Institut Barcelona d'Estudis Internacionals

Academic Year 2021 – 2023

Correlation of availability of computers and students' academic performance for Maths:

Evaluating the "Punjab IT labs" project

Dissertation Submitted by

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in partial fulfillment of the requirements for the degree of

ERASMUS MUNDUS MASTER'S PROGRAMME IN PUBLIC POLICY (MMAPP)

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Barcelona, July 31st, 2023

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Place and date: Barcelona – 31st July 2023

Word count: 15109

Abstract

Despite numerous interventions and investments in the global education sector, learning poverty remains a significant challenge, particularly in developing countries like Pakistan. One of the underlying reasons for this issue is the lack of impact assessment of past policies, leading to the repetition of mistakes and the misallocation of resources. To address this concern, this paper focuses on evaluating a specific interventional project called the "Punjab IT Labs" initiative, which involved setting up computer labs in secondary-level schools. In this study, a sequential mixed methods approach was employed. Initially, the quantitative aspect measured the correlation of computer labs on average math scores in provincial exams. Surprisingly, the findings showed only a negligible increase of 0.533 percent in math scores, representing merely 1.02 percent of the mean scores. To gain deeper insights into this limited impact, qualitative methods were employed through semi-structured interviews with Head Teachers and Teachers. The interviews aimed to understand the reasons behind the minimal effect observed. The field insights gathered during the interviews confirmed the quantitative findings, revealing that the computer labs were primarily used for the subject of 'computer' and not utilized for other subjects. Moreover, the lack of financial autonomy of Head Teachers, operational issue hindered teachers to utilize the labs for math or other subjects was restricted, which further limited the potential benefits of the intervention.

Keywords: computer lab, education policy, correlation, student's academic scores, Head Teacher autonomy

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Acknowledgments

In the name of Allah, the Most Gracious and the Most Merciful.

I would like to express my heartfelt gratitude to the following individuals and organizations who have played a pivotal role in the successful completion of this Masters thesis:

First and foremost, I extend my sincerest appreciation to my esteemed supervisors, Dr. Mihály Fazekas (CEU) and Dr. Fulya Apaydin (IBEI). Your unwavering guidance, expert insights, and encouragement throughout this research journey have been instrumental in shaping this thesis.

I am deeply indebted to the Punjab Education Commission for providing invaluable data on grade 8th students, which formed the cornerstone of this study. Additionally, thanks to the Punjab School Education Department for granting permission to interview Head Teachers and Teachers. Your commitment to academic research and dedication to enhancing the education system in Punjab have been indispensable to this work.

To the Head Teachers and Teachers who graciously gave their consent and participated in interviews, I am incredibly grateful for your invaluable contributions. Your willingness to share your experiences and expertise has added significant depth and context to this thesis.

I would like to extend my profound gratitude to Dr. Asim Khwaja (Harvard Kennedy School) and Muhammad Karim (PhD, San Diego University, California) for being a constant source of inspiration in the realm of educational research in Punjab. Your pioneering work has motivated me to delve deeper into this field and contribute meaningfully to education in the region.

Finally, I cannot overlook the immeasurable support and love from my family, especially my parents. Your unwavering encouragement and understanding have been the cornerstone of my personal and academic growth. I am forever grateful for the sacrifices you have made to see me succeed.

Introduction

Education is considered the developing unit of a society (Yuliani & Hartanto, 2016), particularly for developing countries that faces an unstable economic situation and limited resources (Wen et al., 2022). To improve the education sector, evidence-based interventions are crucial, especially in schools. Just two decades ago, the global community started focusing on increasing enrollment to fulfill the "Achieve Universal Primary Education" objective of Millennium Development Goals (United Nations, 2015) which has continued through the Sustainable Development Goals (*From MDGs to SDGs*, 2014).

However, a decade ago when the policymakers in developing countries were focused on increasing enrollment, the World Bank, declared a global learning crisis (*World Development Report 2018*, 2017). This indicates that the focus on improving enrollment has neglected monitoring students' learning progress. Hence, it is complex and crucial for developing countries to choose the correct intervention to invest in to achieve its goal.

In terms of intervention, historically technological interventions have always been the policymakers' and governments' favorite tool for improving education level (Lemke et al., 2006). It became a global trend to use technology-based interventions in schools, from providing free computers to customized learning programs (Kaye & Ehren, 2021).

Following these global objectives, in 2018, Pakistan achieved the target of 95% enrollment in primary schools according to World Bank statistics (*World Bank Open Data*, 2022) the Government of Pakistan also invested in the provision of technology in schools. In 2005, the federal government initiated a project to establish computer labs with 16 desktops in 515 secondary schools (Qadir et al., 2014). Following this program, Punjab, the largest in terms of population and enrollment, collaborated with national and multinational public-private partners to build 4286 IT labs in secondary and higher secondary level schools. These IT labs were fully equipped with 16 desktops, internet, server computers system to monitor the students working, and an Uninterruptible Power Supply (UPS) to support the lab during electricity load-shedding (NComputing, 2010)

This was a project funded with approximately 700.399 million PKR (equivalent to around 8.6 million US $ at the 2008 exchange rate) aimed at improving students' learning and creating awareness for the field of I.T.(*IT / Computer Science Teachers, Lab Incharge & Computer Labs ProjectMatching Program with Government of Punjab*, 2008). However, amidst this project in 2011, the Annual Status of Education Report (ASER) published significant findings stating that the province of Punjab only had 58% net enrollment in middle-level schools. Additionally, the learning levels of students in

Punjab were found to be worse compared to the students from other regions of Pakistan i.e. Gilgit-Baltistan and Islamabad Capital Territory (*ASER-Pakistan 2011*, 2012). Although, overall enrollment improved to 95 percent by 2019, according to the ASER report 2018, Punjab enrollment only increased 22.7% from 2014 to 2018(*ASER-PAKISTAN 2018*, 2019; *World Bank Open Data*, 2022). Further regardless of the IT lab project, the report indicated a slow improvement in learning losses for the province of Punjab, with around 50% of children in Class 5 still unable to reach the learning levels of Class 2 (*ASER-PAKISTAN 2018*, 2019). Neglecting the need for essential facilities, there have been multiple extensions of the IT labs project and other projects aimed at providing free laptops to students, which have cost a significant amount of public funds. This is evident from Punjab School Census report 2018 which mentioned that around 7000 toilets need repairing (Samee, 2018). This highlights a clear discrepancy between public policy and its objectives. A policy that prioritizes technology while forsaking basic needs is unlikely to achieve its intended goals.

On top of this Covid-19 pandemic worsened the situation globally, particularly regarding learning. This is primarily due to the closure of schools for around 8 months whereas the enrollment also got affected for economically vulnerable communities (Nagesh et al., 2022). According to estimates, only in Pakistan around 7.2 million school-age children dropped out of school during the Pandemic (M. J. Khan & Ahmed, 2021). The World Bank “Collapse & Recovery” Report mentioned that 6% of the age group between 6 and 14 years had dropped out (Schady et al., 2023). This cast a shadow on all the improvements of achieving enrollment to 95 percent by 2019(*Pakistan - School Enrollment, Primary (% Gross) - 2023 Data 2024 Forecast 1971-2019 Historical*, 2023). Moreover, as the World Bank warned in 2022, the learning crisis in Pakistan will lead to a 79% increase in learning poverty (Geven & Hasan, 2020). Similarly, the ASER report 2021 highlights the urgent need for intervention to improve learning performance. Shockingly, only 15% and 21% of third-grade[1] students have proficiency in basic arithmetic and language skills, respectively. Such alarming statistics have led to this generation being labeled as a "lost generation" (*ASER-Pakistan 2021*, 2022).

In Pakistan, existing literature has predominantly focused on technological interventions and their impact within higher education institutions. However, at the elementary or secondary school level, research has been primarily confined to post-covid technology use, focusing on user perception and their adaptation to technology, rather than thoroughly examining its impact on learning outcomes (Nasir & Hameed, 2021; Rehman et al., 2021). Previous research also suggests that evidence-based policy design and impact assessment are relatively new concepts in Pakistan, partly due to the influence of powerful actors in the policymaking and implementation processes (Vaqar Ahmed et al., 2021). This indicates a significant research gap to assess the impact of investing in computer labs on

[1] Grade is often used interchangeably for the class.

students' learning and explore alternative interventions that can effectively improve academic performance.

In addition, the current economic circumstances have made it even more crucial for Pakistan to make informed decisions based on evidence in order to determine which intervention requires investment, given the increasing financial debt and highly unstable economy. This is emphasized by the learning loss status, highlighting the pressing need to assess the impact of computer labs on students' academic performance and provide support for policymakers in making informed choices.

Therefore, the purpose of this paper is to address the research gap by evaluating and understanding the relationship between the presence of computers in public schools and students' learning outcomes. The study focuses on the computer labs set up under the large-scale 'Punjab IT labs project' in the central province of Punjab, utilizing the most recent available data (pre-covid) from the year 2018 consisted of 15,029 schools. To measure the impact, average math scores are selected as a key indicator. The rationale for choosing math scores lies in their ease of measurement and the fact that both math and computers are considered rational subjects, enhancing the potential for a direct correlation.

To achieve this goal, the paper employs an explanatory sequential mixed-methods approach, combining quantitative measurements of the correlation between computers and math scores with insights from the field to identify barriers to achieving this objective. The study outlines three main objectives:

- To measure & identify the correlation between computer labs and average math scores in the public schools.
- To verify the impact, measure and compare the difference in the math scores among 8th grade [2] students in schools that have computer labs and those that do not have computer labs during the year 2018.
- To understand the implementation mechanism with possible hurdles in achieving the objectives and effectiveness of this project "IT labs scheme-Punjab".

The findings shows an extremely minimal correlation coefficient indicating that the presence of computer labs in schools has hardly any notable impact on average math scores. This lack of impact is attributed to limited usage and a lack of autonomy for Head/Teachers to effectively utilize computers for math or other subjects.

[2] 8th-grade students in Pakistan are 13 – 14 years old with 9 to 10 years of education starting from kindergarten at around the age of 3.

The paper is divided into four sections: the first section lays the foundation of the study through the introduction. While the second section consisted of the literature review discusses the existing research with different findings about the impact of ICT facilities in the school on the students academic performance. Moving further, the third section focuses on the data collection and methodology, the third section analyzes the findings to gain insight into the intervention, and the final section concludes the paper.

Education system in Pakistan:

Pakistan is the world's 5th most populated country (*Country Profile Pakistan*, 2023) with 64 percent of the total population is under 30 years old while 29 percent of it is youth i.e. age group between 15 and 30 years (Talib, 2022). This age group ideally belongs to the education attainment phase. To understand the ratio of students enrolled, it is essential to have a background about the education system in Pakistan. There are four types of educational institutions: School (Pre-primary to secondary level), Colleges (higher secondary level/ vocational education), University (Higher education) and Madarassa (Religious education) (*Pakistan - Education*, 2023).

According to World Bank latest statistics, the enrollment in primary schools are 95 percent while it keeps deteriorating with only 10 percent reaches university to attain higher education (Ghumman, 2009; *World Bank Open Data*, 2022). There are several reasons behind the deteriorating enrollment with the higher level of education (Andrabi, Das, & Khwaja, 2008; Hoodbhoy, 2009; Mehmood et al., 2018). This signifies the impact of research focused on schools. As schools are the basic unit of development, the current state of Pakistan's growth in every sector requires more population to become productive and contribute to the development (Ali et al., 2013; Mustafa et al., 2017).

The existing literature on education in Pakistan primarily revolves around the challenges, facilities and very rarely on learning assessment. While the literature that tried to combine the impact of educational interventions and facilities on the students' performance are limited to higher education institutions (Memon, 2007; Rafiq & Ameen, 2012; Wasif et al., 2012; Yusoff & Khan, 2013), which indicates investing the time and skills for improving education for only the 10 percent that reach the university level. Therefore, this paper fills the literature gap by concentrating on policies targeting schools, which have the highest enrollment and can create the most impact.

