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Bridging the Digital Divide in Rural Peru: A Mixed-Methods Analysis of Educational Technology Access, Infrastructure Barriers, and Teacher Preparedness in Andean Communities

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Abstract

Digital education access encounters considerable obstacles in Peru, where technological, social, and geographical issues restrict internet connectivity and educational prospects. The World Bank reports that Peru ranks poorly compared to other Latin American nations in terms of internet bandwidth. In remote areas, children may trek up to three hours to reach in-person classes, while in urban centers like Puno and Juliaca, universities have provided subsidized internet access for students during COVID-19 due to families' limited financial means. This study explores the pandemic's impact on poverty and educational internet access in Peru. Our research indicates that schoolteachers exhibit low levels of ICT competency, yet the Ministry of Education does not offer evaluation or training programs for technology integration. We analyze a case study of an Andean school and assess state initiatives aimed at enhancing internet connectivity infrastructure. The results underscore the ongoing digital divide that hampers educational equity in Peru.

Keywords: Education And Globalization, Digital Borders, Digital Education, Internet Access, Fiber Optic Trunk In Peru.

Introduction

This paper, highlights the limitations that still exist for internet access and education in Peru. In the situational analysis of this country, we focus on the difficulties that schoolage children still have in accessing a radio signal in border areas of mountains and the jungle; they have to walk long distances for almost three hours to get in-person classes that in these days are forbidden. We document that this problem exists even near big cities where the schools do not have adequate infrastructure to implement new technologies and internet access (Khattak et al., 2014). All these limitations happen in a country that has three of the biggest gold mining exploitations

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in the world. This paper also highlights the importance of education at the school level to fight poverty, because these children as adults achieve better income and even reduce the risk of contracting cardiovascular diseases. Therefore, the internet is an essential factor in improving education.

Subsequently, we review the income level and the percentage of families with internet access in Peru, at the Latin American level. Countries such as Chile and Argentina stand out in the bandwidth that they provide. According to the previous diagnosis of how complicated is, to provide education through the Internet in the remote border areas in the Andes or inaccessible parts of the jungle. We found that it is unnecessary to go that far to see children walking for hours to access the radio signal and attend their classes. In Vilque, a village, one hour from the capital of the Puno region in southern Peru, this problem was observed. We relate about the experience of a colleague in the implementation of a computer center and the first computer classes that he gave to children of the School N°70733 of Vilque. In this interesting experience, we also discovered another problem; the computer training of regular primary education teachers, reported in a thesis work of this topic; which has different parameters, such as the use of ICTs for class preparation, teamwork, etc. These teachers achieved an evaluation rank between fair and poor. Therefore, it is essential to implement training plans on computer science issues.

Finally, we comment on the experience of the fiber optic backbone in Peru, which has managed to lay fiber optics for 13 thousand kilometers and provide internet to all secondary schools. This new trunk was the pretext to reduce internet costs. However, internet providers in Peru have increased additional services such as fixed telephony and cable television in this way. Concerning South America, the service continues being expensive and difficult to access due to the family economy, which worsened during the pandemic.

Comparative study of education in Latin America

Situational analysis in Puno

The criticism of digital borders is exposed in a report published by the newspaper *Correo* on May 26, 2020, about the Kantati Ururi community (located 5000 meters above sea level) in the Puno region in the Moho province near the border with Bolivia. The report mentions that the community's children walk approximately 15 kilometers to access the radio signal and thus attend the classes broadcast by the Ministry of Education (*Diario Correo*, 2020). They must do the long walk with one of their parents, which implies that they abandon economic activities that generate income and food for the family. Which further deteriorates the precarious economic conditions in which they live. Analyzing these circumstances, some parents have chosen not to send their children to virtual schools, and the children will dedicate themselves to agricultural work, livestock, artisanal mining, among others, at least until face-to-face classes restart. However, this report on deep Peru denotes the abandonment of the remote peoples of Peru in the border area and the jungle. In addition, it opens the questions: Should we only maintain internet service during the pandemic? With what funds would the internet and electricity have to be paid when the pandemic ends?

