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Ed-tech in the Global South: Research gaps and opportunities

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Acknowledgement

Abstract

This study explores the evolving landscape of educational technology (ed-tech) in the context of increased global and national attention about the topic, with the COVID-19 pandemic accelerating the drive to incorporate technology in education to mitigate issues with access, quality and systems management. Focused on challenges and opportunities in primary and secondary schools in low- and middle-income countries (LMICs), the research identifies three critical dimensions that are central to ed-tech debates and underexplored in LMICs: pedagogical implications, the role of ed-tech in addressing inequalities, and governance structures. Addressing knowledge gaps through regional reviews and expert consultations, the study emphasises the urgent need to prioritise the educational dimension in ed-tech initiatives, placing it at the forefront of debates and initiatives. Findings underscore a need for more understanding regarding children's access to digital tools, their use proficiency, and teachers' preparedness to incorporate technology for effective learning. The study also underscores the inadequacy of rapid technology implementation without a comprehensive plan, asserting that technology alone does not enhance education; its potential is realised within a broader strategy focused on universal learning improvements. Emphasising effective governance mechanisms, the research illustrates the importance of well-organised and robust ed-tech ecosystems for sustained positive impact.

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Acronyms and abbreviations

AI	Artificial Intelligence
DLP	Digital Learning Platform
EAP	East Asia and the Pacific
ED-TECH	Educational Technology
GenAI	Generative Artificial Intelligence
KPIs	Key Performance Indicators
LAC	Latin America and the Caribbean
LMICs	Low- and Middle-Income Countries
MENA	Middle East and North Africa
PCK	Pedagogical Content Knowledge
SDGs	Sustainable Development Goals
SSA	Sub-Saharan Africa
TPACK	Technological Pedagogical Content Model
TPD	Teacher Professional Development
UN	United Nations

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Introduction

Over the past decades, educational technology (ed-tech)[1] has received increasing attention within global and national policy agendas. The recent COVID-19 pandemic accelerated the drive to incorporate technology in education to address problems in access, quality, and systems management. This is in line with the Sustainable Development Goals (SDG), which establish the need to ensure inclusive and equitable quality education for all (SDG 4) and highlight technology in achieving the SDGs (SDG 17.6-8), particularly in low- and middle-income countries (LMICs) (United Nations

> **The current state of digital infrastructure in LMICs is insufficient for ed-tech to equitably support learning, particularly in South Asia and Sub-Saharan Africa.**

[UN], 2015). More recently, ed-tech was chosen as the central theme for UNESCO's 2023 Global Education Monitoring Report [GEM report] (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2021), and the 2022 Transforming Education Summit highlighted the importance of harnessing the digital revolution to improve public education (UN, 2023).

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1 For the purpose of this paper, we define ed-tech as the application of information and communication technologies in education that can facilitate the delivery of instruction and learning processes (Rodriguez-Segura, 2022; Khan et al. 2012). As Haßler et al. (2020) state, the scope of ed-tech also includes "hardware (feature phones, smartphones, radios, televisions, tablets, and laptops); software (for student/teacher use, as well as for management, monitoring, and evaluation); infrastructure (electricity, local connectivity, internet); and other digital approaches (open licensing, open innovation, crowdsourcing)" (p. 5). This paper opted for a broader approach because while in many contexts digital resources and access to the internet are privileged, the high costs of these and the difficulty for establishing connectivity in isolated areas prompts the use of other technologies, such as TV and radio.

The 2023 GEM report states that, although ed-tech serves as a lifeline for millions of learners, the most disadvantaged children are usually excluded from its benefits, as its use and impact vary by "community and socioeconomic level, by teacher willingness and preparedness, by education level and by country income" (UNESCO, 2023a, p. V). While technology is clearly here to stay, the question is how to enhance the promises it holds for education so that it becomes a relevant tool for all teachers and students. In policy terms, the challenge is to improve overall educational results, particularly learning, while reducing inequalities among diverse groups, and developing effective and efficient governance arrangements.