On one hand, there is a lack of literature focusing on measuring impact and providing evidence to support the provincial government's investment in schemes such as free laptops, which have already cost citizens almost 8 Million US dollar of public funds (PakistanToday, 2014). On the other hand, the importance of this research amplifies due to the scarcity of resources for policies especially with the increasing economic crisis including total external debts on Pakistan arose to USD 248.7 billion which is almost 80 percent of its Gross Domestic Product (GDP), while the GDP itself is surviving with 70.7 decreased from 72 percent in 2020, and the national currency suffered from depreciation by 14.3 percent in comparison to the US dollar ("Economic Update and Outlook," 2022).

Given these circumstances, it becomes extremely important for a nation like Pakistan to prioritize and understand where and why they invest the funds. Hence, this study aim to identify the correlation between the provision of computer and students' scores in order to guide such policies in the future. Not only does this paper establish the correlation between computer labs and average math scores but also back it up the findings with insights from the on-site interviews conducted with the implementation unit i.e. Head Teachers and Teachers. Precisely how the lack of access and autonomy to include the computers using creative pedagogy is a major hurdle in creating an impact on learning outcomes especially as measured on math.

Literature Review

Education is the key to modernization with the spread and transformation of knowledge and skills to create a civilized society. Historically, education has always been under debate; initially with formal or informal, moving further it was skills opposed to knowledge and recently it is a human knowledge versus technology (Council et al., 2012; Gill, 1988; Martin, 2004). Yet with years passing the importance of attainment of education consistently increased, especially for development of the society. This is evident through a document published in 1985 by the World Bank called "Education for Development", highlighted that investing in the education sector of developing countries goes beyond fulfilling the basic rights of citizens; it is also a root for productive economy in terms of human capital. This document emphasized that substantial investments in education positively impact national income through an educated labor force (Psacharopoulos et al., 1985). Until today there are various papers written on how education is an essential factor for the prosperous society (Bhardwaj, 2016; Ochilova, 2020).

Consequently to preserve and promote education the international community collaborated to formulate Millennium Development Goals(MDGs) which was extended to be called as Sustainable Development Goals (SDGs), both stressed on mainly the increment in the enrollment for primary schools only the later one also added the inclusive & equal provision of quality education (Nations, 2014). To achieve the goal of increasing enrollment in schools, international organizations provided financial assistance to the developing countries (Ferguson et al., 2019). As a result, governments implemented massive amount of interventions in schools (Asadullah et al., 2020; Klees, 2017). However, executing various interventions is not an equivalent to achievement of goals (Adler-Greene, 2020). Rather it depends on the impact of the intervention and to estimate the most effective intervention evaluation is significant. As Organization for Economic Co-operation & Development (OECD) explained that evaluation is significant to measure the impact but also necessary to identify the degree to which the goal is completed. Further they also suggested that to measure impact using the independent and dependent variable through linear correlation (OECD, 2014).

Despite the frequent evaluation measurement through United Nations for the attainment of MDGs and SDGs (Nations, 2014) developing countries especially in South Asia are behind in achieving the goals. One of the reasons for this failure is the lack of impact evaluation practices. It is a recent trend started during the year 2000 to use the data-driven approach in the developing countries which arose during 2010 and onwards (Sabet & Brown, 2018).

Before the 90s there is very limited literature available about the evaluation of educational interventions. One such paper “Welfare intervention – 1986” is a qualitative review examining the impact of educational experiments or interventions on the economic development measured through growth, equity and students employment. This paper explains how the interventions have direct and indirect nature but could be implemented together. Further, the researcher recommended that the role of government is significant during the evaluation of the interventions. While it is an important paper of that time period which highlights the evaluation of the educational intervention but its very narrow in relevance with the impact of educational interventions impact on learning outcomes (Psacharopoulos, 1986).

Additional in the next year another paper discussed the educational intervention using the economically effective lenses to measure impact; cost-effectiveness and cost-benefit analysis on the secondary data. Considering it reviewed only 6 longitudinal studies of interventions aimed at preschoolers from underprivileged families, limits its relevancy. However, even back then they were able to find out that investment in interventions for preschoolers might be expensive in the short term but will be beneficial in the long run. This paper also stands as it kept the foundation for the impact evaluation on learning of the students through measuring the effect of the intervention on the IQ of the students (Barnett & Escobar, 1987).

With the passage of time there was slight increase in the number of impact assessment research in the field of education, during 90s they focused on the effect of interventions on increasing enrollment or growth of the society. While in 2004, a significant contribution was made through a paper was published by International Monetary Fund (IMF) examining a panel dataset from 120 countries across 25 years starting from 1975 till 2000. This paper measured the effectiveness of the social interventions on achieving the MDGs. The study concluded multiple correlations but specific to education they declared that investing in education will benefit two-third times in immediate five years while half of it in 10 years. This is easier to understand as 1 GDP invested in education will increase the enrollment 6 percent in the 5 years and 3 percent in the long run of 10 years (Baldacci et al., 2004).

Finally in the decade of 2000s researcher got their attention towards the impact of interventions on improving learning outcomes. A renowned economist from America, Eric A. Hanushek, highlights in his paper “INTERPRETING RECENT RESEARCH ON SCHOOLING IN DEVELOPING COUNTRIES” that the investment for improving enrollment gets wasted when students either had to repeat the grade or they drop-out after the primary level of school. Interestingly, as he recommended rigorous evaluation of intervention as a solution for the grade repetition and drop outs, he also mentioned that this approach is new for both developed and developing countries. This is an extensive study where Eric also identified that education system differs across developed and developing countries, further between urban and rural areas while the involvement of multiple stakeholders complicates to implement the feasible intervention. Therefore, the policymakers should focus on quality of education (Hanushek, 1995). Famous economist Lant Pritchett discussed the similar idea in his paper " Where Has All the Education Gone?" that among other factors low quality of education is a hurdle in human capital growth (Pritchett, 2001).

Following the statement by Hanushek that impact evaluation is new to the developing countries By the 2000s great researchers such as Michel Kremer, Abhijeet Banerjee, Esther Duflo, and Asim Khwaja delve deeper into the impact of interventions on learning outcomes particularly in the developing countries. They not just assessed investment or quality of education rather specifically the material or facilities provided as an intervention. Michael Kremer's renowned paper "Many Children Left Behind? Textbooks and Test Scores in Kenya" measured the impact of textbooks provision in Kenya. There findings were strengthening the expected idea of having sufficient number of books with the higher test scores. However, the issue was that this impact was noted on students with established better performance then he investigated further to identify why provision of books did not impact low performing students. There he found that since the books provided are in English that could be a hurdle for the lower performing students. On this he inferred that 'one size could not fits all' which means the issues with current education system makes the intervention difficult to create a uniform effect (Glewwe et al., 2009).

Around the mid-2000s this approach of impact evaluation became one of the most common type of studies being conducted in the developing countries particularly in the field of education. In the same vein, famous researchers Abhijeet Banerjee & Esther Duflo laid the foundation of evaluation of a technological intervention in schools through their remedial program "Balsakhi". This remedial program was a randomized control trial where half of the students were provided with a young teacher to help them with their weakness to improve learning while the rest were given the computer-assisted program to improve learning. Their results proved the positive impact of both treatments but the learning through computer program was higher with 0.38 standard deviations in the first year(Banerjee et al., 2007). Despite the challenges with countrywide scalability of this program, the study highlighted the need for impact assessment especially of the technological interventions. This was essential to correct the prevailing assumption among policymakers that incorporating computers and technological intervention will invariably yield positive results.

Pakistan is one of the top countries with the highest percentage of young school going population. In 2000s, the government of Pakistan was also working eagerly to achieve the global educational goal of high enrollment & literacy rate. Therefore, the renowned Pakistani researcher from

Harvard Kennedy Dr. Asim Khwaja and Pomona college Dr. Tahir Andrabi collaborated with Dr. Jishnu Das from World bank to conduct the first large-scale longitudinal study called “LEAPS” aimed at understanding the educational landscape and measuring students' learning outcomes (Andrabi, Das, Khwaja, et al., 2008a) . The study unveiled a critical issue of 'learning loss' in the province with the highest enrollment growth, a concern that was later confirmed by the World Bank in 2018.

The same team worked further on the impact of a randomized control trial experiment on the learning behavior and performance on students. This Report card study was providing selected parents with the report cards containing test scores as well as detailed performance report of the students while the controlled group of parents was under the same traditional way of announcing results verbally in context of the rural schools. The findings revealed a positive impact on test scores, with an increase of 0.11 standard deviation for those who received the report cards (Andrabi et al., 2017).

Despite the substantial findings of these studies, the government kept implementing grant-driven or conditional-cash-program funded interventions which were barely evaluated and if evaluated were hardly removed or modified. One such important case is the ‘Digital policy’ initiative by the largest province of Pakistan – Punjab. Under this initiative, 270 projects were launched within 5 years consisted of millions of US dollars (*Digital Punjab | PITB*, 2023) The first project aimed at schools was the establishment of “IT labs” in public school with computers alone with internet – aiming to increase the computer usage skills. In one of the project evaluation report published right after the project was completed in 2008 it was clearly declared that even this aim of computer skills was partially achieved (*IT / Computer Science Teachers, Lab Incharge & Computer Labs ProjectMatching Program with Government of Punjab*, 2008). In my opinion this report required a follow up evaluation report tracking the progress instead there have been extensions of this “Digital policy” which provides free computer and laptops to the student which equals to investing millions again.

This does not infer that technology, particularly computers, are useless in schools. But the existing literature contradicts and has diverse point of view. I tried to bunch up the lessons into three categories; First, some studies suggest that such provisions in schools, like computer labs or technology, aid in student retention and enrollment increase. Second, there is evidence indicating that computers or laptops alone may not significantly benefit student learning. Third, based on data, some suggest that if computers are integrated with specific learning programs, they can indeed contribute to students' learning.

First category of papers focused on the general positive impact of technology including on increasing enrollment or retention of students (Andrabi, Das, Khwaja, et al., 2008b; Burgess et al., 2015; Osin, 1998). Very rarely the literature found a notable improvement in students learning but few were able t prove their impact on training students with IT skills relevant for freelance jobs (Osin, 1998; Yeh et al., 2019).

Building on that second type of literature suggest that provision of devices alone would not create an impact ("Can Computers Help Students Learn?," 2011; Karlsson, 2020). This sounds irrelevant especially after Covid-19 pandemic, yet there are developing countries where majority of the students do not have access to the devices. Therefore, it refers to those countries that along with provision of devices devices (Almanthari et al., n.d.; Cawthera, 2002; Fu, 2013), training of teachers (Ghavifekr & Rosdy, 2015; Kong & Wang, 2021; Veen, 1993), and knowledge of students are also essential (Means, 2010).

This was taken further with the third set of literature where researchers emphasized that combining the technology with programs which can assist in learning have the most effective outcome. Some relevant evidence from developing countries includes a comprehensive impact evaluation study and another study from the US, which both emphasize that the provision of devices alone is insufficient, and learning programs are crucial for positive outcomes (Kebritchi et al., 2010; Tamim et al., 2011). Similarly, a study in Ecuador tested a learning software's impact on students' arithmetic scores and found that its success relied on a combination of hardware, software (APCI Platform), and teacher facilitation (Paul Carrillo et al., 2010).However, In a study conducted in India with in-school and out-of-school children, it was concluded that technology-based learning programs should be carefully modified and implemented to suit the on-ground situation (Linden, 2008).

Examining the existing literature in Pakistan, the emphasis has predominantly been on computer labs or online portals in the context of higher education levels. Before the Covid pandemic, both public and private schools heavily relied on traditional teaching methods involving teachers and textbooks, resulting in a lack of evaluation regarding the impact of technology on secondary or lower levels of education (Akhter & Mahmood, 2018; Asad et al., 2020; Perveen, 2016). Consequently, the few papers focusing on the secondary level adopt diverse approaches, with one study analyzing the facilities provided in secondary schools and another PhD student's dissertation investigating computer usability and challenges faced by students at this level in both public and private schools (Akhtar & Tariq, 2015; Ameen, 2017). However, the most pertinent paper aiming to assess the "IT lab project" narrows its focus to teacher perceptions, skills, and the program's usefulness. The results emphasize the need for additional training for teachers before implementing the intervention (Qadir & Hameed, 2018)

Furthermore, the involvement of various factors in a policy intervention, the evaluation should also take them into account. One of the significant factors is the mechanism adopted during the execution of the intervention while its corresponding sub-factor is the autonomy given to the stakeholders; in the case of public schools the Head-Teacher or the Teacher of the school. There is plenty of literature discussing the autonomy of the implementation actor for the policy impact. Almost 5 decades ago, in 1976, John Pincus in his paper "Incentives for Innovation in the Public Schools" discussed that providing authoritative space and trust to the teachers enhances the effect of the policy in the schools (Pincus, 1976). While more recently in 2017, a study from Bahrain highlights the same finding that permitting more authority to the teachers, especially financial freedom to handle budget is highly significant for a successful ICT intervention in Public schools (Razzak, 2015).