The ideal would be to maintain the internet connection even when the pandemic ends. The internet is an indispensable tool for education. The United Nations Human Rights Council in document A/HRC/32/L.20 (*Consejo de Derechos Humanos*, 2016) comments on the importance of the internet and recognizes it as a human right and necessary to close the digital divide.

Reducing or eliminating the digital divide will, among other things, close the gap in access to education and, therefore, that of poverty.

Investing in children is proven to provide high returns (Al-Taie & Khattak, 2024). In this regard, James Heckman concludes that there are four benefits of investing in childhood: preventing the achievement gap of children compared to others even in social skills. Later, it would be more expensive to close that gap. It produces a better state of health if it is invested in nutrition, health, and education; in adulthood, they show lower risks of cardiovascular and metabolic diseases such as diabetes. These diseases lead to an overload of health services. According to studies conducted in Jamaica, where strategies such as home visits were used at an early age, it was possible to improve children's income in adulthood by 25%. Furthermore, as the last benefit, Heckman comments: "It makes dollars and sense," his studies show that the rate of return on investment in the development of children in inequality is 7 to 10% per year. This is reflected in education, health, productivity, socialization, and crime reduction (Heckman, 2021).

The 2019 Nobel Prize winners also emphasize the importance of fighting poverty in Kenya, where they base their research on education (Duflo, Dupas, & Kremer, 2015). Therefore, it is proven that investing in education is the best strategy for developing the regions. The accelerator of this process and its highest quality is the internet that is increasingly at hand in cities, but that is not counted in remote areas. Peru has three geographic regions: Pacific coast, Andean mountains, and Amazonian jungle. Due to the abundance of vegetation, the jungle also has many geographical features such as valleys and deep ravines. Even the construction of vehicular access is complex. The only way to access places as far away as Iquitos is by plane. This makes internet availability limited, expensive, and slow, as commented in the report on connectivity in Peru by the Inter American Development Bank (IDB) (Marín, Barragán, & Zaballos, 2014). The Puno region is above 3500 m. a .s. l., located in the Andes; it also has provinces that are part of the jungle that is accessed by land after several hours of travel. Table, includes the distribution of monetary poverty in Peru according to the geographical area, showing that the rural jungle and the rural Sierra are the most affected regions by economic poverty. These are precisely the regions with the least internet access, and one of the most important causes is that the residents do not have enough income to pay for the service. Satellite internet service costs approximately US\$ 50 per month and requires solar panels and batteries if electricity service is not available.

As shown in Table 1; Peru is an unfortunate example of the proliferation of poverty. This situation is increasing with the current pandemic due to COVID-19. One sector that will be most affected is the population of children. On this subject, UNICEF has developed a report that emphasizes girls, boys, and adolescents. One of the conclusions is that Peru will be one of the most affected countries globally; this is shown in Fig. 1, its GDP will contract by 12% in 2020. It also observes that in the quarter of April, May June 2020; the employed population reduced by 55.1% compared to 2019, and the wage bill reduced by 59.7% compared to 2019 (Instituto Nacional de Estadística e Informática [INEI], 2020). The pandemic will then cause more students to drop out of education because they do not have money to access internet services. The family's income is also being spent on their parents' health care or other relatives who often get sick from working on the streets exposed to COVID-19.

Considering households with access to some ICT, Figure 2 shows the Table 1: Population in situation of monetary poverty, according to geographical scope progress in access to ICTs in Peruvian families. A significant advance occurred from 2007 to 2017, in which only 53.3% of households had access to at least one ICT.

Lima has the most significant number of families with computers and internet access. Table 1 shows these data.