Given the technical and social complexities surrounding the use of technology in education, research must play a key role in informing policy decisions. Our initial exploration of the research field pointed towards several knowledge gaps regarding the role of ed-tech in improving education quality and learning. While this challenge is global, it becomes more pronounced in LMICs due to the presence of higher contextual, institutional, and resource limitations. Consequently, a key question remains largely unexplored in the Global South, namely: how can ed-tech aid in the advancement of learning as well as reduce inequalities in primary and secondary education in the developing world? This is the question that is addressed in this study. Our goal is not to present answers, but to identify key areas where knowledge needs to be developed in LMICs in order to answer this question.

This study presents a comprehensive review on ed-tech across the Global South. The ideas it presents are based on three regional reviews that discuss ed-tech in Sub-Saharan Africa (Adeniran et al., 2023), Asia, the Middle East and North Africa (Vithanage et al., 2023), and Latin America and the Caribbean (Castillo-Canales et al., 2023)[2]. This study also incorporates the findings from a comprehensive literature review and consultations with experts from these regions, as well as scholars and practitioners from the Global North who have conducted research and programmes in LMICs.

The study discusses the challenges and opportunities around ed-tech in primary and secondary schools in LMICs. It focuses on three key areas that our reviews and consultations show as not only central to ed-tech debates, but also those areas where the knowledge gaps in LMICs are more substantive: the pedagogical issues around ed-tech; the ways in which ed-tech can help address and reduce inequalities; and the governance of ed-tech. The choice of topics responds to the knowledge gaps that we

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2 These regional reviews (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023), which are available as stand-alone documents, provide valuable insights for readers interested in southern perspectives on the advances, challenges, programmes, policies, and issues relevant to each region.

have identified through our regional and literature reviews and expert consultations, all of which point to the urgent need to put the educational dimension at the forefront of ed-tech debates and initiatives. The regional reviews and expert consultations showed that existing ed-tech initiatives in the Global South tend to focus on questions of technology provision—infrastructure, hardware, and software—without paying enough attention to educational inequalities, pedagogy, or how governance can help centralise initiatives around sound educational goals. While questions of infrastructure are mentioned in the background and governance sections, they are not the main focus of the study.

The study is structured into five sections: the first section seeks to provide a basic background on the ed-tech landscape in LMICs; it presents basic comparative indicators around access to infrastructure and technology and provides a justification of each of the topics that are covered in the other sections. Sections 2, 3, and 4 focus, respectively, on the pedagogical dimension of ed-tech, on how ed-tech can address inequalities, and on the governance of ed-tech. These sections provide an initial discussion of how the key problems with regards to each of the topics are currently being framed; they then discuss existing knowledge gaps, and end with a series of recommendations for areas and topics on which *knowledge generation initiatives* should focus. Section 5 presents the study's conclusions and a recapitulation of knowledge gaps for further ed-tech research in LMICs.

Understanding the ed-tech landscape in LMICs

Ensuring the right of all children to quality education (UN, 1948; UN, 1989) remains one of the main challenges LMICs face. The pre-existing disparities in school access and student learning have widened as a consequence of the COVID-19 pandemic (World Bank & UNICEF, 2022). While access to digital resources and connectivity (or lack thereof) played a pivotal role in ensuring the continuity of educational provision during the pandemic, many schools closed for extended periods of time, leaving many without access to virtual lessons or other educational resources. As Bayne et al. put it, "technology cannot be seen as a solitary and instrumental actor […] but as an interdependent variable that raises questions of access and equity" (2021, p. 2).

While access to formal education in LMICs has increased over the years, there are still large groups who do not finish secondary education (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023). Moreso, students worldwide are achieving low results in standardised tests and other forms of evaluation, in what has been referred to as a learning crisis (World Bank, 2017; UNESCO et al., 2021). How could technology help improve students' learning?

To answer this question, we first turn to information on the availability of digital infrastructure in LMICs. Ensuring equity of access to infrastructure, networks (electricity/internet), and devices is key for the success of ed-tech programmes (UNESCO, 2023a). The figure below shows the proportion of schools with access to electricity in LMICs in Sub-Saharan Africa (SSA), East Asia and the Pacific (EAP), South Asia (SA), the Middle East and North Africa (MENA), and Latin America and the Caribbean (LAC). It also shows (in orange) the average for LMICs globally.