In Pakistan, many research papers analyzed the mechanism of education policy implementation, few of them do mention the significance of the autonomy of Headteachers and teachers too (Z. Ahmed et al., 2021; Alvi et al., 2020; Parveen & Shafiq, 2021). However, there is still a gap in delving deeper into the mechanism of implementation of technological interventions in schools as to how much Headteachers and teachers have administrative freedom or financial freedom regarding the use of that technology in school.

Conceptual Framework

Impact of school facilities and Students' performance:

Literature in the world of education research emphasizes the importance of 'school' as a factor impacting the students' performance. There are multiple functions of school in the life of a student; a conducive learning environment, teaching methods, infrastructural facilities, and teacher-student interaction (Young, 2009). Among these factors, infrastructural facilities are the easiest to assess as the impact they have on students is more readily observable. The infrastructure facilities refers to all physical tangible facilities present in the space where students are studying which includes the condition of the school building to availability of basic facilities as toilets or libraries to the influence of classroom setting (Akhtar & Tariq, 2015; Cash, 1993; Cheryan et al., 2014; G. Earthman, 2017; Lonsdale, 2003; Schneider, 2002).

A vast literature measuring the impact of different types of facilities in school on the student's retention and performance (Barrett et al., 2019; Jamil et al., 2018; Parnwell, 2015). The aim of these papers was to answer what makes a school - a good school, so that the findings could be used in policymaking to improve the attendance, retention of the students, and ultimately literacy rates. Interestingly, a common trend identified from all these literature was that school facilities does have an affect students learning either directly or indirectly and the intensity may differ; for instance, the thickness of classroom walls could be important indirectly by determining the extent to which external noises disrupt their concentration during lectures (Woolner et al., 2007). Similarly, the condition of the school building may be associated with the temperature, lightening of the classrooms and even the interior of the classroom which is essential for primary level students (G. I. Earthman, 2002). However, some facilities are directly impacting such as type of furniture (chair, table) provided for students, availability of drinking water and toilets further into this separate for gender (Birdthistle et al., 2011; Gilavand, 2016; Snel & Shordt, 2005). In sum, school facilities are worth policy makers' attention to invest for the improvement of students' learning.

Increasing trend of ICT facilities in schools:

In addition to the basic facilities in schools, the rapidly increasing introduction of Information & communication technology (ICT) facilities in schools and often in classrooms demanded attention. As discussed in the Literature review section, ICT facilities in schools can often referred to as educational technology which includes computers, tablets, smart boards, computer-instructional software sometimes specialized by subjects (Skryabin et al., 2015) . Consequently, a good amount of literature examining the effects of technology on student performance in recent years (DiGregorio & Sobel-Lojeski, 2010; Galy et al., 2011; Linden, n.d.; Park & Weng, 2020). In terms of the methodology, several papers have measured effects of a particular technology across multiple subjects (e.g., Mathematics, Science & English) while keeping the rest of the factors in control (Chiao & Chiu, 2018; Fernández-Gutiérrez et al., 2020a; Hu et al., 2018; Slavin, 2013) and a few other papers have focused on measuring on one specific subject such as only in English (Eng, 2005; Huang & Hong, 2016; Sekharan Nair et al., 2012). Besides the subjects, the diversity of research can also be noted on the level of students (i.e. elementary level, secondary level etc.) (Mlay & Sabi, 2019; Olszak, 2015; J. Y. Wu & Peng, 2017). Generally it is complex to measure an isolated effect of a technology is complex while keeping the rest of the factors constant and so the results are mix with significantly impacting or not really impacting the students' performance (Bester & Brand, 2013; Debevec et al., 2006). It is important to understand that since technology came in developed countries before the developing so majority and variety of the papers belong to the developed countries while limited papers are focused on developing countries.

Similar to the rest of the school facilities, students interaction with ICT facilities in consideration with the nature of interaction leads to the theory of change regarding significant or insignificant impact on their academic scores (Wenglinsky, 1998). It is highly significant that what type of ICT facility is implemented, for example, literature suggests that using computer based assistance software are really helping students learn through the interactive activities or games or videos (Kebritchi et al., 2010) especially in the rational subjects such as Mathematics. It is significant to note that having the software is not enough, frequency of use of this software per student really plays a role in completing the effect on the learning (Lei & Zhao, 2007). In a similar vein, increased frequency with computers in general without any specialized software has seen to be insignificant in improving students learning (Mandal, 2004). Therefore, the ICT projects should be carefully evaluated before implementing on National level.

Dire need for impact evaluation for educational interventions in developing countries:

The developing countries are already under economical pressure, loans leading to social issues and low quality of life. Further Covid-19 Pandemic damaged them economically with almost 220 billion US dollars of income (*COVID-19*, 2023) and deepen the learning crisis for the children of 10 years of age as confirmed by the World Bank and other global institutions and the majority of it is coming from the low and middle income countries, affecting almost 250 million children around the world, economically it means losing 17% of Global GDP (*70% of 10-Year-Olds Now in Learning Poverty, Unable to Read and Understand a Simple Text*, 2023). This is an emergency situation for these countries to select correct and effective interventions that would help them cover the learning losses as soon as possible (*COVID-19*, 2023), the literature has shown that impact evaluation of existing interventions is the foundational step to formulate effective future policies (Reed et al., 2021)

Knowledge gap in Pakistan – measuring the affect of the ICT facilities:

Pakistan is among the developing countries where private schools have incorporated advanced technology but its very recent that one of the provinces - Punjab's government took digital policy initiatives for public schools. This policy program consist of establishing the IT labs in secondary and higher secondary schools, followed by the provision of free laptops for high achievers (Hafeez et al., 2016; Salman, 2012). In addition to this, few more sub-projects included introduction of IT management tool for administrative tasks, the LCD screens for the early childhood classrooms for attractive learning videos (*Shahbaz Reviews Project of "Smart Board in Schools,"* 2017). The existing literature is focusing on the higher-education institutes, while on the school level papers are few, covering the benefits of technology or recently during covid the delve into the effectiveness of online classes (Hussain et al., 2022; Khadija Alhumaid, 2020; A. A. Khan et al., 2019; Taj et al., 2023). Hence it lacks the literature required to evaluate the effect of technology provided (i.e. IT labs) in public schools on the student's academic performance. This evaluation is not only filling an important gap in the literature but rather aims to provide evidence for the government for informed decision regarding the investment of scarce public resources on the correct type of technology which contributes the most in students learning.

Importance of teacher access and autonomy for the success of ICT in schools:

There are several factors involved in the success of a policy, from the actors involved to the implementation process as well as the utilization of resources for it. Previous literature emphasis that for the success of technology in schools the compliance of the actors for the adoption of the technology is extremely essential to achieve the aimed outcome (Inan & Lowther, 2010). However, there could be multiple ways the actors might not comply to the policy. First and foremost, the perception of the actors (i.e. Teachers) regarding the technological intervention – in case of computers, the papers suggest that teachers with more age have adverse perception about the use of technology in classrooms (Lau & Yuen, 2013). While if the teachers are willing to use their training plays an important role in use of the technology in daily routine(Veen, 1993). Further the literature emphasized how the freedom of utilizing the technology creatively or the freedom to use it properly without being financially burdened i.e. autonomy of the teachers are significant in successful ICT integration in schools (Razzak, 2015). In addition to the impact of the IT labs on students' Math scores, this paper takes a step further into understanding the implementation mechanism of this policy project. The paper used semi-structure interviews to get insights from the Head Teacher and teachers from the public schools in order to identify the challenges and hurdles they faced during the implementation or to utilize the IT labs to its best.

Evaluation and Evidence based Policy design approach:

In this era of information, the policies should not take the top to bottom approach rather uses data driven approach to formulate a policy representing the correct needs of the actors as well as to design a feasible mechanism for implementation that would increase the compliance and success rate. The policy papers are emphasizing evidence-based policy designs as the most appropriate approach to handle the political influences and authorities (Head, 2008; Pellegrini & Vivanet, 2021). Along with Evidence based policy design the researchers emphasize on evaluation of the previous policies to avoid repeating the same mistake (Banks, 2018; Sanderson, 2003). This approach of evidence based policy design is new in Pakistan and is being endorsed from last decade by the researchers (Vaqar Ahmed et al., 2021). In fact, the basic concept of evaluation of the project remained as a formal bureaucratic report not as a rigorous report to measure the project's impact on students learning and utilization of IT skills. Ultimately the government kept pouring in money in IT relevant projects even until this year. Hence this paper is significantly fulfilling this dire need of evaluation of IT labs relationship with students learning and would guide the map for future education polies.

Hypothesis

The hypothesis for this study has been formulated in guidance with the previous literature. The existing literature relevant with the impact assessment of ICT projects has set mixed results with respect to the context and technological intervention. One type of literature proves that the ICT related intervention has been significantly improving students' academic performance (Osin, 1998; Yeh et al., 2019) while some papers enlighten the reasons behind no relationship among the ICT and student academic performance (Cawthera, 2002; Karlsson, 2020). Besides this few papers also mentioned that there could be adverse effect of ICT on students score (Biagi & Loi, 2013; Fernández-Gutiérrez et al., 2020b; Hu et al., 2018).

Therefore, the three hypotheses for this study are:

Ho = There is no relationship between computer lab in school and the average Math scores of grade 8.

H1 = There is a positive relationship between computer lab in school and the average Math scores of grade 8.

H2 = There is a negative relationship between computer lab in school and the average Math scores of grade 8.

Data & Methodology:

Data & Sample:

Quantitative Data:

The paper utilizes two secondary datasets to assess the impact of a computer lab on the average performance of students per school in the provincial-level Mathematics exam for class 8 in 2018.

The first dataset used is the Government school census in Punjab (Census_18). This publicly available dataset contains comprehensive information about government schools in Punjab across 36 districts.

The second dataset consists of provincial-level examination marks. Officially obtained from the Punjab Examination Commission (PEC) for the thesis, this data includes student-wise marks for all six subjects for the year 2018. To calculate the average Math marks per school, I aggregated the data by computing the average marks from all students and grouping them by each school.

Qualitative Data:

The qualitative data pertains to interviews conducted in 4 schools located in Punjab. Official permission was granted by the Education Officer for Middle schools in Lahore to conduct these interviews. Convenience sampling was used to select the schools, with the criteria being that they should have a computer lab from the "IT lab in Punjab" project and be included in the list for the 8th-grade PEC examination. In total, 14 interviews were conducted, involving 3 Head Teachers and 11 subject teachers, including 4 mathematics teachers and 4 computer lab teachers.

Methodology:

The study employed an explanatory sequential mixed methods approach to investigate the impact of computer labs on average math scores. In the initial quantitative phase, secondary datasets from the Public-School Census & Punjab Education Commission were analyzed. This phase involved three regression models: the first one assessed the relationship between the computer lab and average math scores, while the second model utilized the Coarsened Exact Matching methodology to create a matched dataset, mitigating selection bias. Subsequently, regression was repeated to examine the correlation of the computer lab with average math scores, and the results were consistent with the matched dataset.

Given the consistent findings, I further explored the relationship using a continuous variable, the total number of computers, as a substitute for the computer labs' binary variable. The outcomes remained consistent across all models. However, to gain deeper insights and understanding, qualitative data were essential. Consequently, in the second phase, semi-structured interviews were conducted with 14 Head Teachers and Teachers from schools equipped with computer labs to obtain valuable insights for interpreting the findings.

Quantitative Section:

Preparing the Dataset:

The datasets were merged, but since there were schools in the Census_18 dataset that were not present in the PEC dataset, I dropped the NAs in our outcome variable, average Maths scores. This reduced the dataset to 15134 observations with 50 variables (See the full list of variables in the appendix).

Further, to make the dataset suitable for regression analysis, several adjustments were made. Firstly, observations were excluded where schools lacked electricity, resulting in the absence of a computer lab and both variables being assigned a value of 0. After this step, the dataset was left with 15029 observations.

