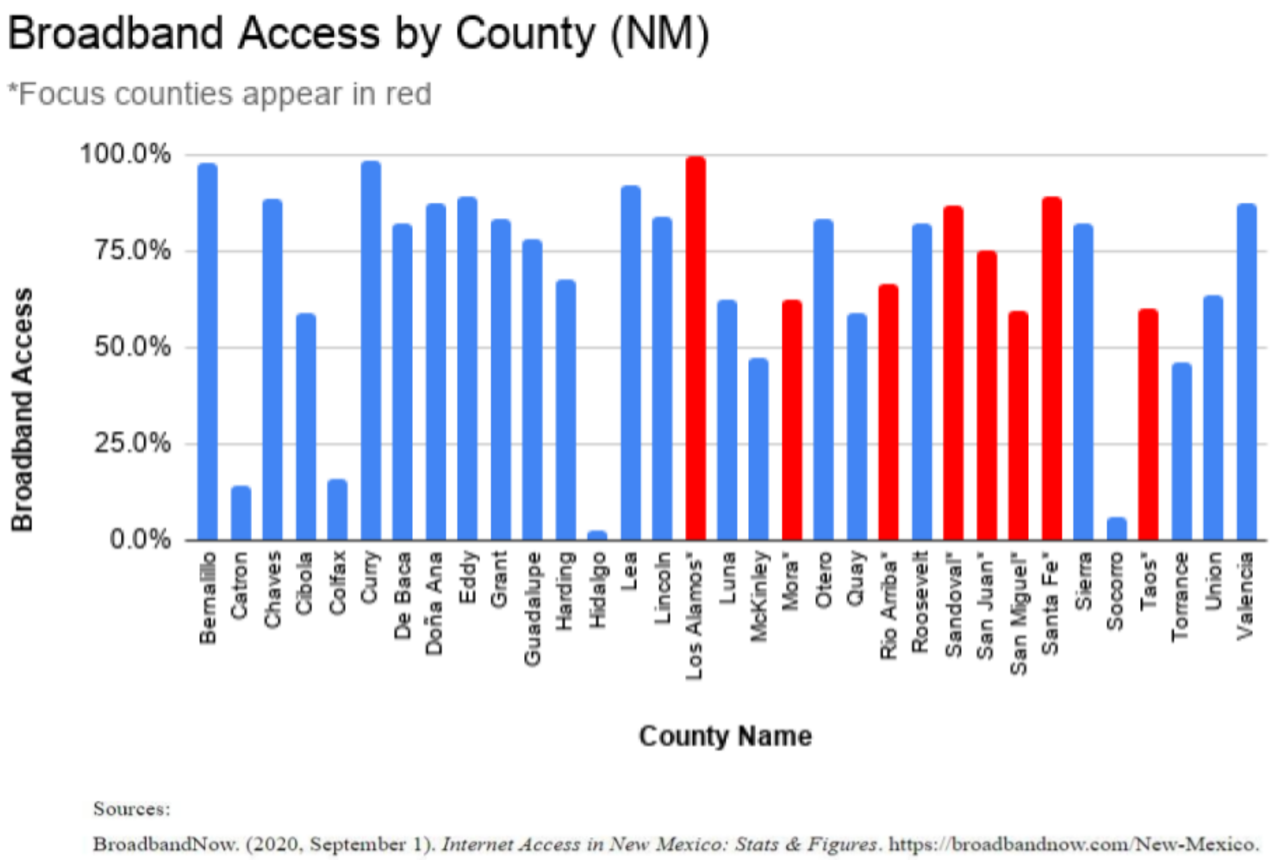


Figure 2. Average broadband access by county, with rurality indicated by color (BroadbandNow, 2020). Green: mostly urban, Yellow: mostly rural, Orange: completely rural. *: areas of focus.

While coverage available is a crucial characteristic to focus on when addressing access to broadband internet, cost is of near equal importance. As shown in Appendix E, there is often a substantial discrepancy between coverage rate and the amount of households that have a broadband subscription. The fact that many of these are rural, lower income areas suggests that price may play a significant role in deterring the adoption of these plans.

4.1.3 Peñasco Connection and Demographics

Peñasco is a small rural town with a population of 3,277 located in Taos county, New Mexico (American Community Survey, 2019) that expressed interest in participating in a pilot test for the New Mexico Connectivity survey. Despite the fact that Taos county placed ninth in the state (out of 35), Peñasco ranks 229th out of 333 communities in New Mexico for broadband access (BroadbandNow, 2020 a). Just 50.9% of households in Peñasco have a broadband internet subscription (American Community Survey, 2019). All residents have one or few options to choose from for ISPs, many of which are adding data caps to their plans. There is very limited access to wired broadband connection, and their most common internet infrastructure types are DSL and satellite. However, DSL tends to provide slower service, and satellite tends to provide inconsistent service due to its vulnerability to weather (BroadbandNow 2020 a).

The average cost per Mbps in Peñasco is $3.76, significantly higher than in major U.S. cities where the average rates are typically around $3 less (BroadbandNow, 2020 a). As of 2017, the median income was $32,685, which is 32% lower than the 2018 statewide median income of $48,059. The same year, 39.6% of the population fell below the poverty line, higher than 2018's 18.2% statewide by a significant margin (City-Data, 2020 b). These factors indicate a likelihood that it is exceptionally harder for residents in this town than for those in others to gain access to broadband internet.

As previously stated, New Mexico schools are currently conducting all classes completely remotely. It would be very difficult for students to participate if they do not have broadband, or of course if they have no internet at all. Inadequate broadband access is now drastically affecting students across the state, with over 25% of students in New Mexico do not have a reliable internet connection (*CommUNITY Connectivity*, 2020).

4.1.4 Access and Equity

As shown previously, there appears to be a positive relationship between income and broadband access. While there are lower income communities that have high access, there are far fewer higher income communities that have poor coverage, which is common in lower income areas (Figure 1).

There is also a distinct opportunity for broadband access to be limited by ethnicity. While there are no direct correlations between the ethnic makeup of New Mexico counties and broadband, there are clear national correlations between income and ethnicity. As of 2017, median income for Indigenous American and Alaskan households was $40,315. U.S. Census Bureau data from 2018 reports a median income of $41,361 for African American households, $51,450 for Hispanic households, and $66,943 for White households (Muhammad, 2019). With income being such a strong determining factor for access, Indigenous American, African American, and Hispanic populations may not be experiencing broadband access equal to those of other racial groups.

This is of particular concern in New Mexico, where 49.3% of residents are Hispanic and 11% are Indigenous American (U.S. Census Bureau Quickfacts, 2019). This disparity can be observed in Peñasco, with a population that is 84% Hispanic or Latino and 10% American Indigenous (Figure 3), and just 50.9% of households holding a broadband subscription. In all New Mexico school districts with a majority (greater than 50%) Hispanic/Latino population, a maximum of 81.3% of households have broadband internet, and a median of 59.8% of households with broadband. Among communities with an Indigenous population of 10% or more, a maximum of 71.3% households have a broadband subscription. These communities have a median of 53.2% households with broadband. In majority white communities (> 50%), have a maximum of 82.3% of households with broadband, and a median of 68.3% (American Community Survey, 2019).