Figure 1. Proportion of schools with access to electricity in LMICs, 2018–2019*[3]
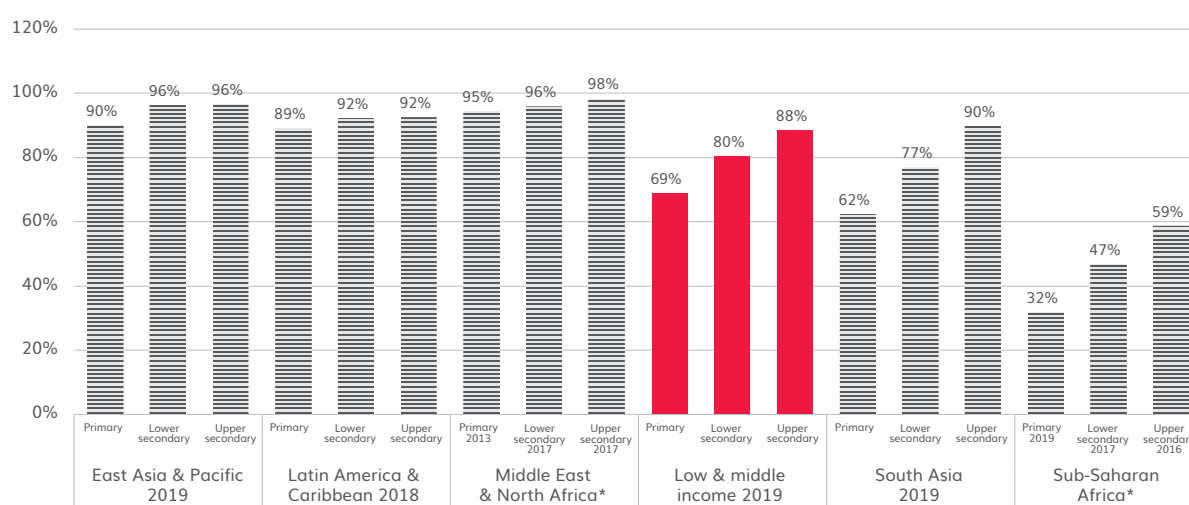
Note. Adapted from the *World Bank DataBank* by the World Bank (2022).

Available data for 2018–2019 (Figure 1) shows that the average access to electricity in schools in LMICs is fairly high (68.8% in primary and above 80.3% in secondary), albeit differences among education levels and regions exist. The percentage of primary and secondary schools that have access to electricity tends to surpass the global LMIC average in EAP, MENA, and LAC (always above 89% and 92%, respectively), but is considerably lower in SA (62.2% in primary and 76.8% in secondary). However, the situation SSA shows a stark contrast, where the percentage is significantly lower for every education level (31.8% in primary and below 59% in secondary).

Data on the proportion of schools equipped with computers for pedagogical purposes for the same years (Figure 2) also reveals an uneven distribution across different

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3 The most recent data for primary and secondary education levels in the MENA region dates back to 2013 and 2017, respectively. For the sub-Saharan Africa region, the latest data available for the indicator is for the years 2019 in the case of primary education, 2017 for lower secondary education, and 2016 for upper secondary education.

education levels and regions. At the primary level, the average percentage for LMICs from EAP, MENA, and LAC (60.7%–68.7%), is above the global LMIC average (40.7%), whereas the average for SA is significantly lower (18.9%). This trend persists at the secondary level, albeit displaying a less pronounced gap between LMICs in SA and worldwide, particularly for upper secondary grades. The available data also indicates that, in relative terms, the MENA region boasts the highest percentage of access to computers for pedagogical purposes for every education level (68.7% in primary and above 79.4% in secondary), whereas, as of 2016, SSA displayed the lowest levels in upper secondary schools (46.1%), suggesting even more limited access at primary and lower secondary grades, where no data was reported.