Additionally, continuous variables, including enrollment (i.e., the total number of students in a school) and class (i.e., log of enrollment divided by the number of 'classes' variable), were log-transformed to achieve normal distribution. Moreover, categorical variables were treated as factors before being used in the regression. These variables included:

School_type:

This variable had six categories representing the type of administration or whether the school was established under any intervention program. The categories were "Government school" (pure public schools), "Pilot Secondary" (schools under interventions), "Community" (schools run by the community), "PSSP" (schools under the Punjab Public School Support Programme), and "Danish Adopted Schools." The categories "Centre of Excellence," "M.C Local" school, and "Junior Model" school had unclear definitions.

School level:

This variable indicated the highest education level offered by the school, such as "Primary" (Class Kindergarten (kachi) till Class 5), "Middle" (Class 6 till Class 8), "High" (Class 9 & 10th), "Higher Secondary" (Class 11 & 12), and "Mosque" (representing religious schools).

School location:

This variable had two categories: "Urban" and "Rural."

Medium:

This variable contained information about the language used for teaching in the school, i.e., "Urdu," "English," or "Both."

Districts:

This variable referred to the 35 cities where these schools were located.

Main Variables:

Dependent variable:

Average Math scores per school (math_avg):

It is a continuous variable created by taking average of all students math scores in a school for the year 2018. With the minimum value 0 and maximum value 90, the average of this variable is 52.29. Its is normally distributed (see Appendix B for the histogram and details). As mentioned earlier, in the guidance of the existing literature the rationale to choose average math scores primarily is the ease of measurement, second math uses the same brain side which is uses the logic and structures while using computers for (Fessakis et al., 2013; Israel et al., 2015; Morsanyi, 2021) so the measured impact would be direct.

Independent Variable:

Computer Labs (computer_lab):

The main independent variable is 'computer labs' which is a binary variable representing the presence of computer labs through 1 or 0. The aim through the use of this variable is to identify the difference of average math scores in schools with computer lab and without computer labs.

However, in the Regression model 3 I also used the variable of 'total_computers' as to delving deeper in to the correlation of number of computers on average math scores. It is a continuous variable but slightly non-normally distributed (see Appendix B for details) as the IT lab project aimed at providing 16 computers but ended up providing more or less depending on the size of the schools.

Variables Selected for control across the Models:

Based on previous studies, the following variables were carefully selected for control. Starting with school size (i.e., log_enroll) and class size (log_class), previous research considered these as important since school size impacts exposure to and usage of computers, and class size affects both computer exposure and Math scores due to the teacher-student ratio (Gómez-Fernández & Mediavilla, 2021; Hu et al., 2018). The number of teachers was also considered significant, as the teacher-student ratio directly influences students' performance (Wenglinsky, 1998).

Moreover, the language of instruction was included as a covariate, as past research supported its association with math scores. The impact of single-gender and co-gender schools on students' performance was also considered, as the literature presented mixed stances on this matter (Pahlke et al., 2014).

To account for school features, city diversity and urban/rural classification were considered as potential confounders. Additionally, the school level (primary, middle, high) and school type were essential control variables, as schools may differ in facilities and administrative styles based on these factors. Literature suggested that the managerial environment of a school could impact students' performance, particularly when comparing public schools that received intervention with non-treated schools (Newhouse & Beegle, 2006; Suna et al., 2020) . Finally, basic school facilities such as the number of toilets and the availability of drinking water were controlled for in the analysis (J. Ahmed et al., 2022; Jasper et al., 2012).

Regression Model 1:

On the original dataset of 15,029 schools I implemented a simple multilinear regression method to examine the correlation. Our independent variable is "Computer Lab," represented as a binary variable, with 0 indicating no computer lab in the school and 1 denoting the presence of a computer lab. The dependent variable, "math_avg," represents the average math scores for each school.

Following a step-by-step regression approach, we ran three sub-models within the regression. The first sub-model included only "b" and "computer_lab." In the second sub-model, we introduced control variables for school size (i.e., log_enroll) and class size (i.e., log_class). The third sub-model consisted of additional control variables for the level of school and school type. Finally, in the fourth sub-model, we included all the variables supported by the literature and mentioned in the "Selected control variables" section.

Table 1

Multivariate Regression Table Comparing Results from All Sub-models for Computer Lab and Average Math Scores

	Dependent variable:			
	math_avg			
	(1)	(2)	(3)	(4)
computer_lab	-1.826***	-1.327***	0.605**	0.211
	(0.175)	(0.215)	(0.302)	(0.281)
log_enroll		-0.531***	0.037	1.083***
		(0.167)	(0.182)	(0.241)
log_class		-1.905***	-2.153***	-0.182
		(0.555)	(0.587)	(0.561)
school_levelHigh			0.601	0.748*
			(0.456)	(0.435)
school_levelMiddle			3.674***	3.065***
			(0.525)	(0.516)
school_levelPrimary			-3.755***	-3.926***
			(1.262)	(1.183)
Constant	53.283***	57.389***	53.031***	45.761***
	(0.129)	(0.884)	(3.170)	(3.413)
Observations	15,029	15,029	14,155	14,123
R2	0.007	0.009	0.031	0.202
Adjusted R2	0.007	0.009	0.030	0.198
Residual Std. Error	10.670 (df = 15027)	10.659 (df = 15025)	10.559 (df = 14138)	9.574 (df = 14064)
F Statistic	109.215*** (df = 1; 15027)	47.283*** (df = 3; 15025)	28.376*** (df = 16; 14138)	61.290*** (df = 58; 14064)

The table above presents the results of all four sub-models. In sub-model 1, a direct correlation without controlling for any variables shows a statistically significant negative relationship, implying that the presence of a computer lab in school decreases the average math scores by 1.82 points. However, the R-squared value is extremely low at 0.07, indicating that only 0.7% of the relationship is explained. To account for potential confounding variables, we controlled for log_enroll and log_class, but the result still remained significantly negative, with the coefficient slightly lowering to 1.327 and an R-squared increase to 0.09, explaining 0.9% of the variance.

Sub-model 3 showed improvement as we controlled for two essential variables, school level and school type, revealing a significant positive coefficient of 0.60. However, the low R-squared value of 0.031 indicates that the sub-model remains weak. Subsequently, in sub-model 4, we included important variables from the previous literature, such as log_enroll, log_class, school_level, school_type, number of teachers, school_location, medium of instructions, gender_studying, total number of toilets, drinking water, and district. The result showed a positive coefficient of 0.211, indicating a possibility of a positive association. The improved R-squared value explains 20% of the variance through the model.

Regression Model 2 using Coarsened Exact Matched Data:

Upon further investigation of the data and methodology, we identified several issues, such as the lack of baseline data due to the non-randomized nature of the "Punjab IT lab" project and imbalanced control/treatment units. Additionally, the dataset "Government School Census" contains various variables that could act as confounders or covariates, influencing the outcome variable of average math scores. This presence of confounding variables makes it challenging to infer the relationship between dependent and independent variables accurately.

To address this issue and measure causal inference, particularly the isolated effect of the exposure or treatment, we need to control for the influence of other variables. Coarsened Exact Matching (CEM) is the best fit for this data as it distinguishes schools with treatment (i.e., computer lab) and non-treated (i.e., no computer lab) and matches them based on the provided list of variables. This allows us to measure the difference in math average scores between the two groups and identify the impact. Additionally, CEM can handle variables with missing values, making it a suitable choice compared to other matching methodologies.

The matching process in CEM involves calculating weights for each unit. They are derived from the balance achieved in the coarsened variables and serve as a measure of each unit's significance in the analysis. These weights act as a fine-tuning mechanism, adjusting the impact of individual units in the outcome analysis. By carefully accounting for the variations in covariate distributions, the weights facilitate a more balanced comparison between treated and control groups. Units assigned higher weights wield greater influence in the results, while those with lower weights have a diminished effect, culminating in a more precise and unbiased estimation of treatment effects (Iacus et al., 2012).

Steps for CEM:

The steps for Coarsened Exact Matching involved trying two sub-models.

Sub-model 1:

In sub-model 1, the goal was to create a matched dataset with similar characteristics for schools with and without computer labs (i.e. control and treated0. The characteristics used for this model are potential confounding such as log_enroll, classes, school_location (urban/rural), school_level (primary/middle, high), medium (English/Urdu), gender_studying, toilets, and play_ground.

The figure 1 below shows the that 6045 matched for control while 4685 for treated schools which were having computer lab in the school.

Figure 1

Matching result using sub-model 1

```
Sample Sizes:
               Control Treated
All             6864.    8165.
Matched (ESS)    570.37  1261.5
Matched         6045.    4685.
Unmatched        819.    3480.
Discarded          0.       0.
```

Once the dataset was matched, through the regression the relationship was examined between the math_avg and computer_lab. The variables included as control were the same as the "Regression Model 1" described in the "Variables Selected for control across the Models" section earlier. Further, in addition to normal regression this consists of the 'weight' function. In the matching process, weights are assigned to the observations to account for the imbalance between the treated (exposed to the treatment, in this case, having a computer lab) and control (not exposed to the treatment, i.e., no computer lab) groups. By using these weights during the analysis, the matched dataset better represents the population, allowing for more accurate estimates of the treatment effect while accounting for the potential bias due to the non-random treatment assignment These weights help to create a balanced sample, ensuring that the matched groups are comparable and reducing the bias that may arise from the non-random assignment of treatment.

Since the matched units for treated schools were 4685. I decided to try with less but important variables in the sub-model 2.

Sub-model 2:

As mentioned earlier, the only difference between these two sub-models are the variables used for matching. Sub-model 2 uses only broader characteristics of school which are school size (log_enroll), school_location if it is situated in an urban or rural area, school_level and if its a school only for boys, only for girls or both. There were 6620 matched schools for the control and 6760 for the treated.

Figure 2

Matching Result Using Sub-Model 2

Sample Sizes:

	Control	Treated
All	6864.	8165.
Matched (ESS)	433.83	1643.98
Matched	6620.	6760.
Unmatched	244.	1405.
Discarded	0.	0.

Followed by the same steps for conducting regression having the same set of control variables and having the weights function.

The results below represent for both of the matched data sets:

Table 2

Multivariate Regression Table Comparing Results from Sub-models 1 and 2 Using Different Variables for Matching

	Dependent variable:	
	math_avg	
	(1)	(2)
computer_lab	0.505**	0.533***
	(0.213)	(0.187)
log_enroll	0.748**	0.926***
	(0.381)	(0.282)
log_class	2.501	0.181
	(1.955)	(0.847)
Teachers	-0.092***	-0.068**
	(0.034)	(0.027)
school_locationUrban	-3.367***	-3.309***
	(0.380)	(0.297)
school_levelHigh	-1.782	-0.567
	(1.713)	(0.910)
school_levelMiddle	-0.164	1.689*
	(1.758)	(0.941)
Constant	58.036***	47.522***
	(5.158)	(3.991)
Observations	10,230	12,668
R2	0.203	0.223
Adjusted R2	0.199	0.220
Residual Std. Error	9.363 (df = 10172)	9.292 (df = 12610)
F Statistic	45.511*** (df = 57; 10172)	63.526*** (df = 57; 12610)

Overall, the regression results suggest that the presence of a computer lab in schools is positively associated with average math scores, even after controlling for other variables such as school enrollment, number of teachers, school location, and school level. To be precise, sub-model1 shows a significant increase with 0.50 in average math scores with p value less than 0.05. While using the sub-model2 dataset the coefficient remained positive but slightly higher i.e. 0.533 and significant on the p-value less than 0.01.

The control variable "log_enroll" is also positively significant which infers that schools with higher enrollment would have an increase in average math scores.

Nevertheless, since the effect is not significant from a policy perspective, it is important to confirm through the proxy variable of computer lab treatment which would analyze if the total number of computers has a stronger and direct impact on the average math scores in the regression model.

Regression Model 3 using total computers variable:

This model is the same as Model 1 but just with a continuous variable as an independent variable i.e total computers which consists of the number of computers in each school where they have a computer lab, otherwise have 0. Using the same step by step regression strategy, the control variable were added in 3 sub-models same as Regression with computer labs variable.

Sub-model 1 : No control variables included

Sub-model 2: controlled for log_enroll and log_class.