	2015	2016	2017	2018	2019
Geographical scope					
Total	21.8	20.7	21.7	20.5	20.2
Lima	11.0	11.0	13.3	13.1	14.2
Rest of Country	26.8	25.3	25.7	24.0	23.1
Residence area					
Urban	14.5	13.9	15.1	14.4	14.6
Rural	45.2	43.8	44.4	42.1	40.8
Natural region					
Coast	13.8	12.8	14.4	13.5	13.8
Sierra	32.5	31.7	31.6	30.4	29.3
Jungle	28.9	27.4	28.6	26.5	25.8
Geographic domain					
Urban coast	16.1	13.7	15.0	12.7	12.3
Rural coast	30.6	28.9	24.6	25.1	21.1
Urban sierra	16.6	16.9	16.3	16.7	16.1
Rural sierra	49.0	47.8	48.7	46.1	45.2
Urban jungle	20.7	19.6	20.5	19.3	19.0
Rural jungle	41.1	39.3	41.4	38.3	37.3

Table 1. Population In Situation of Monetary Poverty, According to Geographical Scope 2015–2019

Source: National Institute of Statistics and Informatics



Figure 1: Estimate of Monetary Poverty in Peru (2020-2021)

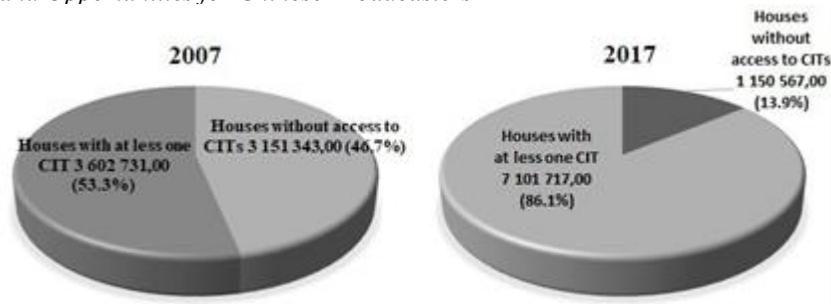


Figure 2: Houses With Access to Cits (2007-2017)

Residence Area	2019 first quarter		2020 first quarter		Absolute PC	Variation Internet
	PC	Internet	PC	Internet		
Total	34,0	36,7	35,6	40,1	1,6	3,4
Metropolitan Lima	49,7	61,8	52,9	62,9	3,2	1,1
Urban rest	38,9	35,7	38,3	40,5	-0,6	4,8
Rural area	6,1	3,7	7,5	5,9	1,4	2,2

Table 2. Peru: Households with access to a computer and Internet, by area of residence

Quarter: January-February-March 2019 and 2020 (Percentage)

Source: INEI

In 2017, the regions with the highest number of homes with connectivity were Lima (1,171,306.00), El Callao (117,689.00), Arequipa (139,893.00), Tacna (30,577) and Lambayeque (88,768.00). The percentages for these regions were between 28.7% and 49.8%, above the national average (28%). The regions with the least connectivity are Pasco (6,626.00), Cajamarca (36,741.00), Apurimac (11,251.00), Puno (30,924.00), Huancavelica (5,230.00), and Amazon (4 783.00); the average ranges of connectivity in these regions are between 4.5% and 9.6%. Another metric of the digital connection is the number of families with a cell phone. In 2017, the regions of Lima, El Callao, Arequipa, Tacna, Moquegua and Madre de Dios, which exceeded the estimated 83.8%. Furthermore, the regions with the fewest families with cell phones are Amazonas, Huancavelica, and Loreto, with percentages lower than 70.0%. As the first quarter of 2020, the percentage in metropolitan Lima is 96.2%, the rest urban 95.2%, and in rural areas 80.3%. Furthermore, it is already important to measure the type of device which they access the internet and whether children under six years of age can access the internet to receive their classes (Instituto Nacional de Estadística e Informática [INEI], 2017).

Situational analysis in Peru

The World Bank has prepared a report on internet access in Latin America and the Caribbean, shown in Figure 4. Aruba, Bahamas, and Barbados stand out with the highest percentage. In South American, countries like Chile stand out in 14th position, the same one that also offers the highest bandwidth in South America, followed by Argentina in position 14th and Uruguay in position 10th. Argentina has increased its investment to expand its fiber optic backbones. Venezuela is in 15th place, in which rates are reducing so that more families can access the

Internet. However, they have a pronounced energy crisis, which restricts access to all types of electrical equipment. In the same report, the World Bank highlights the increase in 2010 from 34.70% to 65.96% in the world in 2019 (The World Bank, 2017).