Figure 2. Proportion of schools with access to computers for pedagogical purposes in LMICs, 2018–2019*[4]
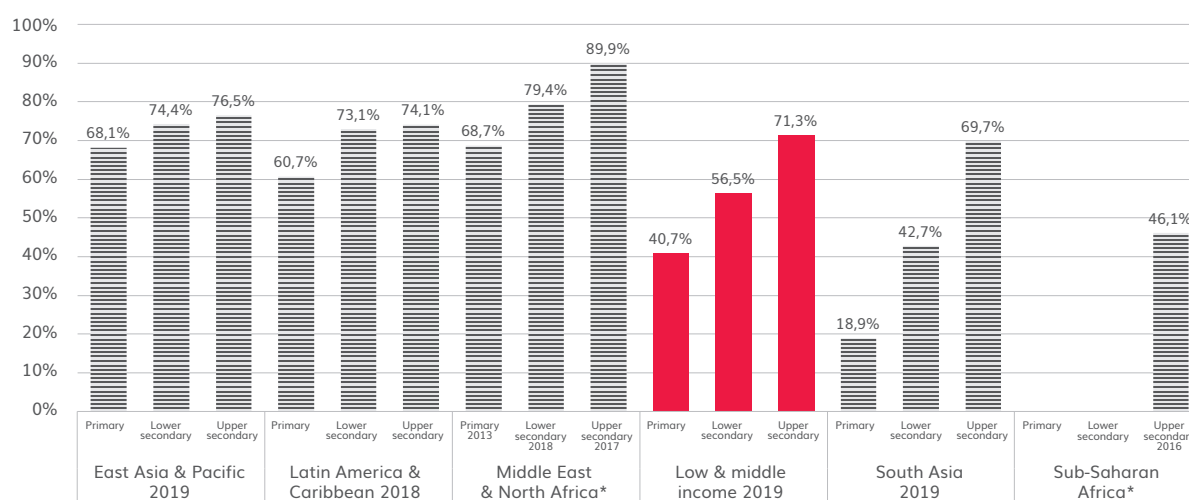
Lastly, Figure 3 shows that the EAP region has the highest proportion of schools with internet access for pedagogical purposes (75.7% in primary and 71.9% in secondary). While the global average for LMIC countries is notably lower than the two preceding variables (40.7% in primary and 56.5% in secondary), LMICs in EAP, MENA, and LAC, surpass other regions. Conversely, SA exhibits a low percentage of primary schools with internet access for educational purposes (18.9%), although this percentage tends to increase at the secondary level (42.7% in lower secondary and 69.7% in upper secondary). The SSA region repeats the same pattern from the previous indicator: a very low percentage for

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4 Data for the primary and lower secondary education levels in sub-Saharan Africa was not available, and the most recent data for primary and upper secondary education levels in the MENA region dates back to 2013 and 2017, respectively.

the year 2016 in the context of upper secondary schools (46.1%), thus implying even lower levels of access for the other grades.

Figure 3. Proportion of schools with access to computers for pedagogical purposes in LMICs, 2018–2019*[5]

Bar chart:

- East Asia & Pacific 2019: Primary 76%, Lower secondary 72%, Upper secondary 82%
- Latin America & Caribbean 2018: Primary 43%, Lower secondary 62%, Upper secondary 67%
- Middle East & North Africa*: Primary 2013 48%, Lower secondary 2019 67%, Upper secondary 2013 57%
- Low & middle income 2019: Primary 32%, Lower secondary 43%, Upper secondary 58%
- South Asia 2019: Primary 11%, Lower secondary 24%, Upper secondary 52%
- Sub-Saharan Africa*: Primary —, Lower secondary —, Upper secondary 2016 29%

Note. Adapted from the *World Bank DataBank* by the World Bank (2022).