Sub-model 3: 4 control variables were added log_enroll, log_class, school_level and school_type.

Sub-model 4: All the control variables as mentioned in the "Selected variables for control" section.

Table 3

Multivariate Regression Table Comparing Results from All Sub-models for 'Total Computers' and 'Math Average

	Dependent variable:			
	math_avg			
	(1)	(2)	(3)	(4)
total_computers	-0.136***	-0.115***	0.036	0.024
	(0.011)	(0.014)	(0.024)	(0.022)
log_enroll		-0.297*	0.079	1.091***
		(0.167)	(0.180)	(0.236)
log_class		-2.052***	-2.173***	-0.191
		(0.554)	(0.587)	(0.561)
school_levelHigh			0.695	0.790*
			(0.457)	(0.436)
school_levelMiddle			3.813***	3.269***
			(0.595)	(0.572)
school_levelPrimary			-3.669***	-3.731***
			(1.293)	(1.207)
Constant	53.340***	56.259***	52.787***	45.550***
	(0.121)	(0.890)	(3.175)	(3.417)
Observations	15,029	15,029	14,155	14,123
R2	0.010	0.012	0.031	0.202
Adjusted R2	0.010	0.011	0.030	0.199
Residual Std. Error	10.654 (df = 15027)	10.647 (df = 15025)	10.559 (df = 14138)	9.573 (df = 14064)
F Statistic	152.955*** (df = 1; 15027)	58.955*** (df = 3; 15025)	28.265*** (df = 16; 14138)	61.304*** (df = 58; 14064)

Table 3 above shows a similar result as Regression Model 1 conducted with computer_lab as independent variable which contrasts with the results with matched dataset, it shows negative highly significant association for the sub-model 1 and 2 while when controlled the confounding or covariates, the coefficient was positive but insignificant value.

In sum, all three models clearly demonstrate the high influence of multiple variables and the usefulness of matching methodology since it enables randomization and closed backdoors to show the relationship with relative isolation.

Qualitative Method:

I used semi-structured interviews as the instrument to collect insights about the usage of the computer labs. Once the Education Department for Middle schools approved the permission, I used convenient sampling to shortlist the schools following only two criteria: first that the school should have received the treatment (i.e. IT labs under the project) and second they are affiliated with PEC Board for 8^{th} grade provincial examinations. Fulfilling the second criteria would eventually means that I have their 8^{th} grade data from PEC dataset.

Instrument:

The interview questionnaire had the basic information section same but the rest of the questionnaire was differently designed for Head Teachers and teachers but both consisted of the following three sections;

1) Perception of the use of computer in public schools – the purpose was to understand their opinion about the use and impact of computers in general on the learning of the students in public schools.
2) Details and Perception about the lab project – this section focused on understanding the mechanism of implementation of the IT labs project. How they initiated, were teachers involved or not, trained or not and then the perception of the respondent specific to project and its usefulness.
3) Perception on the role of teachers in making the computer useful for their educational performance: this section was a follow up based on their responses on section 1 & 2. The goal was to probe about the missing puzzle part for utilizing the computers for more learning especially for other subjects.

The link for the interviews are attached in Appendix C. Although the respondents gave consent for the interview following the ethical considerations, I kept the teachers names anonymous.

Results

Table 4

Multivariate Regression Table Comparing Results from All Regressions Models

	Dependent variable: math_avg (1)	(2)	(3)
computer_lab	0.211	0.533***	
	(0.281)	(0.187)	
total_computers			0.024
			(0.022)
log_enroll	1.083***	0.926***	1.091***
	(0.241)	(0.282)	(0.236)
log_class	-0.182	0.181	-0.191
	(0.561)	(0.847)	(0.561)
school_levelHigh	0.748*	-0.567	0.790*
	(0.435)	(0.910)	(0.436)
school_levelMiddle	3.065***	1.689*	3.269***
	(0.516)	(0.941)	(0.572)
school_levelPrimary	-3.926***		-3.731***
	(1.183)		(1.207)
Constant	45.761***	47.522***	45.550***
	(3.413)	(3.991)	(3.417)
Observations	14,123	12,668	14,123
R2	0.202	0.223	0.202
Adjusted R2	0.198	0.220	0.199
Residual Std. Error	9.574 (df = 14064)	9.292 (df = 12610)	9.573 (df = 14064)
F Statistic	61.290*** (df = 58; 14064)	63.526*** (df = 57; 12610)	61.304*** (df = 58; 14064)
Note:			*p<0.1; **p<0.05; ***p<0.01

Table 4 above demonstrates consistent results across the three regression models (Model 1, Model 2, and Model 3). In Model 1, the regression indicates an insignificant positive coefficient, suggesting that having a computer lab in a school lead to an insignificant percentage increase of 0.211 in math scores. The R-squared value for Model 1 is 0.202, indicating that approximately 20.2% of the variance in math scores can be explained by the presence of a computer lab.

However, when we utilize the matched dataset and incorporate weights generated by CEM in Model 2, the coefficient remains positive and becomes highly significant at a confidence interval of 98%. The higher coefficient of 0.533 indicates that, after accounting for other variables, having a computer lab leads to an increase in math scores. The R-squared value for Model 2 is slightly higher than Model 1, i.e., 0.223.

Additionally, in Model 3, besides the binary variable of a computer lab, we aim to assess the effect of the number of computers in the school on math scores. Unfortunately, this coefficient aligns with Model 1, showing a positive association but weaker and more insignificant, with an increase of just 0.024 math scores for each additional computer in the school. The R-squared value for Model 3 is 0.202.

Based on the findings of Model 2, i.e., a highly significant positive association between the presence of a computer lab and average math scores, we can reject the null hypothesis i.e. there is no relationship. The positive nature of the coefficient indicates that we cannot rule out an alternative hypothesis - H1, as there is a possibility of a positive relationship between computer labs and students' math scores. However, since the coefficient is extremely low, further investigation is required to rule out the possibility of H2, i.e., the negative impact of computers on average math scores.

Furthermore, the consistently positive and significant coefficient for log_enroll across the regression models suggests that larger school size leads to higher average math scores. However, the low coefficient in Model 2 points towards the need for more in-depth research to ascertain this impact with certainty.

Similarly, the log_class variable shows a different nature of relationship in Model 1 & 3 compared to Model 2. This indicates that it requires further examination. While the results differ for the different school levels, showing uncertain associations for High schools and primary schools, there is a consistently positive and statistically significant coefficient for middle-level schools across all the models. In Model 1, there is an increase of 3.7 points in average math scores, while in Model 2, the increase is 3.02 points. In the matched dataset of Model 3, the increase is only 2.1 points in average math scores.

Despite the statistically proven positive relationship, the coefficient of 0.533 represents just 1.02% of the mean of average Math scores (52.29). Thus, from a policy perspective, it appears to have almost no impact. This finding is not surprising given that all Head Teachers mentioned during the interviews that they exclusively utilize computer labs for the subject of 'Computer'. As a result, the correlation might indicate an indirect effect, considering the existing psychology literature suggesting that both computer and math are rational subjects (Bergman-Nutley & Klingberg, 2014; Sánchez-Pérez et al., 2018)

This situation highlights a significant gap commonly found across developing countries, i.e., the disparity between the provision of technology and its usage (Davison et al., 2000; Fong, 2009). When delving deeper into discussing why they are unable to utilize computers for other subjects, particularly math, there were main themes of challenges that restrict them from using the computer labs for any other subject.

The first theme is financial constraints. This refers to the high maintenance cost for all equipment in the lab, including electronic wiring, UPS, furniture, hardware, and software, including the renewal cost of licenses for the server that connects all the 16 computers with the teacher's computer, required every 6 months. One of the female Head Teachers, mentioned that "on average, each year the computer lab requires 50 to 60 thousand Pakistani rupees," (1 Head Teacher, 2022) which is equivalent to approximately 200 US dollars per academic year. In the same context, a male Head Teacher expressed in agitation, "Should I get toilet repair or school paint or maintain the computer lab?" (3 Head Teacher, 2022). Considering that there is no separate budget provided to the Head Teachers for the maintenance of the computer labs, they are hesitant to use them creatively for other subjects.

The second theme that emerged is the lack of autonomy, as the computer labs are ordered to be used only by the computer teacher, and the education team visits to check the condition of the computers, but no extra funding is provided even if anything requires repairing. This restriction is limiting the creative usage of computer labs for any other subject than ‘Computer’ which only teaches how to use computer that could not improve students' learning. This pressure trickles down from the Head Teacher to teachers, and they also know that there is no space to utilize the computer labs for teaching any complex concepts using videos or games. Out of 11 teachers, only 2 mentioned that they tried to use the computer lab for their subjects (i.e., Science and English), but they were unable to do so due to operational challenges, including the lack of availability of computer labs and the computer-student ratio.

This leads to the third theme, operational issues, that hinder the full utilization of the computer lab. Operational issues include the computer-student ratio, availability of computer labs, and lack of time for creative usage due to the loaded syllabus that needs to be completed each year. The computer labs have a maximum of 16 computers, and the mean enrollment is 492 students, which means there are only 0.03 computers per student, not even 1 full computer per student. This significantly affects the exposure time that students can use the computer, making it extremely difficult to manage this computer-student ratio to use the computer lab even once a week for Maths. Additionally, all the teachers expressed, in one way or another, that the priority is the syllabus from the higher-ups, leaving no time for being innovative and creative about the usage of computer labs. All these challenges have already been reported in the previous studies particularly in the context of the developing countries (Amuko et al., 2015; Y. Wu & Wu, 2018; Ziphorah, 2014) so this raises an important concern why the Government of Punjab is unable to learn and repeat the same methods.

Recommendations & Conclusion

The study found a negligible positive relationship between the presence of computers in schools, contributing only a 1.02% increase in average math scores annually. This limited impact is due to almost no use of computers for leaning math in schools because of the lack of access and autonomy of head teachers and teachers, which is further compounded by the operational challenges such as the computer-student ratio. The use of specialized matching technique CEM bolstered the validity of the quantitative results by addressing potential causal inference biases. These findings are consistent with previous literature emphasizing the positive effect of computers on student performance in math, but the insignificant correlation with the total number of computers warrants further investigation.

Considering the literature suggesting that it may take time for the impact to become noticeable, this study examined the correlation after six years of computer implementation, focusing on the constant exposure in 2018 when the "IT lab in Punjab" project had set up the labs in 2012. Despite the elapsed time, the marginal 1.02% increase in average math scores is considered insignificant from a policy evaluation perspective, raising doubts about the justification for further investment in technological interventions.

In addition to the quantitative findings, the qualitative insights from the schools reaffirmed the literature that setting up the computers with the internet is not enough; rather, incorporating them as tools for learning is crucial. Alongside the discrepancy in usage, the teachers reported the same old challenges of lack of autonomy and resources, which were already reported as challenges years ago. This raises questions about the implementation mechanism of this project in Punjab.

Amidst global learning poverty, high dropout rate of students from public school post-covid and extremely unstable economic situation in Pakistan, this paper is important for providing essential findings to contemplate the required improvements before investing further in the technological interventions in schools. Therefore, this study would like to recommend the following suggestions to the policymakers and government

Recommendations for Punjab - specific to the context of Pakistan

The study focused on a Punjab-specific project, evaluating the correlation of the computers set up under the “IT lab in Punjab schools” project with the average math scores of 8th-grade students in Punjab government schools. Therefore, based on the findings, the following recommendations are suggested to the stakeholders of schools particularly the Provincial Government and Education Department of Punjab, aiming to improve similar policies in the Pakistani context:

1) The positive association indicates the need to explore the hidden potential impact of the existing 4286 computer labs on student learning, instead of investing in additional new projects. This requires proper planning involving Head Teachers and teachers. Previous

research papers highlight that involving teachers is mandatory for the optimum implementation of technology.

2) According to qualitative findings, it is crucial to provide financial autonomy and creative freedom to teachers in using the computer labs for learning in any subject they deem fit. Existing literature supports the positive impact of teachers' autonomy for the successful integration of technology in schools.

3) Rather than investing in new technology, supplying the existing labs with more computers, additional complementary software, or educational games for the students would optimize the computer-to-student ratio. Exposure to technology is essential for creating an impact.

4) Finally, the government should maintain a record of important indicators of success for every implemented project. The lack of significant variables relevant to the usage pattern of computer labs across schools was a limitation of this study.