With the COVID-19 pandemic, these percentages have increased, although there is no official data yet. Still, in this point, we have to notice: the price, the type of access, and bandwidth provided in each country. As shown in Table 3, Chile leads statistics with bandwidth greater than 25 Mbps, a standard in the USA, Europe, and Asia. While in countries like Venezuela and Cuba, the bandwidths of home connections are below 6Mbps.

Respecting mobile access bandwidth at the South American level, all have a download bandwidth between 6 and 25 Mbps. Uruguay is topping this ranking with 23.10 Mbps, Saint Martin with 22.65 Mbps, and Mexico with 22.05 Mbps. Countries with the lowest download bandwidth are Haiti with 9.33 Mbps, El Salvador with 8.83 Mbps, and Venezuela with 7.74 Mbps (Ookla, 2021). Access to the internet by cell phone has become essential during the pandemic, as the monthly costs of home connections are still prohibitive for majorities. The data not published is the percentage of bandwidth that internet providers guarantee in each country.

The lowest price in the region is approximately US\$ 10.00 per month (Argentine). While in Peru, the minimum cost is US\$ 40.00 per month, the cost includes access to cable television, Wi-Fi modem, and phone service.

Country	Mean Download (Mbps)	Mean Upload (Mbps)
Chile	47.40	9.28
Uruguay	35.97	9.38
Puerto Rico	35.39	7.85
Panamá	34.94	7.21
Martinique	29.71	11.39
Parguay	27.84	8.00

Table 3. Latin American Countries with Fixed Broadband Speeds - 25 Mbps Speed test Data from Q2-Q3 2018

Cable TV and phone services are unnecessary in the pandemic and only make internet access more expensive.

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Natural Region	2011	2015	2016	2017
Total	84.5	89.9	91.6	92.3
Coast	92.0	94.8	95.5	95.7
Sierra	77.8	86.3	88.7	89.8
Jungle	70.1	78.4	82.0	84.5

Table 4. Homes With Access to Electricity Service Through the Public Network, According to Natural Region, 2011 - 2017 (Perú)

For majorities. The data not published is the percentage of bandwidth that internet providers guarantee in each country.

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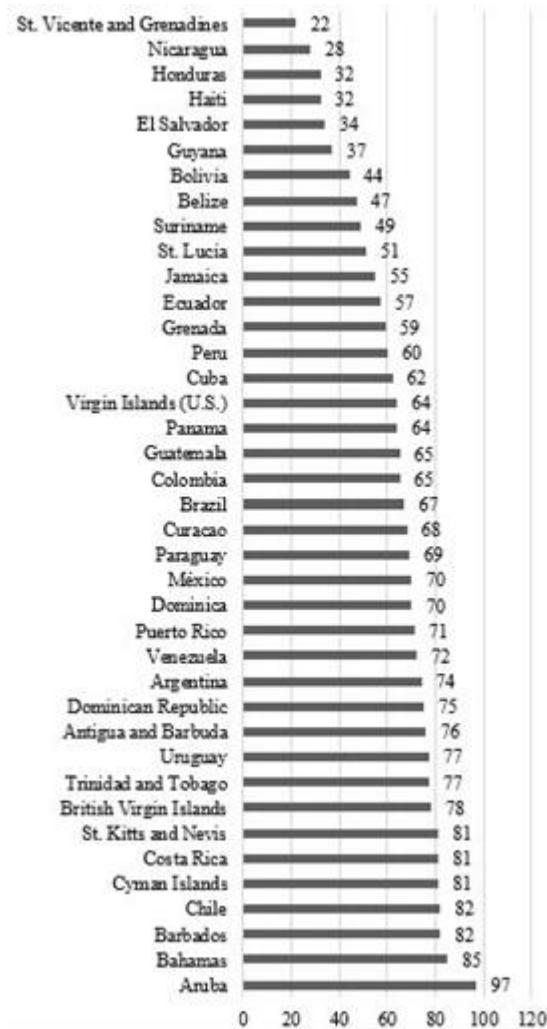


Figure 3. Houses With Access to Cits (2017-2027)

Energy Supply

As shown in Table 4, between the years 2016 - 2017, the percentage variation is 0.7% and 12%. Between the years 2011 - 2017, the percentage variation is 14.4% in mountain and jungle regions, where there was significant abandonment of this service (Instituto Nacional de Estadística e Informática [INEI], 2021). In Latin America, in 69% of the countries, 100% of their populations already have electricity (The World Bank, 2021a). Figure 4 shows the countries that by 2018 still do not reach 100% of the population. Among them Haiti, which has not yet recovered from the 2010 earthquake, and although Venezuela reports 100% of its population with access to electricity; It is one of the first countries to feel the energy crisis as a result of climate change and has been periodically suffering cuts and restrictions in the electricity supply (The World Bank, 2021b).