Three conclusions can be drawn from the information presented:

- First, the current state of digital infrastructure in LMICs is insufficient for ed-tech to equitably support learning, particularly in SA and SSA.
- Second, secondary education learners appeared to be favoured in access to digital infrastructure as compared to their primary education peers. There seems to be no pedagogical justification for this.
- Third, the absence of robust digital infrastructure limits the viability of ed-tech strategies. Any adoption of ed-tech within educational systems should always consider the contextual constraints set by the state of digital infrastructure. In essence, the state of the digital infrastructure imposes parameters within which ed-tech landscape actors must move to set objectives and design interventions.

While this study does not specifically address issues around digital infrastructure, it is worth complementing the above information with some of the findings from our reviews (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023) as a background to our discussion of the three areas on which this study focuses.

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5 Data concerning primary and lower secondary education levels in sub-Saharan Africa was unavailable, and the latest available data for primary and upper secondary education levels in the MENA region was from the year 2013.

Some of the interviewed experts argue that in a context of limited financial resources, the development of digital infrastructure often diverts attention from other more urgent investments. This situation can also become susceptible to issues of corruption. Experts raised questions about the conventional allocation of responsibility for digital equipment distribution within the education sector. They suggest that this responsibility pertains to a larger issue of social inclusion and development policy that could be more suitably addressed by another sector or a combination of sectors within the government.

The literature review on ed-tech within LMICs revealed several unresolved policy and research questions which will be discussed in the forthcoming sections. However, we know what will not work: the provision of equipment (with or without internet) to schools and students, with no pedagogical, financial, or infrastructural support as shown in many international studies (e.g. Cristia et al., 2017). We call this a 'naive model' as illustrated in Figure 4.

Figure 4. 'Naive' (failed) model on ed-tech
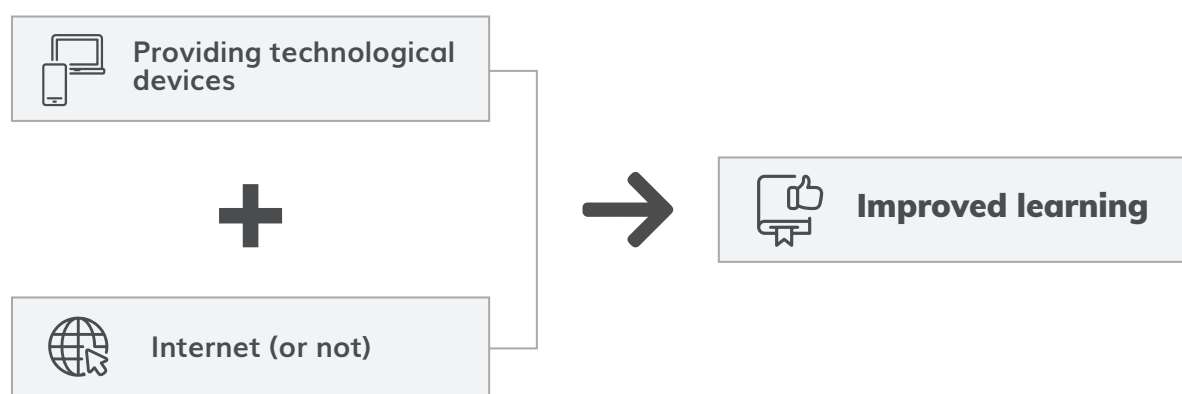
Note. Elaborated by the authors.

The use of ed-tech as a resource for teachers and students requires careful planning. In an analysis of a variety of ed-tech programmes, Arias Ortiz and Cristia (2014) concluded that "guided interventions" showed higher levels of impact on learning. Such interventions are characterised by careful consideration of the software or platforms to be used, the time they should be used weekly in schools, training of teachers, and some form of pedagogical and technical support. In a recent review of studies, Angrist et al. (2023) similarly found that structured pedagogy and teaching at the right level[6] with technology showed immense benefits.

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6 Teaching at the right level (TaRL) seeks to "move away from input-oriented education systems to change classroom practices for learning" (Chakera et al., 2020, p. 28). TaRL "groups children by learning level rather than by grade or age" (Adigu, 2021), thus allowing teachers to help children learn foundations in reading, understanding, expressing as well as arithmetic skills.