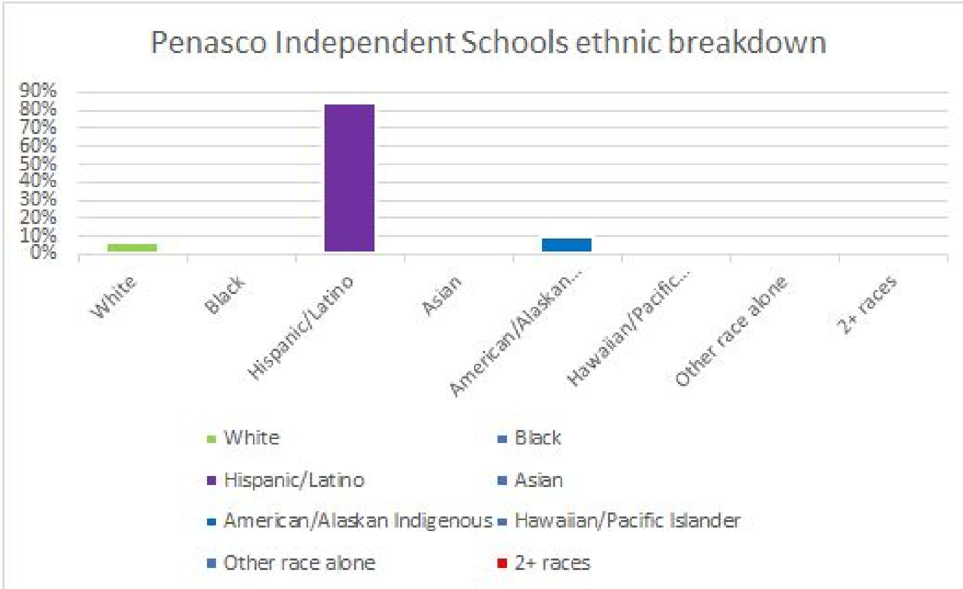


Figure 3. Ethnic makeup of the town of Peñasco

This lack of access and inequity in access is the driving force behind our project. With the need for a fast and reliable connection greater than ever during distance learning, New Mexico schools are prioritizing efforts to identify which families are in need in order to best help them. To help our sponsors plan how to best ascertain the needs of students and families, they helped us work with Peñasco Independent Schools to deploy the New Mexico Connectivity survey to local students, teachers, and parents as a pilot program.

4.1.5 Conditions of Broadband Access in New Mexico

Across levels of organization in New Mexico, there are inconsistencies in access to broadband internet. However, there are certain common threads between them. In all cases, there are more low-income areas with poor coverage than there are medium or high income areas with poor coverage. This is also true of rural areas. While some rural areas have a high percentage of broadband access, and some urban areas have poor access, it is more common for rural areas to fall below urban ones. Perhaps the most distressing disparity, towns with greater proportions of Hispanic and Indigenous appear to have significantly less access, at large, to broadband than majority white communities. There are many individuals in New Mexico lacking access to broadband internet, and there are specific groups within New Mexico who face a considerably greater challenge in gaining access than the rest of the state.

4.2 Peñasco Survey Results

The New Mexico connectivity survey was distributed to the independent school district of Peñasco on 11/30/2020 and as of 12/4/2020 we had a total of 82 responses. The responses consisted of k-12 students, college students, teachers, and parents/guardians (the breakdown of each group is shown in figure 4). When we look at the data on where the respondents were connecting, the vast majority were connecting from either their home or a family members house (shown in figure 5) .

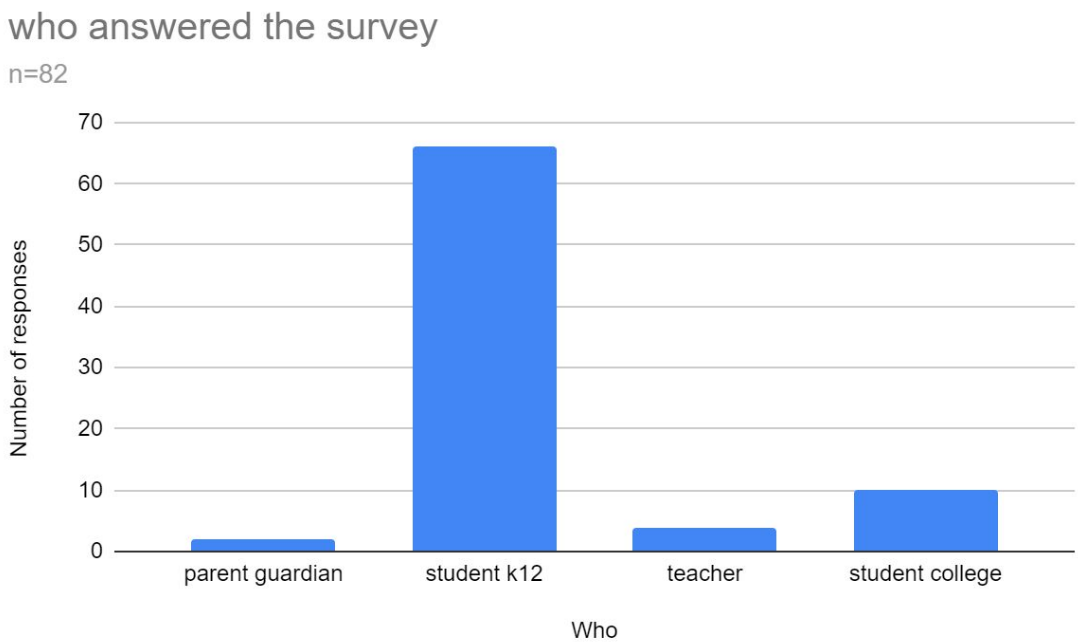


Figure 4: Breakdown of who answered the survey

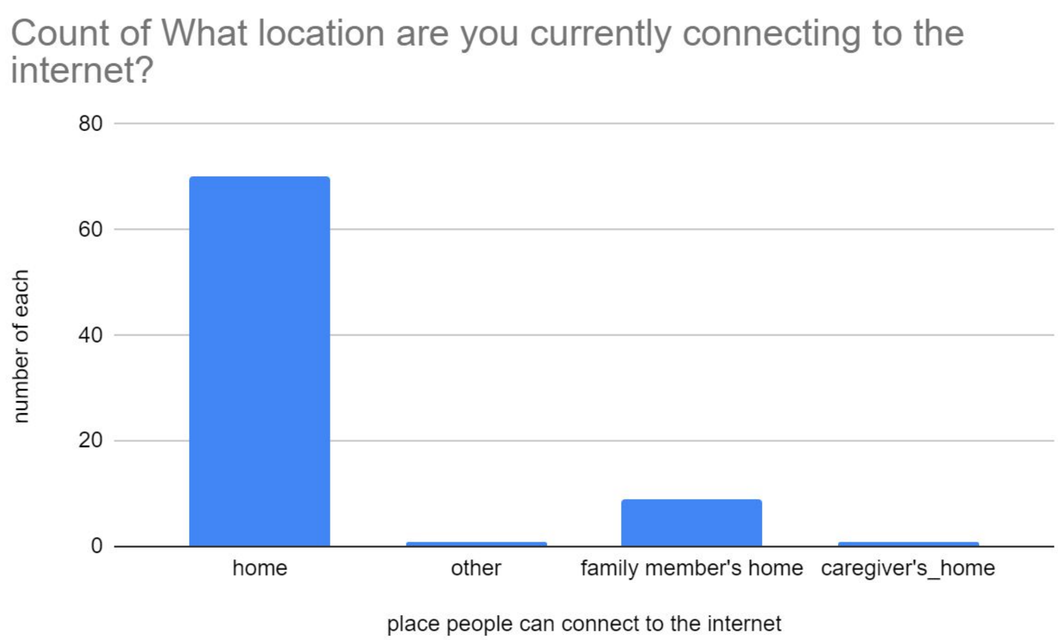


Figure 5: Places people are connecting to the internet

4.2.1 Speed analysis

Out of the 82 respondents who took the survey, 80 responded saying they had internet access with 2 saying they didn't. When we take into account that multiple answers could be put due to some people staying at multiple houses within a week, the majority of respondents had fiber or did not know which type of broadband access they had (shown in figure 6).we looked at the data and found the average, median, max and min for our upload and download speed(Appendix G). We then looked and found that 50.7% of the respondents were below the FCC standard in upload, download, or both.