Recommendation for Developing Countries:

Despite the specificity of this paper, it is equally relevant to all developing countries. In general, the paper covers the evaluation of the impact of technological intervention in schools, particularly focusing on states with tight financial resources suffering from a learning crisis. Thus, the following points could be considered for developing countries:

1) There is a need for continuous evaluation of technology, not just in the beginning, but even years later, to monitor the disparity between technology access and usage.

2) The involvement of Head Teachers and teachers is significant to utilize technology innovatively and creatively, rather than limiting it to a single subject or usage pattern. This is evident from the findings, as even though the computer labs were primarily used for computer subjects, there was an indirect impact, suggesting the potential use for other subjects like mathematics.

3) Furthermore, it is essential to record variables, especially during the baseline and usage pattern, to understand the current usage and plan for prospective utilization of hardware and software.

4) Simply setting up a computer lab would not be as effective as combining it with learning-assisting software and games, which can be beneficial.

By implementing these recommendations, developing countries can make the most out of technological interventions in their education systems and potentially improve the learning outcomes

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Foot notes

Grade: In the previous literature the word ‘grade’ has been used interchangeably with the word ‘class’ to refer to the academic level of the students (Mushipe & Ogbonnaya, 2019; Shatri, 2020).

8th grade in Pakistan: The students in the 8th grade are of around 17 – 18 years of age with 9 to 10 years of education starting from kindergarten at around the age of 3. (*Pakistan (Punjab) Education Fact Sheets I 2022. Analyses for Learning and Equity Using MICS Data*, 2022)

Appendix A

Summary of the final dataset

Total observations : 15029

Total variable: 50

List of variables

Variable_name	**Variable_type**	**Variable_name**	**Variable_type**
EMIS	Numeric	total_toilets	Numeric
school_name	Character	usable_toilets	Numeric
district	Factor	need_repairing_toilets	Numeric
math_avg	Numeric	teachers_toilets	Numeric
computer_lab	Binary (1,0)	boundary_wall	Binary
total_computers	Numeric	main_gate	Binary
enrollment	Numeric	sewerage	Binary
Teachers	Numeric	play_ground	Binary
log_enroll	Numeric	security	Binary
log_t_s	Numeric	cricket	Binary
log_class	Numeric	football	Binary
log_comp_std	Numeric	hockey	Binary
head_type	Factor	badminton	Binary
head_grade	Numeric	volleyball	Binary
medium	Factor	table_tennis	Binary
school_shift	Factor	students_with_furniture	Binary
school_location	Factor	library	Binary
gender_studying	Factor	total_books	Binary
school_level	Factor	science_lab	Binary
school_type	Factor	total_computer_training_students	Numeric
est_year	Numeric	internet	Binary
bldg_status	Factor	sum_sports	Numeric
bldg_condition	Factor		
functional_classrooms	Numeric		
dangerous_classrooms	Numeric		
under_construction_classrooms	Numeric		
classes	Numeric		
sections	Numeric		
drink_water	Binary		
electricity	Binary		
toilets	Numeric		

Appendix B

Additional information about independent and dependent variable

Independent Variable:

Regression Model 1 & 2 : Computer Lab

Type of variable – Binary with 1 = the school have Computer lab , 0 = there is no Computer lab in the school.

Regression Model 3: Total Computers

Type: Continuous variable with numeric values.

Summary table

Min	1st Quantile	Median	Mean	3rd Quantile	Max
0.00	0.00	5.000	7.742	16	86

Dependent Variable

Average Math scores

Type: Continuous variable with numeric values.

Summary

Min	1st Quantile	Median	Mean	3rd Quantile	Max
0.00	45.09	52.13	52.29	59.40	90

Appendix C

Consent form:

My name is Ayesha Ahmed, I am pursuing my Erasmus Mundus joint degree program of Masters in Public Policy. This research is for my thesis as a mandatory part of my degree. The topic of my thesis is "Correlation of availability of computers and students' academic performance: Evaluating the "Punjab IT labs" project". In this paper I tend to examine the correlation of the computer labs setted up in public schools with the Maths scores of 8th grade students in the Punjab Education Commission (PEC). The research methodology is mixed methods, with quantitative methods for measuring correlation, while qualitatively complimenting the findings through semi-structured interviews of the head teachers and teachers.

Therefore, I am asking you to take part in my research study regarding the computer labs in the government schools. I would like to have a discussion and have a few questions for you, related to the availability of computer labs and your perception of using education technology tools in your teaching. The survey should take about 15 minutes.

I assure that all of your responses will remain confidential and will not be shared with your head teacher, any other teachers, or anyone from the education department. The survey will not contain questions that can identify you as a person.

I will keep the data I collect confidential, and I will not share your personal information with anyone outside the research team.

Being in this study is voluntary. Please confirm, if you do not want to participate.

Audio recording consent if they volunteer for the interview:

Thank you for participating in this research, for record purposes would you allow me to do an audio recording of this interview?

For the findings and copy of the interview please provide your email or whatsapp number

For further queries my contact details are aahmed@ibei.edu.org or +92-332-3019101

Appendix D

Questionnaire 1 - For Head teachers

Data of their school from the census dataset (for your own context)

Section 1: Basic information

1. Gender
2. Years.of experience
3. Education

Section 2: Perception of the use of computer in public schools

1. Throughout ___ years, what do you think of the role computers play in school?
2. (if he says yes it does) How?
3. (If he says no it does not) Why? Then what is the point of having a lab? (3b)

Getting them back on track by discussing lab project

Section 3: Details and Perception about the lab project

1. When did he join this school -> this will clarify if he was there when the lab was setted up
2. So, could you please elaborate on the process of setting up the lab
    1. How they started - with nay meeting with you, did they ask for enrollment
    2. In your understanding, what was the objective of this lab setup?
    3. Do you think that objective is achieved?

Section 4: Perception on the role of teachers in making the computer useful for their educational performance

1. How many classes does each class have in the computer lab
2. What does the teacher teach in the lab?
3. Do you think a more skilled teacher or more classes would help students to use computers for their studies?
4. (If the school owner feels like computers were not setted up for improving the performance) Do you think a software like khan academy would help utilizing the computers for the learning performance of students?
5. Does the government keep a check on the operational computers and non-operational?

Appendix E

Questionnaire 2: For school teachers

Section 1: Basic information

1. Gender
2. Years.of experience
3. Education

Section 2: Perception of the use of computer in public schools

1. Throughout ___ years, what do you think of the role of computers in school?

Getting them back on track by discussing lab project

Section 3: Details the lab project

1. Did you or any other specific teacher get any training from the government during the lab setup?
2. How many classes does each class take in the computer lab?
3. All the grades have computer lab class or some of them?
4. Students must have enjoyed this class,
    1. (if they say yes - then ask why? - they might expand that since they were allowed to play games or with the paint etc.)
    2. If no then ask why - to understand what were they teaching in the lab class

5. Was it allowed to take students in any subject to a computer lab for showing any documentaries or games etc.

a. If yes, then when did any teacher utilized it

b. If no, then why not?

c. (If there are projectors which are used for such activities) have you tried using it for strengthening the concept in students mind?

i. If yes - did it work

ii. If no - why not

Section 4: Perception of what is the best technique to teach students - especially during covid the students were taught on computers

Appendix F

Interview summary:

Figure below provides the summary of the number of interviews conducted per school. Out of total 14 interviews; 3 were of the Head Teacher (2 Female & 1 Male) while 11 were teachers (9 Female & 2 Male).

Table 5

Summary of distribution of interviews per school

Schools	Enrollment	Teachers	Interviewed(H)	Teacher	
Govt. girls Canal view	1240	20	1	2	
Govt. girls Wafaqi	905	20	1	1	
Govt boys wafaqi	410		1	2	
Comprehensive school wahdat road	2169	78		6	
Total			3	11	14

Insights Summary:

This cross-tab summary of the findings from the interviews per school:

Table 6

Distribution of insights per question

	H_T		Teacher	
	Yes	No	Yes	No
Computer lab impact their performance	1	2	2	9
Are they using it for other subjects?		3		11
Do you think generally technology is helpful for the students learning	3		8	3
Are you using the lab to its optimum level?		3	11	
Is the lab used only for computer subject?	3		11	

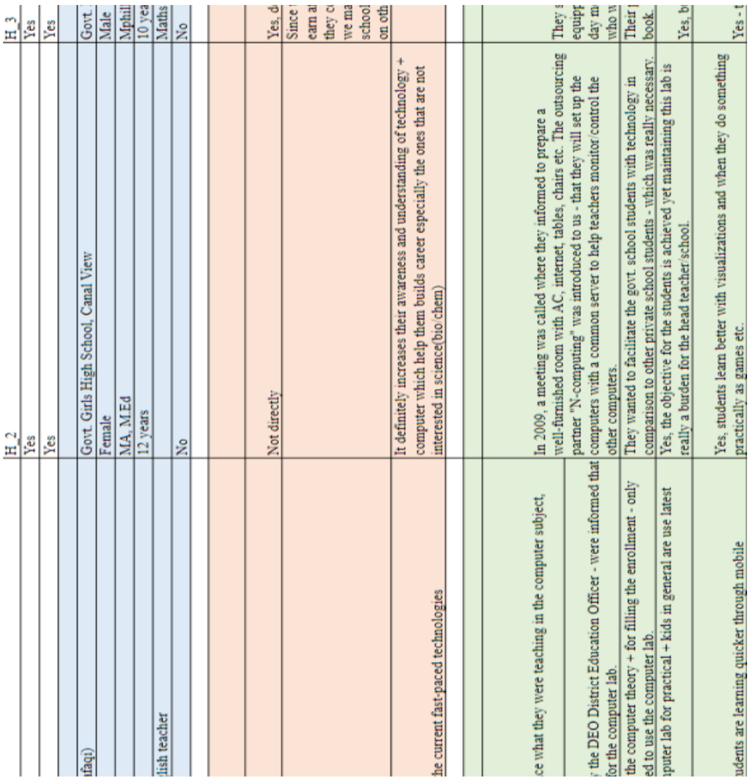
Appendix G

Head Teacher interview response sheet

The figure on the next page provides a glimpse of the response from the Head Teacher. The full version of the interview response sheet can be accessed through the link: https://docs.google.com/spreadsheets/d/1G3fJSz05hyIchPitI0zT27tBKIgOYB9V/edit?usp=sharing&ouid=118140468260796931308&rtpof=true&sd=true

Figure 3

Glimpse of the Head Teacher survey - link for the full sheet is https://docs.google.com/spreadsheets/d/1G3fJSz05hyIchPitI0zT27tBKIgOYB9V/edit?usp=sharing&ouid=118140468260796931308&rtpof=true&sd=true



Appendix H

Teachers interview response sheet

Interviews could be accessed through the link

https://docs.google.com/spreadsheets/d/1G3fJSz05hyIchPitI0zT27tBKIgOYB9V/edit?usp=sharing&ouid=118140468260796931308&rtpof=true&sd=true

While below given figure 8 is just as an evidence.