One question that emerges is why governments spend significant amounts of funding on purchasing equipment but so little resources to plan their interventions. The old adage, "it seemed like a good idea at the time" may explain part of it, given the high hopes of policy makers for the incorporation of technology, as the newest "silver bullet" in education. It is worth noting also that there has been a considerable push by international organisations, such as the World Bank, for countries to develop ed-tech initiatives (World Bank, 1999). Another factor seems to be related to the

> **The complex political dynamics that characterise the ed-tech landscape in LMICs greatly influence the success or failure of initiatives.**

high expectations of the population on the provision of technology, which is an incentive for any public officer seeking to increase their approval rates (Balarin, 2013). More tangible investments in education tend to be popular among citizens: school buildings in the past, and technological devices in the modern world (Hooft Graafland, 2018). Nevertheless, evidence shows that the 'naive model' is not the model to choose. We will revisit these issues in the section below.

The focus on pedagogy, inequalities, and governance

Evidence suggests that LMICs face immense challenges when implementing ed-tech strategies (Khan et al., 2012; Kimenyi et al., 2020; Sharma, 2003). From poor infrastructure to low institutional capacity and corruption, low levels of teacher readiness and a potentially greater role of negative political economy dynamics, the hurdles faced to benefit from ed-tech in LMICs seem to be higher than in the Global North. Gaining a more precise understanding of how and why this is the case is therefore critical for developing ed-tech initiatives that are conducive to greater and more equitable learning for all students.

Our literature review and consultations coincided in the urgency of putting pedagogy, equity, and governance at the centre of knowledge production strategies around ed-tech. In the sections below we turn to identifying policy and research gaps in these three areas. While questions around digital infrastructure tend to absorb policy makers' energies, research shows that more emphasis is needed on promoting better use of available technology in classrooms and developing adequate governance

structures to ensure egalitarian ed-tech ecosystems[7]. Moreover, while equity concerns should permeate all ed-tech initiatives, there is also a potential space for generating knowledge specific to ed-tech programmes tailored to address the needs of vulnerable populations, ultimately bridging inequality gaps.

The second half of the 20th century saw a boost in enrolment across LMICs at the pre-school, primary, and secondary levels of education. However, studies have shown that access to formal schooling does not guarantee that students acquire the knowledge and skills they need to continue learning through life (Angrist et al., 2023). According to the World Bank, 53% of children aged 10 years (or at the end of primary) in LMICs could not comprehend simple sentences, which have led to talk about a global crisis in learning (Azevedo et al., 2021).

Thus, governments and international stakeholders are moving beyond the traditional focus on access to include the promotion of learning. In this context, ed-tech is seen as an alternative to increase the learning opportunities of all children, particularly those that have shown traditionally poor results. However, ed-tech inclusion goes beyond the mechanical use of technology and raises complex questions regarding which educational results might be improved, as well as the factors that promote technology inclusion for achieving educational goals in LMICs. This involves the new dynamics of teaching and learning that emerge and how to define teachers' and students' roles while upskilling their capacities.

If ed-tech is meant to accomplish its potential in fighting the learning crisis, policy and research need to ensure inclusion and equity for all, since LMICs are at risk of suffering additional technological, economic, and social divides. Quality education is a human right of all students, and the need for education to respond to students' diversity with concrete inclusion practices has been almost unanimously recognised (UNESCO, 2020). While there have been advances for some groups, this is not true for everyone. For example, many children with disabilities, girls, refugees, the chronically ill,

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7 Within the ed-tech research field, the term "ecosystem" can be traced back to the work of Zhao and Frank (2003), who define it as an open and ever-evolving system where different factors that influence the impact of an intervention interact and adapt over time, and where elements continuously enter and exit. Building upon this ecological framework, Chrisholm (2020) underscores how this perspective precisely serves as a theoretical framework for understanding the interdependency of these factors, leaders, teachers, and innovative processes emerging amongst the most critical. Likewise, the Omidyar Network (2019) adds further depth by identifying four key factors within the ed-tech ecosystem: "supply and business models, enabling infrastructure, education policy and strategy, and human capacity". Lastly, calling for a political economy turn, Pellini et al. (2021) emphasise the role of the broader context in which ed-tech operates: structures, formal and informal rules, as well as power dynamics and interests governing education policymaking and stakeholders' actions.

incarcerated, or those living in extreme poverty conditions do not have access to formal education (UNESCO, 2019b, 2019c, 2019d, 2020). Furthermore, among those who have access, many do not achieve expected learning results (World Bank, 2017; UNESCO et al., 2021).