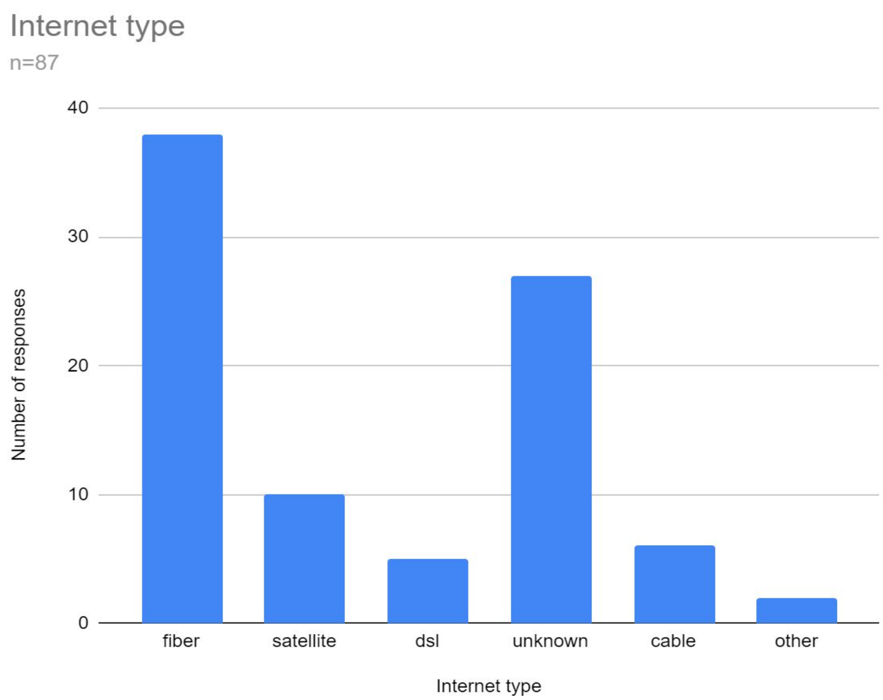


Figure 6: different internet types

4.2.2 Device access

The majority of the respondents used school provided chromebooks. These chromebooks, for the most part, were dedicated solely to that one person. There were also some who put personal laptops, desktop computers, or smartphones. These were almost entirely dedicated with only one being shared. Another result was that 23 participants responded that they need help with basic computer skills and 7 said that they needed help supporting their children with online learning. This suggests that residents in the Peñasco Independent school districts would benefit from an increase in digital literacy knowledge.

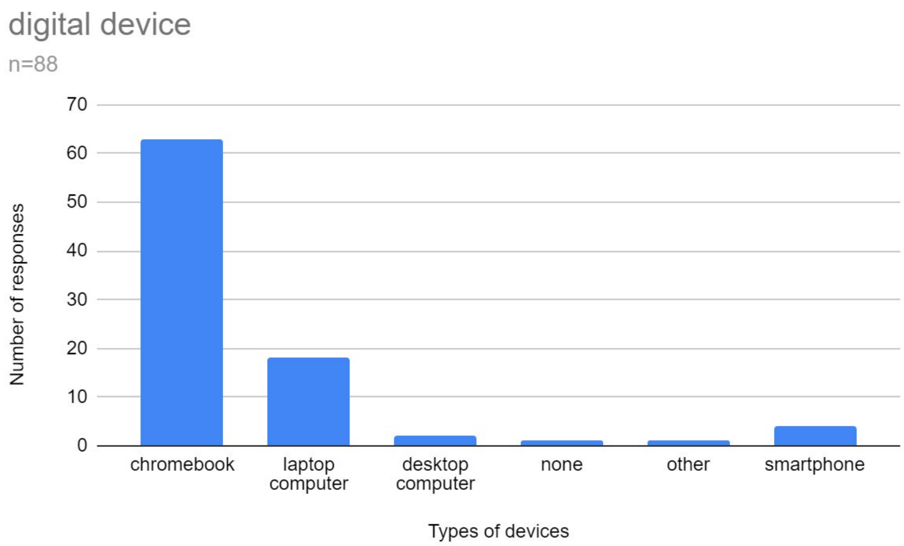


Figure 7: types of digital devices used

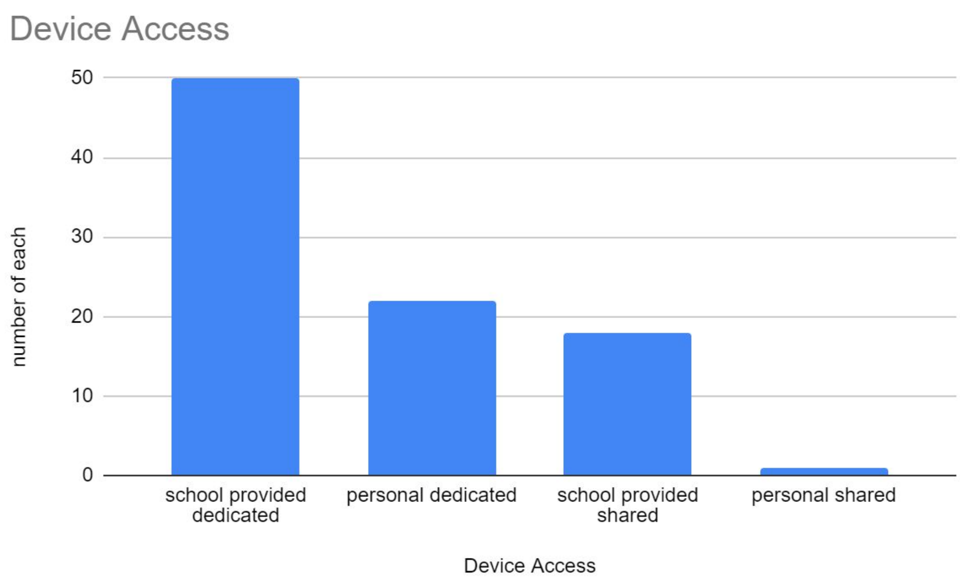


Figure 8: Device Access types

4.2.3 Comparing Survey Results to Existing Data

When comparing the results of the New Mexico Connectivity survey in Peñasco to our findings in section 4.1, several outcomes stood out. We found that in Taos county, 61.1% of its residents have access to the FCC standard for internet speeds. This is 11.8% higher than the 49.3% of respondents that had access to the FCC standard. This difference reinforces that, while some counties have access to the FCC standard, some regions in the county may fall below the average. Additionally, we found that 50.9% of the households in the Peñasco Independent school district lack broadband access. This suggests that our survey results may not be representative of the town at large, as 98% of participants claimed to have broadband access. This discrepancy reveals that there are additional considerations to be made with the deployment of the New Mexico Connectivity survey, as it is primarily being completed by students with internet access.

4.2.4 Connection Type Issues

Additionally, 26 respondents indicated that they did not know what type of connection they are using when they connect to the internet for distance learning. This makes the process of accurately assessing the quality of different types of connections within the district significantly more difficult. If there is an issue with a given type of connection in the town this may make it impossible to identify.

4.3 Policy and Infrastructure

Examining state policy is an important step for determining what strategies can be used to improve internet access in northern New Mexico. To do this, we considered three things. First, the current internet usage in New Mexico. Second, the rules for government funding and donations in New Mexico, which are different from other states. Third, we examined a number of "success stories," or projects that positively affected broadband development in other communities.

4.3.1 Internet Infrastructure and Access in Northern New Mexico

According to recent statistics on BroadbandNow, DSL, cable, satellite, and fixed wireless internet are the most common choices for internet in New Mexico. They are suitable choices for rural residential internet, due to wide coverage or high availability compared to other technologies (Appendix B). They are reasonably priced, but high speed plans for multiple people or devices are more expensive. Compared to fiber internet, these technologies only provide moderate bandwidth (50-100 Mbps max, except for cable) for the same cost. The reason residents do not have access to fiber is because the cost to install fiber-optic lines to their home would cost several thousand dollars, which neither residents nor ISPs are likely willing to pay. Unless local municipalities jumpstart broadband development, residents are likely going to have no option but to continue to use "cheaper" services instead of fiber.