Digital implementation in schools in the peruvian case

Due to the information initially collected to know the most vulnerable populations in digital terms in Peru, it is necessary to travel several hours to the border, by plane, or by the river to go deep into the jungle. We contacted professionals who provided satellite internet service for more details on the route we must follow (HughesNet del Peru). They already followed the road.

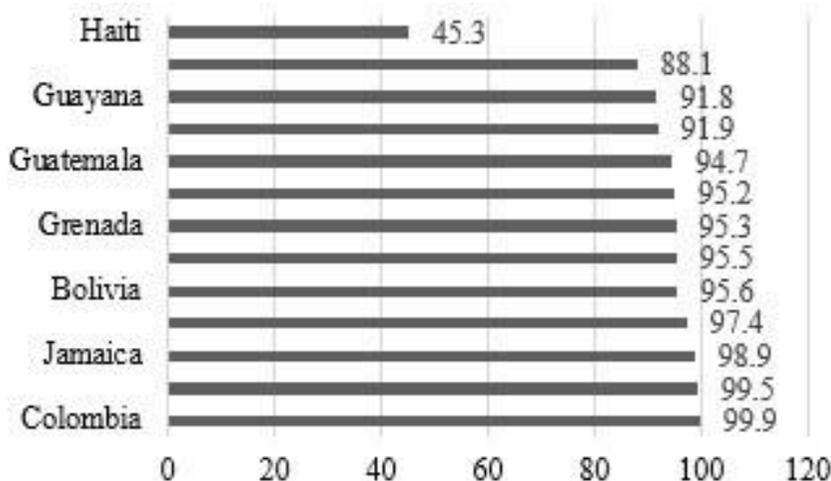


Figure 4. Access to Electricity (% of the Population)

that we proposed to do and many others in different ecological floors of Peru in Puno above 4000 m.a.s.l. or the jungle.

One of the surprises of this previous information gathering to develop our pro-education digital aid plans was that it is not necessary to go far to verify digital limitations. To only one hour from the capital of Puno in the Yanarico town center of the Vilque district, we can ascertain precarious educational conditions; the only school here is “Primary Educational Institution No. 70733 - Yanarico”. The children of the neighboring towns of Yanarico also walk for hours to access the radio signal or get to school to access education. Just one hour from Puno (the region’s capital), parents sometimes choose not to take their children to school because they are very far away. Nor can they access satellite internet service because their economy does not allow them to buy the equipment or pay for the monthly service. In Figure 5, you can see the proximity of the Vilque district to the capital of the Puno region.

The Primary Educational Institution N ° 70733 - Yanarico has only one teacher to teach all the primary grades, as shown in Figure 6; this institution has electricity.

The only teacher at the school did not know about computers. Friends of HughesNet Peru found computer equipment donated and due to ignorance, were stored. Despite being Pentium II and Pentium III computers, it helped our friends to make them work and teach a computer course. According to the technician engineer, the teachers at the school did not know computing. In Figure 7, we can see the improvised computing laboratory. The technician and now improvised and enthusiastic computer teacher narrate with much emotion the moment lived by the students, parents, and community. Our friend tells how did for the students broke their fear of using computers.

In April 2025, the authors visited the Yanarico school, where we confirmed its location to be 15 minutes from the town of Vilque by car. But, on foot, it takes approximately two and a half hours, according to the version of the teachers who work in the place. Even so, it is close to the capital of the Puno region. Unfortunately, the computer center no longer exists because the computers have broken down. And due to their age, there are no accessories for their repair. The Yanarico School currently has 18 students divided into 1st to 6th grades; and now 03 teachers. The number of students has meant that the Ministry of Education does not consider them for the implementation of its computer center (innovation classroom). In addition, they don't want to provide an internet connection. Only they have given ten tablets that are used for the communication and mathematics courses. The school director states that the Municipality of Yanarico wants to refrain from supporting them to implement computers and internet in the school. But, in past administrations, they have built two new classrooms, one made of concrete and the other heated to face the low temperatures in the area.