The complex political dynamics that characterise the ed-tech landscape in LMICs greatly influence the success or failure of initiatives. This includes the diversity of actors that compose that landscape (private, public, developers, policy makers, brokers, users, etc.); the different incentives to which they respond (profit, learning, educational justice); and the different interests that drive them (economic, political, educational). These political dynamics make ensuring alignment around common educational goals a key challenge. To make matters more complex, the novelty and quick

> **Education outcomes do not depend on technology itself, but instead on how technology supports teachers to meet educational goals.**

political returns of promoting ed-tech have meant that decisions have often followed hype (Selwyn, 2016)—seeking to capitalise on political and economic gains, rather than to advance educational ones. Critics also point to the 'solutionism' that characterises ed-tech initiatives, where technology is marketed as a "quick fix" to almost every educational problem (Teräs et al., 2020), but there is a lack of clarity as to the systemic and long-term contribution of different initiatives.

These complexities raise important challenges for the governance of ed-tech, especially in the Global South, where institutions and governance structures and capacities are often weaker (Levitsky & Murillo, 2013; Wood & Gough, 2006). While ed-tech governance has become a central focus of research and debate in the Global North (Peruzzo et al., 2022), this is still a fairly under-researched area in the Global South (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023). This section pays special attention to the challenges and knowledge gaps that emerge in this area, which should be addressed in future research.

Putting education ahead of technology: the pedagogical dimension of ed-tech

Part of the complexity of ed-tech interventions stems from the fact that they require ongoing efforts to promote sound pedagogical use by teachers, students, and parents (Khan et al., 2012). In this regard, although first-order barriers, such as resource constraints, have been documented as posing significant obstacles to achieving technology integration (O'Mahony, 2003; Pelgrum, 2001), underlying second-order barriers, such as teacher attitudes and beliefs, knowledge, and skills, appear to be the greater challenge (Dexter & Anderson, 2002; Ertmer, 1999; Ertmer et al., 1999). Evidence suggests that education outcomes do not depend on technology itself, but instead on how technology supports teachers to meet educational goals (Haßler et al., 2016).

Evidence from the literature review and expert interviews show consensus in that providing digital resources and connectivity ahead of a pedagogical model (see Figure 1 above) does not yield positive results. The gradual shift in policies from provision to digital proficiency has become stronger in LMICs after COVID-19 (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023). Defining clear policy or programme goals beforehand is necessary for an effective adoption of technology in classrooms (what some call the "vision of success"). When this is clear, resources need to be provided and activities planned to promote outputs and intermediate changes that eventually will help students achieve a set of goals. Ed-tech can be part of this complex planning as a tool for teachers and students. How to do this remains a matter for discussion as there is little empirical research from the Global South. Below, we address some of the topics where further research is needed.

Setting educational goals for ed-tech

Setting educational goals is a necessary first step in the design of educational programmes, with implications for monitoring and evaluation, as well as programme implementation and provision of resources. Yet, from our regional reviews (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023) it seems that researchers do not find these clearly defined. Below are a few considerations about what seems to be prevailing in regard to ed-tech goals in LMICs.