4.3.2 Donations and Funding Private Projects

Many non-profit organizations and public works projects rely on government funding to achieve their goal. Typically, the government can invest taxpayer money back into the community in the form of development projects, job creation, or educational services. However, the state of New Mexico is subject to an Anti-Donation Clause, which restricts the state from funding private companies. In 2002, New Mexico released the Local Economic Development Act, which exempts certain projects from the anti-donation clause. Specifically, the state can partner with private companies for local economic development projects and economic benefit. In 2017, the New Mexico House committee passed House Bill 60 (Krasnow & Mexican, n.d.), which qualified broadband internet development as economic development, and thus exempt it from the anti-donation clause. In addition, it allowed local governments to open public trenches to private telephone/internet companies. In effect, this action lowers the cost for companies to install wireline broadband and promotes broadband expansion in unserved locations. The most cost-effective way to install wireline or fiber service is for companies to share the cost of installation with help from local governments.

4.3.3 Successful Strategies For Increasing Broadband Access

In our research, we collected 28 different broadband improvement projects from communities all over the world. A full list of every project can be found in the appendix. After documenting the themes of all 28 projects, we compared and contrasted them to derive any available commonalities. For the first theme, rurality, we found that the most common location type was rural or remote with 14 projects. 5 projects focused on urban locations, and another 3 projects focused on both rural and urban settings. Lastly, 6 projects did not explicitly state this information. From these groupings we can see that digital divide projects tend to focus on rural or remote areas. This aligns with the trends that we have explained previously, such as in sections 2.1 and 4.1. gathered in our background chapter.

For the theme of affected demographics, we found that it was very uncommon for these projects to explicitly state this information. However, any mention of demographics revolved around low-income families or households. This included students with free or reduced lunch and HUD-assisted households.

When looking for common solutions, we found implementation of fiber-optic infrastructure to be a very common strategy. This particular solution was commonly backed with funding received from grants and donations. One common funding source was the ReConnect program from the USDA. This program provides loans, grants, and combinations of both for areas of rural United States that do not have adequate access to broadband. Another common solution among these projects was the implementation of technology donations. Rather than recycling old or broken electronics, several projects implemented a donation system where they would refurbish these electronics and distribute them to communities lacking access.

5 Reconnecting New Mexico Website

Northern New Mexico is just one of many regions in the United States that lack the digital infrastructure and resources needed to create a reliable internet connection for their students, teachers, and families (National Broadband Plan, 2010). We created a website that can be a tool for New Mexico residents to use to learn more about broadband access and equity. We display relevant data sets, maps, and provide guidance on participation in bridging the digital divide by completing available surveys. Communities lacking digital infrastructure and resources outside of New Mexico could also use this website for similar reasons.

The website that we created, called "Reconnecting New Mexico", is modeled after the Michigan Moonshot's three pillar approach. The Michigan Moonshot is a program run by Merit that aims to end the digital divide in Michigan by providing its communities with broadband coverage maps and other data collection resources to inform residents about infrastructure planning. To do this, The Michigan Moonshot uses the following three pillars to organize their work:

- Data & mapping
- Policy & funding
- Education & resources

Our sponsors found this method of using three pillars to present information to be effective, so we used The Michigan Moonshot website as a model for organizing the website we created. The Reconnecting New Mexico website contains the results of our research, analysis, and other useful resources to inform community members and direct them toward additional materials for expansion of broadband access. To organize this information, the website we created is broken into three different sections that our sponsor thought would be best to present our data and findings from our previous objectives. The section of the website, "data & maps", is a place where visitors to the website can view the data that we have processed. From the data that we collected in objectives 1 and 2, we were able to create multiple different ways to present our findings. The content on this section is as follows:

- Data tables
  - Data on each county of New Mexico including statistics such as population, demographic makeup, and average access to the FCC standard for internet speeds.
  - Data on each school district in New Mexico including statistics such as population, median household income, and percentage of households with broadband access.
  - Data from the New Mexico Connectivity survey results. This includes all survey responses as of 12/4/2020.
- ArcGIS maps.
  - An interactable ArcGIS map that contains all of the school district data mentioned in the previously mentioned data table.
  - A photo of an ArcGIS map that shows where each response from the New Mexico Connectivity Survey was taken from. This map is not interactable due to privacy concerns.

The next section, “policy and funding”, is a place where visitors to the website can view existing policies from New Mexico, and the United States as a whole, that relate to providing broadband access to the state or entire country. Additionally, visitors can access information regarding funding that New Mexico has received to bridge the digital divide.

The final section, “resources”, is a place where visitors to the website can learn about how they can help to bridge the digital divide or learn more about it. The content on this section is as follows:

- Connectivity survey
  - Here, visitors can take the New Mexico Connectivity survey, and to ensure that each participant understands each question, we have provided an instructional video.
- Infographics
  - An infographic that describes the 8 most popular internet services along with the pros and cons of each.
  - An infographic that presents a timeline of satellite internet and how it has improved over the last 10 years.
  - An infographic of the New Mexico Connectivity survey results.
- Success Stories
  - Here, we provide an interactive ArcGIS map of the 28 different projects that we gathered for objective 3. Visitors can use the map to learn more about each project or they can click on the tiles provided below the map to be taken to the project’s website.
- Terms
  - Here, we provide definitions to any broadband related terms that we have mentioned on the website.

6 Recommendations

In this chapter we outline recommendations to gain further insight into conditions of a given district, improve the process of survey deployment, and potential actions to take to improve broadband access and use in New Mexico school districts.

6.1 Gaining Teachers' Perspectives to Inform Survey Results

We recommend that in future use of this survey, additional information is sought from teachers in the school district. Initially we had planned on deploying a survey specifically to teachers in addition to the New Mexico Connectivity Survey in order to gain a more complete understanding of the state of connectivity in Peñasco. Many of the respondents have poor and/or limited access to broadband and different types of internet capable devices. For this reason, it is possible that some of them, especially younger children, do not have the experience or vocabulary necessary to fully describe the shortcomings of their connection or devices. To avoid the potential for these gaps in information to arise, we created a set of questions specifically for teachers to answer. Upon suggestion from our sponsors, we have realized that deploying an additional survey to teachers who already have heavy workloads may not be the most effective way to gain this information. Our conclusion is that districts should individually decide what is the best way to allow teachers to indicate connectivity problems they or their students face that interfere with teaching or learning which may not be reflected in the connectivity survey. In all cases, we recommend that districts attempt to gain the information requested in the survey questions, available in Appendix D.

The survey we created asks questions regarding availability of technological resources and observed quality of internet connection for both students and teachers. We also ask how these factors influence their teaching, if at all, and if there are any other recurring technology or internet issues they notice while conducting distance learning. We recommend these questions or questions adapted from them are sent to teachers concurrently with launching of the connectivity survey to students, teachers, and guardians.

The main obstacle we faced in having this survey sent to teachers during our pilot program was the fact that it did not receive approval from the Public Education Department (PED). Therefore, the first step taken in preparation to send this survey to teachers, or deploy whatever plan for gaining this information the district has constructed, should be promptly submitting it for approval by PED and making any required changes as soon as possible.

Once the submission receives approval, it should be sent to superintendents or principals for distribution to teachers. The purpose of this is to increase response rates by having the survey come from a person whose instructions they are used to following. Ideally administrators should also request (not instruct) that teachers provide them with this information by a given time. This unofficial deadline would preferably be within a week or less of dispersal to teachers. Because the goal of assessing the needs of the district is to find a way to fulfill them as quickly as possible, the party or parties enacting the district's plan should encourage respondents to make their submissions as quickly as possible.