Figure 5. Location Map of Vilque and Its Proximity to the Capital of the Puno Region.



Figure 6. Training of IES 70733 students

The Local Educational Management Unit has updated the tablets with applications that do not require an internet connection. Cell phone signal is scarce in the area. The teachers mainly access through the prepaid modality. “Claro” is the company that has the best coverage in the area. In school, you can only access a cell phone signal in some parts of the yard. Access to the internet via cell phone is almost non-existent. It is required to go to the nearby hills to have a better internet signal. During the pandemic, teachers commented that the children went to the hill closest to the school to be able to download the educational material and their homework through the WhatsApp application; later, the teacher, through a cell phone call, carried out the lesson. Making a video conference using applications such as Google Meetings is impossible. Teachers also state that students still have difficulties handling tablets and their applications. According to information from the school. 44% of students walk more than an hour to get to school. 95% of the students’ families are dedicated to agricultural and livestock activities. Therefore, the economic stratum of the students is poor. The number of family members is an average of 4. Regarding their computer knowledge, teachers state that it is essential and intermediate. And the Ministry of Education does not evaluate or program training to update ICTs for teachers. Which we consider a weakness of the Peruvian State.



Figure 7. At IES 70733 Yanarico Together with The School Teachers. In The Background, You Can See New Infrastructures.

The director and the teachers have not remained with their arms crossed before the abandonment of the authorities; they prepared a project for implementing their innovative classroom; presented it to the “National Fund for the Development of Peruvian Education (FONDEP).” The same one has been the winner, and the Peruvian state will give them S/. 16,000.00 (approx. \$4,200) for the acquisition of 05 personal computers. The authors of this research have also provided them with information to access financing from nonstate institutions such as the Rotary Club, among other efforts in which they are being supported for us. The IEP 70040 school in the town of Vilque has also been visited at the district capital. We have met with its director and the teacher in charge of the innovative classroom. Here the scenario is different. The number of students is 175, 12 teachers, and its innovation classroom has 30 computers, “HP core i3,” and 90 tablets the State provided four years ago. The innovation classroom also has a data network. The State has also provided them with a satellite internet connection, but unfortunately, since March 2024, it has not worked. The Director has tried to connect with the support of the provider company without favorable results. However, the State would continue to pay for this service. According to the Director, the bandwidth during 2022 was limited, supporting a maximum of 11 connected computers. According to inquiries, the costs of satellite internet are still expensive.



Figure 8. IES 70733 Computing Laboratory

HughesNet charges S/. 345 a month. What is still impossible to pay for the Yanarico school.

Concerning computer skills by teachers in the Puno region, we reference the thesis: “Level of Use of CITs by Teachers of Educational Institutions in Desaguadero District - 2015” (Atauchi, 2015). In his research, the author defines the research problem: “What is the level of use of ICT in the professional work of teachers in educational institutions in the district of Desaguadero 2015?”. Desaguadero is a province of Puno and is the border with the Republic of Bolivia. The specific objectives are to identify the level of use of ICTs in the following dimensions:

- In the acquisition of information.
- In teamwork.
- As a teaching learning strategy in their professional work.

It is required to measure the following aspects to know the degree of information acquisition:

- Surfing the Internet.
- Entering the national educational portal through the web page.
- Performing searches for school assignments and performing advanced searches.

About the last parameter, 17% of teachers have an insufficient level, 43% have a regular level, 30% have a good level, and 10% have an excellent level. The use of email, chat, virtual forums, and publications on Wikipedia are parameters to measure “Teamwork.” About the use of chat, 3% of teachers have an insufficient level, 20% have a regular level, 40% have a good level, and 37% excellent level.