A	B	C	D	E
	Teacher 1	**Teacher 2**	**Teacher 3**	**Teacher 4**
General consent to participate	Yes	Yes	Yes	Yes
Consent to record audio	Yes	Yes	No	Yes
Basic Information				
School	Govt. Girls High School, Canal View	Govt. Girls High School, Canal View	Govt. girls Wafaqi	Comprehensive school wahdat road
Gender	Female	Female	Female	Female
Education	MS Computer	MA.MEd	MA Urdu	MCS
Years of expeirience	12	32	39	11
Which subject they are teaching?	Responsible for Computer lab & teaching computer	Urdu	Urdu & Arabic	Higher secondary Computer lab teacher
Perception of the use of computer in public schools				
Do you think having a computer lab in the school impact students performance?	No	Yes	Yes	No
How?		It helps them learn latest technology	These videos are so effective even the babies are learning so much through mobile	
Then what is the point of having a lab?	To expose them to the computer			It ignited interest for them to take it as a career
Details and Perception about the lab project				
Did you or any other specific teacher get any training from the government during the lab setup?	Yes I got training during the project setup	No, we are not even allowed to use computer labs	No, the computer teacher was responsible	Yes after hiring - they trained us
All the grades have computer lab class or some of them?	8,9,10			Its only allowed to the higher secondary i.e. 11th & 12th
How many classes does each class take in the computer lab?	only allow 8th class onwards to have practical. While only 9th and 10th class go to the lab regularly but for the 8th grade its			11th till 12th have classes daily or thrice a week
Students must have enjoyed this class,	It depends in the students,			Yes - some what
(if they say yes - then ask why? - they might expand that since they were allowed to play games or with the paint etc.)	the students that enjoy are either really looking forward to it as a career or glad that its practical so they dont have to learn anything			yes 80 percent enjoy but 20 percent really want to take it as career
If no then ask why - to understand what were they teaching in the lab class	mobile is so common these days taht its sometimes bore the studnets			
Perception on the role of teachers in making the computer useful for their educational performance				
Was it allowed to take students in any subject to a computer lab for showing any documentaries or games etc.	No	No		No
If yes, then when did any teacher utilized it				
If no, then why not?		Its instructed from education officer that		

Annexure – Thesis Report

Correlation of availability of computers and students' academic performance:

Evaluating the "Punjab IT labs" project

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September 15, 2022

Abstract

Despite the implementation and investment in many interventions, Pakistan's education space suffers from learning poverty. One of the reasons behind this is the lack of impact assessment of the previous policies which leads to the repetition of the same mistakes and wastage of scarce resources. Therefore, this paper focus on evaluating one such interventional project "IT labs in public schools of Punjab" where they provided only computer in schools for the secondary level. I aim to examine if the presence of computers has any correlation with the student's scores in provincial exams. Moreover, the study will look into the qualitative side of the effectiveness of this policy by conducting in-person interviews with the principal and teachers of public schools.

Keywords: computer lab, education policy, correlation, student's academic scores

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Introduction

Pakistan's unstable economic condition demands a fully informed policy to invest limited public funds. Since, education is considered an essential unit of progress for a country, the world focused on increasing enrollment to achieve the Millennium Development Goal of "Achieve Universal Primary Education" (United Nations, 2015). Pakistan was also one of the countries where low-enrollment was alarming, precisely, 1in every 5 students was out of school (UNDP, 2004). However, improving enrollment shadowed the concept of evaluating the learning outcomes of currently enrolled students. Hence, in 2008, the first large-scale research in Pakistan; "Learning Educational Achievement of Punjab (LEAPS)" pointed toward a learning crisis referring to increased enrollment but decreased learning of students. One of their findings mentioned was that only 19% of class 3 students could divide the three-digit number, while 69% cannot compose a simple sentence from the word 'school' (Andrabi et al., 2008). This clearly depicts the lack of data-driven policy implementation in Pakistan.

Since, during the 2000s, policymakers and governments were inclined toward using technology as a policy intervention. Believing on the same line the donor community started pouring money into the technology. Following the global trend, developing countries invested their finances in the provision of technology for the improvement of the education sector too. Similarly, in 2005, the Federal government of Pakistan introduced a project to provide 16 computers for IT labs in 515 secondary-level schools. Subsequently, in 2008 a much larger project was initiated by the provincial government of Punjab to establish 4286 IT labs consisting of 16 computers, internet, and a power supply system in case of power outrage in the secondary and higher-secondary public schools (NComputing, 2010).

Despite this intervention, in 2018 Annual Status of Education Report (ASER) published findings of the consistent learning crisis with a slight improvement. The report shows that even in 2018 grade 5 is unable to achieve the learning objectives of grade 2. Further, it also stated that the difference between the expected years of schooling and the adjusted years of learning is of almost 4 years (*ASER-PAKISTAN 2018*, 2019). In the same year, researchers at the World Bank announced a global crisis in academic learning referring to increased enrollment and lowered learning (*The Education Crisis*, 2019).

The evidence was calling out the policymakers to evaluate the impact of investing in providing computers to understand the impact related to learning and identify better interventions that would be able to achieve the objective of improving the learning outcomes of students. However, before the government of Pakistan would have taken any action about this. Corona Virus Pandemic started to spread, causing schools to be shut down for almost 8 months continuously (Fouzia Malik et al., 2021).

This situation exacerbated the learning losses among students. The World Bank report 2022 updated used the term global learning poverty to emphasize the intensity of learning loss. It states that the rate of global learning poverty in low and middle-income countries has risen from 57 percent pre-pandemic to 70 percent now. This report urges the governments to take immediate action toward learning about poverty (*The State of Global Learning Poverty: 2022 Update*, 2022). Similarly, in the context of Pakistan, ASER report 2021 states the learning performance requires urgent action, especially with just 15% and 21% foundation learning in Arithmetic and language subjects, grade 3 makes it a “lost generation” (*ASER-PAKISTAN 2021*, 2022). This makes it evident that the intervention are implemented without analysis leading to waste of scarce resources including public funds, human resources and time to fix the problem.

Previous studies proved the significance of impact evaluation of the intervention. Understanding the dynamics of evidence-based policymaking in Pakistan, the data-driven policy is relatively new – according to a report by Strengthening Evidence Use for Development Impact (SEDI) the policy-making process in Pakistan was heavily driven by powerful actors rather than evidence (Vaqar Ahmed et al., 2021).

Additionally, current economic situation made it even more crucial for Pakistan to have an informed evidence-based decision to finalize which intervention needs investment, due to the increasing financial debt and highly unstable economy (*Economic Update and Outlook*, 2022). Hence, considering the learning loss status, it is indeed a dire need to evaluate the impact of computer labs on students’ performance to support policymakers in making informed decisions. Therefore, this paper aims to fill the research gap in understanding the correlation between having computers in public schools with students learning.

Literature Review

Education is always considered the mainstay of society with respect to knowledge, skills, and civilization. Nevertheless, there has been a debate about formal or informal education. Later the debate evolved into skills versus knowledge and in the current era, it's between technology and human knowledge. Still, the vitality of education kept increasing when linked with the economy or other sectors. In fact, the World Bank document published 36 years ago in 1985 "Education for Development" states that investment in the education sector of developing countries is not just to fulfill the basic rights of citizens rather it is the seed to a productive economy in terms of human capital. This document showed evidence of a significant share to improve national income due to the education of the labor force (Psacharopoulos et al., 1985). Even to date, several studies were written on the role of education in the progress of society (Bhardwaj, 2016; Ochilova, 2020).

As a result, the global community decided to keep education specifically enrollment in schools a priority goal in Millennium Development Goals (MDGs) or later in Sustainable Development Goals (SDGs) to achieve. Consequently, developing countries were funded to work on the sole purpose of achieving increased enrollment in primary schools. As a result, governments flooded the education sector with various interventions.

It is important to understand that implementing tons of interventions doesn't assure the achievement of goals. Hence, impact measurement is essential to determine which intervention is more effective. This simply means to measure "what works" before investing in scale-up or other interventions. According to Organization for Economic Co-operation & Development (OECD), the evaluation question refers to not just answering the impact of the research but rather it's the measurement of the extent to which the goal is achieved. They also discussed the simple linear correlation model of evaluation which used the independent and dependent variables to understand the impact or change (OECD, 2014).

Fortunately, for the MDG goals, United Nations Agencies were involved to conduct the impact evaluation periodically measuring the extent of success in achieving the goal (*From MDGs to SDGs*, 2014) Because the concept of impact evaluation for data-driven policy making was new to the developing countries and started to rise around 2000 onwards while specifically in South Asia it rose from the year 2010 onwards (Sabet & Brown, 2018). As a result, despite the implementation of multiple interventions, there has been still a gap in achieving the objectives for the education sector.

To understand the evolution of evaluation for education intervention-based literature, very few papers existed during the late 80s emerging from developed countries such as the US. One of them is a qualitative review "welfare intervention - 1986" which aims to examine different educational interventions focusing on economic growth, equity, or student employment in the future. The researcher categorized the intervention as direct or indirect but declared that it can be implemented simultaneously. The detailed evaluation follows the recommended role of the government. Even though the paper is one of the few evaluation assessments of that time period, but then the scope was narrowed to economical intervention and impact not learning (Psacharopoulos, 1986). On the same note, the second paper is a review paper that uses secondary data to focus on more specifics about the economical strategies to analyze; cost-effectiveness, and cost-benefit to understand the impact. In terms of methodology, the usage of only 6 longitudinal studies particularly preschool early intervention and the students were only taken from the disadvantage families is too less to generalize. As per their findings, the investment in preschool interventions is expensive in the short run but in long term it is beneficial. A slight positive aspect was that this paper shed light on the learning aspect, by correlating the intervention with the improvement of IQ in specific preschool students in non-school activities. To emphasize this paper also suggested the need for more impact evaluation papers for the education sector (Barnett & Escobar, 1987).

As the years passed, we saw a slight increase in the impact of assessment papers in the education field of the world. During the 90s there were few papers published relevant to the impact of the intervention on enrollment or social growth. In 2004, IMF published a rigorous review paper that mentioned the early studies which continued the measurement of impact for multiple variables, such as the positive correlation between enrollment and social growth. Further, the paper examined the impact of social intervention on fulfilling MDGs. In my opinion, it is a significant contribution to the literature as they used a panel dataset of 25 years from 1975 to 2000 from 120 countries. However, to minimize error or fluctuations they used averages from every 5 years. One of the factors that make this paper complicated to learn from my perspective is the collective analysis of investment works for all MDGs goals, not solely education but health, poverty, and social growth. So, the study was successful to conclude multiple results relevant to all goals, to my interest they declared that spending on the education sector has almost two-thirds benefits in the immediate 5 years as well as in the next span of five years. To be precise, the expenditure of 1 GDP on education is associated with a 6 percent increase in enrollment in the current 5 years while 3 percent in the following 5 years (Baldacci et al., 2004).

In the late 90s and early 2000s grew the focus on improving learning outcomes, not just enrollment. In one of the papers written by renowned American economist Eric A. Hanushek, he pointed out the potential issue of grade repetition and high dropout rates wasting the investments focusing on enrollment. It is interesting that he recommended extensive experimental evaluation as a solution to grab existing inefficiencies but also mentions that this concept of evaluation is not known by the education sector of both developed and developing countries. It is a comprehensive paper where Eric has elaborated on the complexity of schools in terms of how their system differs – developed, developing countries, urban, and rural with multiple stakeholders involving teachers, students, and parents. Therefore, he concluded that policies should be focused on quality not just on increasing accessibility (Hanushek, 1995). Similarly, another well-known economist from the US, Lant Prichett wrote in his paper “ 'Where Has All the Education Gone?” he declared that the development impact of education is not meeting the expectation due to three factors, among which one of the most important was the low quality of education led to no contribution on human capital (Pritchett, 2001).

In terms of working toward the concern about the learning outcomes, new researchers took the work forward including some great names such as Michel Kremer, Abhijeet Banerjee, Esther Duflo, and Asim Khwaja worked to measure the research happening in developing countries with the objective of introducing evidence-based policymaking or implementation. One of the most anticipated impactful outcomes on students' learning would have been the textbook provision in Kenya in the year 1995. But as Michael Kremer describes in his paper

"Many Children Left Behind? Textbooks and Test Scores in Kenya" there was a significant impact since the schools in rural Kenya was without a sufficient number of books but the problem was that this effect was only on the already intelligent students – as he digs deeper the reason behind emerged to be the medium language of the books i.e. English. On this, he inferred that existing distortion in the education system is the core hurdle in achieving a uniform impact of an intervention applied to all (Glewwe et al., 2009).

The impact assessment trend was rapidly increasing, when in India Nobel prize winners renowned economists Abhijeet Banerjee and Esther Duflo did a randomized experiment related to instructional medium and the learning outcomes of students. They tested two types of instructional medium; a remedial program "Balsakhi" in which a young teacher would especially teach weak students in literature and Math, while the other type was a computer-assisted learning program only for Math. Their findings were that such remedial interventions are creating a direct impact on learning as the students with "Balsakhi" improved by 0.6 standard deviations in the second year while the school receiving this support observed an improvement of 0.14 standard deviations in the first year. The same result was from the computer-assisted learning program as the students had increased by 0.38 standard deviations in the first year (Banerjee et al., 2007). The programs were effective but the scalability of such intervention is an issue for a government of a developing country. In my opinion, it was an important study to suggest the value of impact assessment even of the computer-assisted learning programs to correct the general mentality of the policymakers of developing countries that computers or technology is definitely going to be effective.