After most or all responses have been received, resulting data should be analyzed and compared to that from the connectivity survey. If both sets point towards the same prevalent issues and the same degree of severity, it is likely that the connectivity data is accurate and can be used to meaningfully help those in need within the district. If there are significant discrepancies between the sets, this would indicate that there may be significant inaccuracies in one or both. In this case, further examination should be performed.

6.2 Implementation of a Second Pilot Survey

We recommend implementing a second pilot survey before deploying the New Mexico Connectivity to the rest of New Mexico. The deployment of the survey to the Peñasco school district, mentioned in our second objective, was a pilot test. In order to ensure that the survey was functional, easy to understand, and produced useful results, it was deployed to only 1 of the 89 different school districts in New Mexico; Peñasco. After survey completion in the Penasco school district, this program will continue to be distributed to all other school districts in northern New Mexico. This process will be continued by our sponsors, CLN and NMDoIT, with approval from PED. In order to improve the number of responses and limit the time it takes to receive a meaningful portion of data, we recommend performing a second pilot test to continue refining methods of integrating the survey, its videos, and instructions on the state canvas page, set up by the PED so that all the needed information for the survey can be found in one location. This would make it easier for teachers to get familiar with, learn about, and then distribute the survey to their students.

Once the state canvas page to give respondents access to the survey is ready, we believe the next step is to distribute the survey to several additional school districts, ideally with a larger number of schools and students. Central consolidated school district is a great example of a district we think should be included in the next round of surveys due to its increased population, similar lack of majority broadband access and similar demographic. After this second round of survey distribution, we recommend designating a period of time used to gather feedback from the new school districts surveyed as well as Peñasco schools/teachers. After these revisions are made, statewide deployment of the survey can begin through the canvas page.

6.3 Digital Literacy Recommendations

We recommend looking into implementing a digital literacy improvement program. In addition to having internet access, new consumers need to learn how to use digital devices and software effectively. In Penasco, 23 participants responded that they need help with basic computer skills and 7 said that they needed help supporting their children with online learning. For this, we suggest implementing digital literacy courses in schools for students and teachers. These would ideally train students to be able to use Office apps, manage files or cloud storage, practice internet security, and more. An online course could be extended to parents or adults to cover topics such as online banking and tools for working remotely. The CLN has a “digital literacy toolkit” on their site (*Digital Literacy Training Toolkit*, n.d.), which covers topics from basic computer functions to managing privacy and security. Promoting these resources and expanding the “courses” will benefit the community.

6.4 Technology Assessment Recommendations

We recommend using the results from the New Mexico Connectivity survey to determine what connection type might be most effective for the 8 northern counties in New Mexico. From the results of the New Mexico Connectivity survey, it’s apparent that some students are unsure of what type of internet service they are using. When asked what type of internet service they are using, 23 students selected “unknown” for their connection type. This lack of knowledge may have led to skewed results, where respondents selected the wrong type of connection, causing an incorrect average upload and download average for each connection type. Due to this, we are unable to make any concise technology recommendations for the Peñasco Independent school district. However, we suggest that in further deployment of the New Mexico Connectivity survey, the average download and upload speeds for each type of service be investigated in order to determine what the best internet service type would be for each county.

6.5 Policy Recommendation

We recommend a strategy for increasing broadband development in New Mexico based on the 'Ammon Model' in cases where the use of fiber is practical (Appendix A). This approach allows residents to pay a discounted fee to install fiber to their house in conjunction with neighboring buildings. The city maintains the network as an open access utility, and providers and residents can subscribe to use it. Having realized the success of broadband development in Ammon, Idaho, we think it would be worthwhile to investigate if a similar strategy can be applied in New Mexico.

7 Conclusion

Over the course of this project, our observations of the surveying process and results have led us to several conclusions on what is advisable to continue doing and what is not. A method that our group would have liked to use in addition to the survey would have been teacher interviews. Although we would not be able to interview a similar number of people as the amount of people we surveyed, the answers from those interviews will be in more detail as their answers don't need to come from a predetermined list of answers. Our group would have liked to have a combination of both to try and get as much information as possible, but time constraints limited what we could do so a survey on New Mexico connectivity was our best choice.

7.1 Demographic Patterns

Trends in the data we have collected appear to show several consistent inequities in broadband internet access. Overall, low income areas seem to be less likely to have high broadband access, while high income areas rarely have poor access. Similarly, rural areas make up a larger portion of areas with lacking access than urban areas, and urban areas make up a larger portion of areas with higher access. Another troublingly prominent disparity in equity can be seen in areas with higher Hispanic and Indigenous populations, which have lower median access than majority white communities by 8.5% and 15.1% respectively.

7.2 The New Mexico Connectivity Survey

We received 82 total responses from the New Mexico connectivity as of 12/4/2020. These responses are from 76 students, 2 parents and 4 teachers from the school district of Peñasco. Originally the survey was going to be sent to 8 different counties in northern New Mexico but due to issues in getting the survey approved by PED we were limited to the school district of Peñasco. The one thing that could have been done to first get more responses in general and second allow for more school districts to be surveyed is simply started the process for approval earlier. The survey was only distributed 4 days prior and simply having more time to allow for people to partake in the survey would increase the number of responses. Additional steps should be taken to improve the comprehensiveness and timeliness of responses, as well as to gain supplementary information.

7.3 Digital Literacy

Although obtaining broadband access is important, knowing how to effectively use digital resources can be just as imperative. From the results of the New Mexico Connectivity survey, many participants noted that they needed help with basic computer skills or online learning. Several respondents also said that they are unsure of what type of internet service they are using. An increased knowledge of digital resources would not only provide more reliable survey results but it would more importantly help the community to take advantage of available information and communication technologies.

References

2018 Broadband Deployment Report. (2018, February 5). Federal Communications Commission. https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2018-broadband-deployment-report

2019 *Broadband deployment report*. (2019, May 19). Federal Communications Commission. Retrieved from https://docs.fcc.gov/public/attachments/FCC-19-44A1.pdf

American Community Survey. (2019). *Peñasco Independent Schools, NM*. Institute of Education Sciences, National Center for Educational Statistics. https://nces.ed.gov/Programs/Edge/ACSDashboard/3502040.

Anderson, M., & Perrin, A. (2020, May 30). Nearly one-in-five teens can't always finish their homework because of the digital divide. Retrieved November 10, 2020, from https://www.pewresearch.org/fact-tank/2018/10/26/nearly-one-in-five-teens-cant-always-finish-their-homework-because-of-the-digital-divide/

Annual Rate Committee Meeting Public Notice and Agenda. https://www.doit.state.nm.us/.

Auxier, B., & Anderson, M. (2020, July 27). As schools close due to the coronavirus, some U.S. students face a digital 'homework gap'. Retrieved November 10, 2020, from https://www.pewresearch.org/fact-tank/2020/03/16/as-schools-close-due-to-the-coronavirus-some-u-s-students-face-a-digital-homework-gap/

Best Dial-up Internet. (n.d.). *BroadbandNow*. Retrieved November 24, 2020, from https://broadbandnow.com/internet/best/dial-up

Blais, J. J., Craig, W. M., Pepler, D., & Connolly, J. (2008). Adolescents Online: The Importance of Internet Activity Choices to Salient Relationships. *Journal of Youth and Adolescence*, *37*(5), 522–536. https://doi.org/10.1007/s10964-007-9262-7

BroadbandNow. (2020 a, November 27). *Internet Access in Penasco New Mexico*. broadbandnow.com. https://broadbandnow.com/New-Mexico/Penasco.

BroadbandNow. (2020 b, December 1). *Internet Providers With Data Caps*. https://broadbandnow.com/internet-providers-with-data-caps.

Krasnow, B., & Mexican, T. S. F. N. (n.d.). *Bill aims to help broadband expansion in NM*. NMPolitics.Net. Retrieved December 4, 2020, from https://nmpolitics.net/index/2017/01/bill-aims-to-help-broadband-expansion-in-nm/

City-Data. (2020 b). *Penasco, New Mexico (NM) Poverty Rate DataInformation about poor and low-income residents*. Penasco, New Mexico (NM) poverty rate data - information about poor and low-income residents living in this city. http://www.city-data.com/poverty/poverty-Penasco-New-Mexico.html.