Participating in collaborative projects, use office programs and educational games, download books and magazines from digital libraries, and creating a web page are parameters to measure “the application of ICTs for team learning.” As expected, the development of a web page gave

catastrophic results with 90% poor, 3% acceptable level, 3% good level, and 3% excellent. Concluding, the evaluation of teachers is between regular and poor grades in the application of ICTs and obtain an average of 7.25 (based on 20).

Precisely to overcome this reality exists: "Red Kipus Peru". It is part of the network of teachers for Latin America and the Caribbean sponsored by the United Nations Educational, Scientific, and Cultural Organization. Let us remember that the presence of the COVID has made the processes of automation, learning, and use of ICTs now indispensable and not just a technical pedagogical option. As UNESCO mentions, "today there is agreement that the computer should not be used simply as a typewriter or a calculator, but should be used to enhance learning according to the pedagogical project of the institution" (Martín & Marchesi, 2006).

Experiences in the pandemic

To the question: How do we face the teaching and learning processes in a non face-to-face education? The Kipus network has prepared a synthesis of the experiences during 2020. Of which we can rescue the following:

- Response of the training institutions. They have responded by improving educational services to the best of their ability to deal with the pandemic.
- Regarding students, a diagnosis must be made considering emotional health, physical health, personal and family situation of students, and connectivity. In addition, we designed academic tutoring plans through WhatsApp virtual platforms, institutional emails, cell phones, etc.
- It was necessary to ensure that students have connectivity to access educational platforms.
- It is necessary for teachers to self-train and participate in the training sessions to strengthen technological and pedagogical knowledge of the Technological Pedagogical Content Knowledge (TPACK) model.
- The implementation of synchronous and asynchronous activities was necessary.

About good practices, we can highlight creativity and innovation in non face-to-face teaching, as the exchange and collaboration between teachers and inter-learning groups (Red Kipus Perú, 2020).

The Peruvian fiber optic backbone

In Peru, to expand internet access, the National Optical Dorsal Network project was developed, extending for 13,000 kilometers in the national territory at the cost of US\$ 232 million. Its conception promises to reduce internet costs by up to 80% and improve the Peruvian's quality of life. The fiber optic backbone was recently completed. It was the excuse put by internet providers to lower the costs of connection. Nevertheless, the operators have included services like cable TV and landlines, in addition, they have expanded the internet bandwidth to maintain the high costs (Pro Inversión Perú, 2021). The policy of the state is that the internet service reaches every secondary school with this dorsal network. However, sometimes many of the equipment provided was stolen; or they deteriorated rapidly so that the computing labs have not served their purpose.

Figures 8 and 9 show photographs sent by one of my students that were taken in April 2020. They show the Aymaña town in the district of Corani, province of Carabaya located six hours

from the capital of Puno region. Where university students climb the hill to be able to follow their classes.



Figure 9. Aymaña town in the district of Corani province of Carabaya in Puno

An outstanding case in South America is the fiber-optic network in Argentina, a country with a larger geographic area than Peru. Nowadays Argentina has a coverage of 22 thousand kilometers of fiber optics in the backbone network and 25 thousand km in regional networks. This network is accompanied by educational policies such as public internet booths to share experiences (Baladrón, 2019).

Another aspect of the inequality of social classes in Peru is the high cost of private universities. Graduates of private universities have priority in work positions, even in the government. This situation makes it essential to break down technical and political boundaries so that education can become global. As a result, more people with fewer economic resources could access international level education and so overcome the social gap that does not allow them to get better jobs.



Figure 10: Students In Aymaña Hills Attending Virtual Classes

Conclusion

After analyzing the limitations that still exist to access education, we can conclude:

- Education in childhood has the advantage of preventing the academic performance gap, developing social skills, produces a better state of health. In adulthood, the children show lower risks of cardiovascular and metabolic diseases such as diabetes.
- Education allows in adulthood to achieve higher economic income (up to 25%). Therefore, it is the most efficient strategy in the fight against poverty in still developing countries.
- Internet access is the most important accelerator to the democratization of education in the world. Now it is possible through the internet to access prestigious universities in the world. Therefore, it is essential to reduce its costs and create plans for expansion and increase the bandwidth for data transmission.

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