In Pakistan, around the same time – in the early 2000s the renowned researchers - Dr. Tahir Andrabi and Dr. Asim Khwaja started to work in the education sector. They initiated the first-ever large-scale longitudinal study to understand the educational sector and measure the learning outcomes of students. It highlighted a very crucial fact of 'learning loss' in the province where the enrollment increased the most, the same was declared ten years later in 2018 by the World Bank. The study also informed about the changing educational space due to the drastic increase in private schools which grew from 32000 to 47000 in just 5 years. The contribution of these private schools turned out to be quite significant as every 3 children enrolled in primary level is studying private school. Consequently, the share these schools are adding in the literacy rate is also remarkable as the paper assessed students from public and private schools and found that private school student from class 3 is able to solve the questions from the 8th class. On the same line of impact evaluation another paper "Report Cards: The Impact of Providing School and Child Test Scores on Educational Markets" by Dr. Tahir Andrabi and Dr. Asim Khwaja partnered with Dr. Jishnu Das from World Bank was based on the effect of information provision upon the market–customer behavior for public and private schools. It was a randomized control trial experiment was conducted and selected parents received the report card with test scores. The findings showed that where they received report card it had a positive impact on test scores as it increased by 0.11 standard deviation.

Unfortunately, even such studies were unable to bring any change in the ill-practice of implementing grant-driven or conditional cash transfer funds conditioned interventions. Thus, a few years later the government of the most populated province Punjab decided to set up the computer lab in secondary and higher secondary schools with the aim of providing education on computer usage and improving learning outcomes. As I understand, the existing literature regarding technology in schools has categorically three views about the impact of providing free facilities of computers or laptops. First, found the provision of facilities in the school (i.e., computer lab/ technology) as the means of retention and increment of enrollment. Second, the one that has evidence that only computers or laptops are not useful for students learning at all. Third, that suggests on the basis of data that if the computer is facilitated with any learning program, then it will contribute to the learning of the student.

It is a general concept that having high technology (such as computers, biometric attendance of staff or students, automatic messages for parents etc.) would add value to the place. In Pakistan, it is essential for private schools to add a technological component for attracting customers (i.e. parents). Mentioned studies have supported this idea in the past but the focus as they stated was the enrollment or retention of students. Which is irrelevant in the context of improving the academic performance of students (Andrabi et al., 2008; Burgess et al., 2015; Osin, 1998). While few papers found sole computers are indeed significant to equip students with knowledge about computers and technologies to prepare them for the global levels (Osin, 1998; Yeh et al., 2019).

It a fact that providing only devices does not have a direct impact on the students learning ("Can Computers Help Students Learn?," 2011; Karlsson, 2020). The studies that supported this idea presented the few reason which were relevant in old times of developed countries but is still logical in context of developing countries. The reasons includes: availability of devices (Almanthari et al., n.d.; Cawthera, 2002; Fu, 2013), knowledge of students (Deobrah Kay Defrieze, 1998) or skills of teachers on using devices (Ghavifekr & Rosdy, 2015; Kong & Wang, 2021; Veen, 1993), managing the device during the class (Means, 2010).

However, to back the third category of researchers, there are many studies due to the latest version of research in the developed countries revolve around the type of programs complementing with devices are most effective. Discussing few evidence relevant with developing countries circumstances, one of the paper is a comprehensive impact evaluation study along while the other study is from US, mentions that only the provision of devices is not effective alone until complemented with learning programs (Kebritchi et al., 2010; Tamim et al., 2011). To have a similar study with Pakistani context, I found a study where they did a randomized control trial with computer-assisted learning program among in-school and out-of-school children in India. They concluded that even the learning program based on technologies should be modified and implemented carefully according to the on-ground situation (Linden, 2008). Further paper from Ecuador tested a learning software to examine its impact on arithematic scores of students,. The program was beneficial yet it was a combination of hardware (provision of computers and a computer lab), software (APCI Platform) and teacher (as facilitators) (Paul Carrillo et al., 2010). My concepts align with these studies where an additional program helps students learn specifically about the subject not just merely computer devices.

Take into consideration the existing literature in Pakistan upon the association of computer labs or even online portals for students management but they aimed at the higher education level. The logic behind is simply that before Covid, public and majority private schools were only using traditional way of teaching and learning i.e. teachers and books dependent (Akhter & Mahmood, 2018; Asad et al., 2020; Perveen, 2016). Therefore, no one tried to evaluate the influence of technology on secondary or lower level of education. As a result, the papers focusing on secondary level are different in nature such as one paper aimed at analyzing the facilities provided in secondary schools while a phd student’s dissertation is on the usability of computers and challenges faced by the secondary level students in public and private school (Akhtar & Tariq, 2015; Ameen, 2017).

However, the most relevant paper which is also trying to assess the usefulness of the “IT lab project” but this paper narrowed it down with regard to the perception, skills and if it is helpful for the teachers. The results emphasized on the provision of additional training for teachers before implementing the intervention (Qadir & Hameed, 2018).

I could add the following paragraph (if the above framing is not justifying the reason of the research or reflects the abstract)

Nevertheless, considering the various factors involved in the policy implementation. One of the significant factors is the mechanism adopted during the execution of the intervention while its corresponding sub-factor is the autonomy given to the stakeholders; in the case of public schools the Head-Teacher or the Teacher of the school. There is plenty of literature discussing the autonomy of the implementation actor for the policy impact. Almost 5 decades ago, in 1976, John Pincus in his paper “Incentives for Innovation in the Public Schools” discussed that providing authoritative space and trust to the teachers enhances the effect of the policy in the schools (Pincus, 1976). While more recently in 2017, a study from Bahrain highlights the same finding that permitting more authority to the teachers, especially financial freedom to handle budget is highly significant for a successful ICT intervention in Public schools (Abdul Razzak, 2015).

Rationale of the study:

As mentioned, none of the impact evaluations focused on the school level and especially on the concept of effect of technology/computers on students or on their learning. As a result, the provincial government keeps investing in schemes comprises of free laptops, which so far have costed the citizens more than 4 billion PKR of public funds (reference of PT). Considering recent economic crisis with the total external debts on Pakistan arose to USD 248.7 billion which is almost 80 percent of its Gross Domestic Product (GDP), while the GDP itself is surviving with 70.7 decreased from 72 percent in 2020, and the national currency suffered from depreciation with 14.3 percent in comparison with US dollar (*Economic Update and Outlook*, 2022). In addition, as per United Nations International Children's Emergency Fund (UNICEF), the recent catastrophic rain and floods cause damage to almost 18,000 schools creating an alarming situation for funds and correct policies (*Devastating Floods in Pakistan*, 2022).

Thus, it is extremely important for a nation like Pakistan to understand where and why they invest the funds. Hence, my study aim to identify the correlation between the provision of computer and students scores in order to guide such policies in the future.

Research Methodology

This section aims to discuss the objective of the study, the research question, the theoretical framework, and the data to be analyzed. This study would examine the correlation between the number of computers set up in the school and students' academic performance in provincial exams. The concept is to evaluate and understand if investing in such a public policy is worth it. The mixed method strategy let me examine the association through quantitative calculation while the in-person interview surveys enable me to get an insight into the on-ground usage of these computers to validate the findings of the correlation.

Recent studies support the adoption of mixed research methods to explore the reasoning to understand the perception and implementation behavior (Kong & Wang, 2021).

The objective of the research:

- To assess any difference occurring in the score of 5th grade students for the provincial exams after the year 2010.
- To understand the usage pattern of computers available to students in the computer lab.
- To determine if policies such as “IT labs scheme-Punjab” are worth investing in or not.

Research Question:

- Is there a relationship between the number of computers in the school and the scores of the students?
- How often do students use the computers in the IT lab?
- What are the activities students use computers for? Are they allowed to use it for learning?
- What are the perceptions of the staff about the use of computers?
- How many skilled teachers are appointed to teach computers to students?
- Do the student use computer skills at home for learning?

Hypotheses:

Ho= There is no relationship between the computers in the school and students' scores.

H1= There is a relationship between the computers in the school and students' scores

Theoretical framework:

There are two sections of analysis of this paper; section I – will be quantitative analysis while section II is the qualitative assessment for the field activities. Therefore I choose two theories to support each sections. The theories are explained below:

Section I - Quantitative analysis using the secondary data:

The activity theory proposed by a psychologist Sergei Rubinstein aligns with my concept to identify the impact of the presence of computer facilities at school.

To reflect, this theory helps in mapping the input of external tool and the series of reaction/adaption of actors towards the tool. Further, this theory is comprised of three basic components the subject (students), mediating tools (computers), and object (improved learning). While three more components are additional to understand ICT in the schools; Community (School staff), Rules (When they use computers), and Division of labor. As a whole, this leads to accomplishing the outcomes i.e. increased scores. Using this theory for evaluation of technology in educational institutes is very common (Holen et al., 2017; Scanlon & Issroff, 2005).

The picture below demonstrates the activity theory molded for this topic.

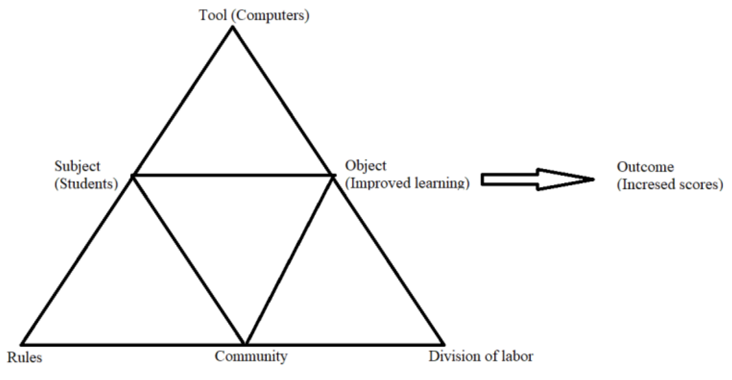

Figure 4. Activity Theory diagram with modified components as per this study (source: (Almalki et al., 2016))

Section II – Qualitative insights from the field:

This section is based on the in-person interview survey using on the theory of reasoned action – this theory is used to assess the perception of actors and user behavior. This theory will guide me to understand the opinion of the principal and teachers regarding the computer lab project. This is also relevant to psychological behavior of the actors, similar to the Activity theory, this has been used in research paper related to education and technology too (Buabeng-Andoh, 2018; Kong & Wang, 2021). Figure 2 shows the general model of theory of reasoned action.

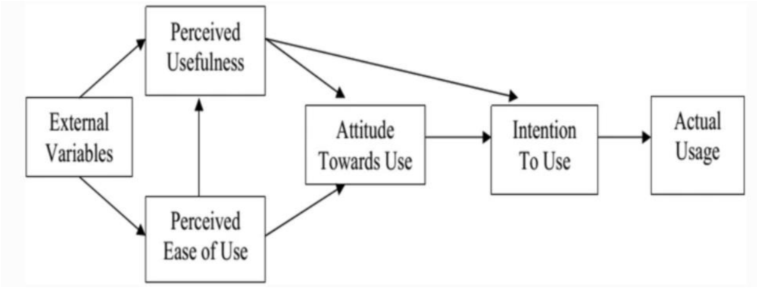

Figure 5. Source (Buabeng-Andoh, 2018)

Data:

For section I i.e. quantitative analysis for correlation between number of computer and students performance, I plan to use secondary data from the Punjab Education Commission board takes exams at the provincial level for grade 5. This data consists of per school per student cumulative score. This data consists of all schools including the schools that received the "IT lab project – 2009-10". I aim to compare the scores of the school which received this intervention of having a computer lab facility with the schools without any computer lab. Further, we could also track the trend of per year basis if the fluctuation in functional computers effect the scores of the students. Comparison across districts and gender could be possible too.

While for the section II which will be qualitative insights, I will be visiting Pakistan to conduct semi-structured in-person interview survey with the principals and teachers of the public schools that received this intervention in 2010.

Timeframe:

The tentative timeline of the major tasks are given below. I aim to complete the thesis by May to keep the month of June and July for the feedback from my respected professors and as a cover up months for unprecedented situation.

Month	Activity
Oct - Nov	Extended literature review
Nov	Sampling + Survey Questionnaire
Nov - Dec	Data collection – secondary from PEC and in-person interviews during Christmas break
Jan - March	Data Analysis
April – May	Result and discussion

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