CommUNITY connectivity. (2020). Community Learning Network. Retrieved September 18, 2020, from https://www.communitylearningnetwork.org/community-connectivity.html

Cooper, T. (2020 a, October 28). Cable Internet in the United States at a Glance. Retrieved from https://broadbandnow.com/Cable

Cooper, T. (2020 b, October 28). DSL Internet in the United States at a Glance. Retrieved from https://broadbandnow.com/DSL

Cooper, T. (2020 c, March 30). Fiber-optic Internet in the United States at a glance. Retrieved from https://broadbandnow.com/Fiber

Cooper, T. (2020 d, October 28). Fixed Wireless Internet in the United States at a Glance. Retrieved from https://broadbandnow.com/Fixed-Wireless

Cooper, T. (2020 e, September 01). Internet Access in New Mexico: Stats & Figures. Retrieved from https://broadbandnow.com/New-Mexico

Cooper, T. (2016, October 24). Powerline Broadband Internet in the United States at a Glance. Retrieved from https://broadbandnow.com/Powerline

Cooper, T., & Tanberk, J. (2020, March 3). Best and Worst States for Internet Coverage, Prices and Speeds, 2020. Retrieved from https://broadbandnow.com/research/best-states-with-internet-coverage-and-speed

Da, R. (2020, August 20). New study shows 25% of NM students lack internet access. Retrieved from https://www.koat.com/amp/article/new-study-shows-25-percent-of-nm-students-lack-internet-access-teachers-schools-new-mexico-news/33650300

Digital Literacy Training Toolkit. (n.d.). Community Learning Network. Retrieved December 4, 2020, from https://www.communitylearningnetwork.org/digital-literacy-training-toolkit.html

Fixed Wireless Internet Providers. (n.d.). *HighSpeedInternet.Com*. Retrieved November 25, 2020, from https://www.highspeedinternet.com/providers/wireless

Kasiviswanathan, S. P., Eidenbenz, S., & Yan, G. (2011). Geography-based analysis of the Internet infrastructure. 2011 Proceedings IEEE INFOCOM. doi:10.1109/infcom.2011.5934915

KRQE. (2020, November 10). Santa Fe Public Schools to return to remote learning. https://www.krqe.com/news/education/santa-fe-public-schools-to-return-to-remote-learning/.

Lancker, W. V., & Parolin, Z. (2020). COVID-19, school closures, and child poverty: A social crisis in the making. The Lancet Public Health, 5(5). doi:10.1016/s2468-2667(20)30084-0

Lathan, J. (2020, January 08). What is Educational Technology? [Definition, Examples, Etc.]. Retrieved November 27, 2020, from https://onlinedegrees.sandiego.edu/what-is-educational-technology-definition-examples-impact/

Lujan, E., Sanchez, M. R. (2018). State fiscal year 2019 - 2021. Retrieved September 19, 2020, from https://www.doit.state.nm.us/docs/strategic_planning/strategic_plans/361-DoIT%202019-2021%20IT%20Plan%2009042018.pdf

Malecki, E. J. (2003). Digital development in rural areas: potentials and pitfalls. *Journal of Rural Studies*, *19*(2), 201–214. https://doi.org/10.1016/s0743-0167(02)00068-2

Mansfield, E., & Conlon, S. (2020, April 1). Coronavirus for kids without internet: Quarantined worksheets, learning in parking lots. Retrieved November 17, 2020, from https://www.usatoday.com/story/news/education/2020/04/01/coronavirus-internet-speed-broadband-online-learning-school-closures/5091051002/

Meyer, L. (2016, June-July). Home connectivity and the homework gap. T H E Journal [Technological Horizons In Education], 43(4), 16. https://link.gale.com/apps/doc/A460060798/AONE?u=mlin_c_worpoly&sid=AONE&xid=7d801980

Merriam-Webster. (n.d.). Digital divide. In Merriam-Webster.com dictionary. Retrieved November 27, 2020, from https://www.merriam-webster.com/dictionary/digital%20divide

Muhammad, D. A. (2019, December 4). *Racial Wealth Snapshot: American Indians/ Native Americans " NCRC*. https://ncrc.org/racial-wealth-snapshot-american-indians-native-americans/.

National Broadband Plan. (2010, March 17). Federal Communications Commission. https://www.fcc.gov/general/national-broadband-plan

Pew Research Center. (2020, June 05). Demographics of Internet and Home Broadband Usage in the United States. Retrieved November 24, 2020, from https://www.pewresearch.org/internet/fact-sheet/internet-broadband/

Prieger, J. E. (2013). The broadband digital divide and the economic benefits of mobile broadband for rural areas. Telecommunications Policy, 37(6–7), 483–502. https://doi.org/10.1016/j.telpol.2012.11.003

Pros And Cons Of Satellite Internet. (n.d.). BroadbandNow. Retrieved November 25, 2020, from https://broadbandnow.com/guides/satellite-internet-pros-and-cons

Santillana, M., Sraubhaar, J., Schrubbe, A., Choi, J., & Strover, S. (2020). Digital inequalities: Homework gap and techno-capital in Austin, Texas. First Monday, 25(7). https://doi.org/10.5210/fm.v25i7.10860

Schafer, D. (2019, December 2). How Much Does Satellite Internet Cost? *SatelliteInternet.Com*. https://www.satelliteinternet.com/resources/how-much-does-satellite-internet-cost/

The History of the Internet. (n.d.). Plusnet. Retrieved November 24, 2020, from https://www.plus.net/home-broadband/content/history-of-the-internet/

The Michigan Moonshot. (2020). Retrieved November 10, 2020, from https://www.merit.edu/community/moonshot/

US Census Bureau. (2016, December 22). *A Comparison of Rural and Urban America: Household Income and Poverty*. The United States Census Bureau. https://www.census.gov/newsroom/blogs/random-samplings/2016/12/a_comparison_of_rura.html.

U.S. Census Bureau QuickFacts. (2019). 2019 Population Estimate. U.S. Census Bureau. https://www.census.gov/quickfacts/fact/table/NM/PST045219 (Accessed on November 30, 2020)

What Is Fiber Internet? (n.d.). CenturyLink. Retrieved November 24, 2020, from https://www.centurylink.com/home/help/internet/fiber/what-is-fiber-internet.html

Appendices

Appendix A: Digital Inclusion Programs

A.1 Programs

Program/Organization	State/Province
Community Learning Network (CLN)	New Mexico
Department of Information Technology (NMDoIT)	New Mexico
New Mexico Department of Education (PED)	New Mexico
Michigan Moonshot	Michigan
Federal Communications Commission (FCC)	National

A.2 The 'Ammon Model'

The 'Ammon Model' refers to a strategy where "the municipality facilitates the financing and construction of the infrastructure and then takes on the responsibilities of maintenance and operation after construction. This is all done with the participation and support of the people served." (Patterson, 2018). In short, residents pay a discounted fiber installation fee, because the town paid for a "bulk install" for that street.

Patterson, B. (2018, June). What Is the 'Ammon Model'? BroadbandCommunities. http://www.bbcmag.com/community-broadband/what-is-the-ammon-model

Appendix B: Internet Types and Availability

B.1 Types of Internet

Connection Type	Description	Speeds	Data Cap	Cost	Major Providers in New Mexico
Dial-up	Very slow, uses phone lines, requires dialing provider to turn on	56 Kbps	None	$5-20	N/A
DSL	First broadband connection available, uses phone lines, typically ADSL (faster download)	20-50 Mbps	1 TB - Unlimited	$30-50	CenturyLink, Tularosa, Windstream, EarthLink, Cyber Mesa Telecom
Cable	Broadband over cable infrastructure, faster than DSL	20-1,000 Mbps	Unlimited	$20-100	Xfinity (Comcast), Spectrum, Sparklight
Mobile Wireless	Wireless broadband, delivers internet to smartphones via a cellular connection	3-10 Mbps	Unlimited	$30-150	At&T, Verizon, T-Mobile
Satellite	Wireless broadband, wide area coverage, high latency, affected by weather and elevation	12 - 100 Mbps	10-300 GB	$30-150	Viasat, HughesNet
Fixed Wireless	Wireless broadband over radio towers, wide area coverage, affected by to weather and obstacles	5-250 Mbps	Unlimited	$30-150	TWN Communications, Kit Carson, Tularosa, Plateau, Southwestern Wireless, NMSurf
Long Range WiFi/ Repeaters	Extends a WiFi signal to detached buildings/locations, reliable, but require line of sight	WiFi	None	Varies by device	N/A (business/personal)
Hotspots/ public access	Provides free WiFi at businesses and public transportation, not secure, slower with more connections	WiFi	None	Free	N/A (business/personal)
Mesh Networks	Made up of wireless nodes that communicate with each other, less secure	10-50 Mbps	None	$0-30	Lokket
Powerlines (BPL)	Broadband over power lines, susceptible to wireless interference (no insulation)	20-90 Mbps	Unlimited	$30-50	None
Fiber	Fastest broadband via light through glass cables, low latency	50-1,000 Mbps	Unlimited	$30-100	CenturyLink, Tularosa, Windstream, Plateau

Cooper, T. (2020 c, March 30). Fiber-optic Internet in the United States at a glance. Retrieved from https://broadbandnow.com/Fiber

Cooper, T. (2020 d, October 28). Fixed Wireless Internet in the United States at a Glance. Retrieved from https://broadbandnow.com/Fixed-Wireless

Pros And Cons Of Satellite Internet. (n.d.). BroadbandNow. Retrieved November 25, 2020, from https://broadbandnow.com/guides/satellite-internet-pros-and-cons

The History of the Internet. (n.d.). Plusnet. Retrieved November 24, 2020, from https://www.plus.net/home-broadband/content/history-of-the-internet/

B.2 Internet Types Pros and Cons

Type of Connection	Pros	Cons
Dial-up	Cheap	Very slow, few providers in NM
DSL	Wide availability, lots of providers in NM	Can be slow
Cable	Moderate speed	Fewer providers
Mobile Wireless	Good coverage, fast	Expensive
Satellite	Wide area coverage, moderate speed	Expensive, low data caps, only 2 major providers
Fixed Wireless	Wide coverage, many providers, cheap, moderate speed	
Long Range WiFi	Cheap, long range, fast	
Hotspots/public access	Free, convenient	Can become slow
Mesh Networks	Cheap, wide access, moderate speed	Few providers
Powerlines (BPL)	Fast speed, cheap	No providers in the US
Fiber	Very fast, lots of providers	Expensive, low coverage

B.3 Availability of Internet Services in New Mexico

NM County	% Coverage	# Providers	Available Services
Bernalillo	97.70%	25	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Catron	14.20%	6	DSL, Mobile Wireless, Satellite
Chaves	88.50%	17	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Cibola	58.80%	12	DSL, Fixed Wireless, Mobile Wireless, Satellite
Colfax	16.10%	13	DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Curry	98.30%	13	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
De Baca	82.30%	9	DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Doña Ana	87.60%	17	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Eddy	89.30%	17	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Grant	83.20%	14	Cable, DSL, Fixed Wireless, Mobile Wireless, Satellite
Guadalupe	77.90%	10	DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Harding	67.90%	10	DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite

NM County	% Coverage	# Providers	Available Services
Hidalgo	2.70%	11	DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Lea	92.10%	14	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Lincoln	83.80%	17	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Los Alamos	99.50%	17	Cable, DSL, Fixed Wireless, Mobile Wireless, Satellite
Luna	62.50%	16	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
McKinley	47.20%	14	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Mora	62.70%	10	DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Otero	83.40%	21	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Quay	59.00%	11	DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Rio Arriba	66.60%	16	DSL, Fixed Wireless, Mobile Wireless, Satellite
Roosevelt	82.40%	14	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Sandoval	86.80%	26	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
San Juan	75.40%	13	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
San Miguel	59.40%	17	DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Santa Fe	89.10%	25	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Sierra	82.10%	13	Cable, DSL, Fixed Wireless, Mobile Wireless, Satellite
Socorro	5.90%	17	DSL, Fixed Wireless, Mobile Wireless, Satellite
Taos	60.00%	12	DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Torrance	46.30%	18	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite
Union	63.90%	13	DSL, Fiber, Mobile Wireless, Satellite
Valencia	87.30%	17	Cable, DSL, Fiber, Fixed Wireless, Mobile Wireless, Satellite

Cooper, T. (2020 e, September 01). Internet access in New Mexico: stats & figures. Retrieved from https://broadbandnow.com/New-Mexico

Broadband Map Gallery: County Focus Maps & Statistics. (2014, October 1). https://www.doit.state.nm.us/broadband/map_county_availability.shtml

Appendix C: New Mexico Connectivity Survey

C.1 Questions

1. I am a [select option]
    a. Student K12
    b. Student - College
    c. Teacher
    d. Parent/Guardian
    e. Other
2. Your address where you connect to the internet: [type address]
3. What device does the student most often use to complete schoolwork at home?
    a. Chromebook
    b. Desktop Computer
    c. Laptop computer
    d. Tablet
    e. Smartphone
    f. none
    g. other
4. Is the primary learning device a personal device or school provided? Is the primary learning device shared with anyone else in the household?
    a. personal - dedicated
    b. personal - shared
    c. school provided - dedicated
    d. school provided - shared
    e. other
5. Can the student access the internet on their primary learning device at home?
    a. yes
    b. no
6. What is the primary type of internet service used at home?
    a. fiber
    b. cable
    c. DSL
    d. microwave
    e. satellite
    f. Dial-up
    g. personal hotspot
    h. school provided hotspot
    i. unknown
    j. none
    k. other
7. Can the student stream a video on their primary learning device without interruption?
    a. yes no issue
    b. yes, but not consistently
    c. no
8. How many locations do you connect to the internet on a weekly basis?
9. What location are you currently connecting to the internet

   a. home
   b. family members house
   c. caregiver's home
   d. church
   e. library
   f. other
10. Go to the mLab website and run your Speed Test [type in internet statistics]
11. Do you need help with: [select option]
    a. Basic computer skills (technical)
    b. Supporting your child/children with online learning
    c. Other
12. Please type in your email if you want to be contacted

Appendix D: Success Stories

Name	Rurality	Affected demographic	Solution.
LabGov New York: The Harlem e-Project	Urban	Not stated	Community Network & Edge Cloud
Close The Gap	Rural/Remote	Low income	Refurbished technology donations.
Leslie County High School	Rural	Not stated	Fiber infrastructure implementation
Linux4Africa	Rural	African communities	Refurbished technology donations
EveryoneOn - ConnectHomeUSA	Nationwide	Low income, HUD-assisted households	Provides free or low-cost broadband access, devices, and digital literacy training. (Funding)
City of San Diego's Push to Tackle Digital Divide Moves Forward	Urban	Not stated	Refurbished technology donations
Sharing the NextLight	Rural	Low income, students who receive free or reduced lunch	Free income-qualified internet connection for children from pre-K through college. (Funding)
Chicago Launches Groundbreaking Initiative To Bridge Digital Divide	Urban	Low income, students eligible for free lunch	100,000 CPS students will receive free high-speed internet access for the next four years. (Funding)
Kit Carson Electric Cooperative Fiber-to-the-Home Project	Rural	Not stated	Fiber infrastructure implementation (Funding)
California - Closing the Digital Divide Initiative	Both	Not stated	Learning Loss Mitigation Funding (LLMF)
E2D	Urban	Low income families	Use of donations (used tech, time and money) to provide devices to students
Connected Nation - Texas	Rural	Not stated	Use of funding from Texas Rural Funders to help provide broadband
CDE Lightband	Not stated	Not stated	Fiber infrastructure implementation
Rocket Fiber	Urban	Not stated	Fiber infrastructure implementation
Chariton Valley	Rural	Not stated	Fiber infrastructure implementation
Mainstream Fiber Networks	Rural	Not stated	Fiber infrastructure implementation
Lumos Networks	Not stated	Not stated	Fiber infrastructure implementation
Greenlight Networks	Not stated	Not stated	Fiber infrastructure implementation
Digital Divide Data	Not stated	Not stated	Digital literacy programs
Connected Nation - Michigan	Rural	Not stated	Use of funding to help provide broadband
Human-I-T	Not stated	Not stated	Refurbished technology donations, discounted internet subscriptions, and digital literacy training

Name	Rurality	Affected demographic	Solution.
DayStarr Communications	Not stated	Not stated	Fiber infrastructure implementation
USDA Rural Tennessee Communities	Rural	Not stated	Fiber infrastructure implementation (USDA ReConnect)
The 'Jio Effect'	Not stated	Not stated	Introduction of 4g wireless internet
MainOne and Orange ink deal	Rural/remote	Developing countries	Investment into two new cable landing stations
USDA Rural Alaska	Rural	Not stated	Fiber infrastructure implementation (USDA ReConnect)
Airtel	Rural/remote	Not stated	High speed 4g networks were expanded into 26 villages.
Ammon	Urban	Not stated	The 'Ammon' Model

Appendix E: Teacher Survey

1. What devices do you have available that help you to conduct class virtually?
2. Do you have mostly usable (functional; enough to be used effectively) technology available to you for teaching purposes?
3. How does this impact your ability to teach effectively?
4. Do you have access to an internet connection and technology that allows you to effectively communicate with your students once you leave the classroom?
5. What has more of an effect on your ability to teach effectively?
6. Which of the following frequently interfere with your ability to teach effectively?
7. For the selections made above, do these frequently occur due to your connection, or that of your students?
8. If any of the factors in the previous question do affect your teaching, which aspects?
9. What methods of communication do you regularly use to relay information to your students outside of class?
10. Do you notice that any students have a consistent lack of access to adequate internet or technology for educational purposes?
11. Are there any other barriers to digital learning not previously mentioned that you have consistently or frequently faced while teaching?

Appendix F: Demographics for Target Areas

		Los Alamos	Mora	Rio Arriba	Sandoval	San Juan	San Miguel	Sante Fe	Taos
Internet	Broadband Access	99.5%	62.6%	77.4%	87.3%	76.1%	63.2%	91.0%	61.6%
	Households with Broadband Subscription	86.1%	51.2%	52.1%	81.6%	63.0%	52.9%	78.7%	61.3%
	Available ISPs	9	5	8	13	7	9	12	12
Income	Median Income ($)	115,248	26,968	N/A	59,420	50,582	31,660	59,192	36,758
	Poverty	3.9%	23.5%	22.0%	12.6%	23.1%	28.2%	12.2%	21.4%
	Unemployment	4.2%	8.5%	9.1%	9.6%	11.3%	8.8%	9.2%	12.2%
Population	Rurality*	Mostly urban	Completely rural	Mostly urban	Mostly urban	Mostly urban	Mostly urban	Mostly urban	Mostly rural
	Total Population	19,572	4,521	38,921	146,748	123,958	27,277	150,358	32,723
	Population Density (people/mile^2)	164.4	2.5	6.9	35.5	23.6	6.2	75.5	15.0

Cooper, T. (2020 e, September 01). Internet access in New Mexico: stats & figures. Retrieved from https://broadbandnow.com/New-Mexico

Broadband Map Gallery: County Focus Maps & Statistics. (2014, October 1). https://www.doit.state.nm.us/broadband/map_county_availability.shtml

New Mexico Workforce Connection. (2020, October). *Labor force, employment, and unemployment for New Mexico in October, 2020*. https://jobs.state.nm.us/vosnet/timeout.aspx?lblErrorMessage=GSIPage+L258+no+AUS+from+results.aspx+at+instantiation.

US Census Bureau. (n.d.) *U.S. Census Bureau QuickFacts: San Miguel County, New Mexico; San Juan County, New Mexico; Sandoval County, New Mexico; Rio Arriba County, New Mexico; Mora County, New Mexico; Los Alamos County, New Mexico*. Census Bureau QuickFacts. https://www.census.gov/quickfacts/fact/table/sanmiguelcountynewmexico,sanjuancountynewmexico,sandovalcountynewmexico,rioarribacountynewmexico,moracountynewmexico,losalamoscountynewmexico/PST045219.

US Census Bureau. (n.d.). *U.S. Census Bureau QuickFacts: Taos County, New Mexico; Santa Fe County, New Mexico*. Census Bureau QuickFacts. https://www.census.gov/quickfacts/fact/table/taoscountynewmexico,santafecountynewmexico/PST045219.

US Census Bureau. (2020, February 24). *Urban and Rural*. https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural.html.

Appendix G: Survey results on Download and upload speed

Internet Access Type in Residence	Download	Upload
fiber	49.23	49.91
fiber	344.9	11.52
fiber,other		
satellite	12.22	1.29
fiber	101.99	77.36
fiber	5.45	1.54
fiber	66.05	90.44
fiber	40.77	48.29
fiber	16.66	62.33
fiber	23.24	1.69
fiber	95.3	37.12
fiber	29.37	26.54
satellite	2.3	14.74
dsl	9.85	1.34
unknown	0.37	0.57
satellite	2.19	1.41
satellite	43.71	21.47
unknown	45.8	55.29
cable,satellite	3.32	1.43
fiber	86.73	100
fiber	6.96	62.56
fiber	13.9	27.15
satellite	24.53	67.81
unknown		
fiber	16.88	1.58
fiber	195.37	145.28
dsl	63.31	25.96
dsl	12.44	29.6
unknown	6.6	66.51
unknown	49.42	6.72
cable	12.36	4.11
fiber	19.9	32.55
fiber	275.68	106.62
unknown	196.53	146.5
fiber	Denver, US	21.91
fiber		
fiber	9.27	8.42
unknown,other	43.46	78.16
unknown	336.79	10.63
unknown	63.33	56.3
satellite	6.77	1.25
fiber	160.54	136.38
fiber	0.86	0.92
unknown	29.67	84.16

Internet Access Type in Residence	**Download**	**Upload**
unknown		
unknown	5.74	4.89
unknown	50.4	59.47
unknown	0.64	0.28
unknown	82.09	61.91
unknown	27.01	40.52
fiber	23.49	13.68
cable	1.56	79.47
unknown	69.67	78.68
unknown	0.3	17.57
unknown	4.53	19.19
unknown	15.81	0.88
unknown		
cable,unknown	54	
satellite	33.39	0.1
fiber,unknown	46.73	49.95
dsl	15.08	1.52
cable	5.62	1.43
fiber	36.46	23.61
fiber	92.05	21.06
fiber	81.2	87.93
unknown	14.51	15.04
dsl	60.2	94.88
fiber	39.88	30.45
fiber	70.42	58.73
fiber	96.28	84.81
fiber	12.98	17.45
fiber	77.71	83.47
fiber	85.75	17.99
fiber	16.32	72.58
satellite	2.86	2.02
cable	0.05	0.2
satellite	0.11	0.29
unknown	28.88	14.78
fiber	40.86	91.88
fiber	9.37	10.41
fiber	185.06	147.71
unknown	.84	.63
average	51.47197368	39.87921053
median	27.945	24.785
Max	344.9	147.71
Min	0.05	0.1