Findings from regional reviews (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023) as well as much of the literature about learning in LMICs has focused on the impact of ed-tech on language and math, which are considered

foundational skills, given their importance for learning in other areas and throughout life (Arias Ortiz & Cristia, 2014). These skills are expected to be acquired during the first grades of primary education. Ed-tech may be an alternative for contexts where students' skills are low (e.g. where students in large classrooms need individualised tutoring or teachers may be poorly qualified; Burns, 2021). The literature and regional reviews (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023) also address the need for countries to incorporate information and communications technology (ICT) skills as part of their national or subnational curricula, which is already the case for some LMICs. However, while this has been incorporated by some countries, the review from LAC (Castillo-Canales et al., 2023) highlights the dangers of narrowing down the focus of digital literacy to basic technological usage as this overlooks the potential to foster critical thinking, empowerment, and creativity among users, limiting their ability to apply digital skills in diverse contexts, beyond academic settings, and in their everyday lives.

Given technology's potential to implement scalable solutions, a question remains on its capacity to improve other types of skills linked with citizenship, art, social sciences, cognitive and metacognitive skills (such as self-guided and autonomous learning, collaborative learning, and problem solving), and skills linked with socio-emotional well-being (Colás-Bravo, 2019). For example, in countries where gender stereotypes are very strong, educational platforms have incorporated content that implicitly presents a non-traditional view of the roles of boys and girls, challenging cultural norms. This is the case of Conecta Ideas in Peru[8] or ABRACADABRA[9] in Africa. The same could be done with other issues linked with racism, prevention of violence, environmental sustainability, and others. We have found no research on ed-tech linked with these topics.

Promoting the use and adoption of technological resources

Several theoretical models have been proposed to comprehend the use and adoption of technology, such as the Technology Acceptance Model (TAM) (Davis, 1993), Motivational Model (MM) (Davis et al., 1992), or the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003). All these models have in common the inclusion of factors, previously called internal or second-level barriers. Thus, for example, factors associated with the subjectivity of users, such as the perception of ease of use of the technological resource (effort expectancy), the assessment of whether there are adequate conditions (facilitation

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8 See more at www.conectaideasperu.com.

9 See more at https://literacy.concordia.ca/resources/abra/teacher/en/.

conditions), the cost involved in improving their performance (performance expectancy), or the degree to which other people influence individuals' decisions (social influence), are variables used to explain the adoption of technologies. The above models also consider moderating variables such as sex, age, or experience that influence the probability of adopting technological resources (Venkatesh et al., 2016).

However, there is not much evidence about the relevance of these theoretical models in LMICs or whether the factors that explain the use of technologies by teachers, parents, or students would vary depending on specific contexts in the Global South. For example, one of the regional reviews revealed negative attitudes towards technology from parents, teachers, and government officials in South Asia (Vithanage et al., 2023). According to the review, the lack of interest coupled with lack of acceptance of digitised learning might hinder the adoption of ed-tech in the region. Another example is Southeast Asia, where the use of personal gadgets at school is prohibited due to cultural and religious factors and a traditional educational culture represented by aged teachers who showed resistance to innovation, as they took longer to adopt online platforms and digital tools (Vithanage et al., 2023). The barriers for ed-tech inclusion are specific to certain contexts and need to be identified and included in planning for programmes to be accepted by the principals, teachers, and students that are targeted by policies and programs.

There are also models that discuss the level at which teachers employ technology, which could range from adoption to appropriation, adaptation, and implementation. Ed-tech entails a highly intricate process, outlined in technology adoption models; the models start at an attitudinal stage towards technology, moving forward to occasional use, understanding the benefits of its incorporation, and finally including technology tools as central for curriculum development (Hidalgo & Gisbert-Cervera, 2021; Niess et al., 2010; Dwyer et al., 1991). At least two levels warrant attention for future research: 'adoption', where the integration of technology is primarily operational (the same task could be accomplished with or without this resource); and 'appropriation', where teachers give rise to novel instructional dynamics such as collaborative teaching, interdisciplinary project-based learning, and individually paced instruction (Dwyer et al., 1991).

This difference raises a crucial question for research: what do we mean when we talk about the use of ed-tech in LMICs? Are we expecting teachers to use technology as a mechanical aid or do we expect tech to be integral in students' learning? How is ed-tech used currently in a variety of contexts, and how do they compare with the original plans? What is the impact of different strategies in promoting higher levels of use of technology by teachers and their students? Some studies, reflecting teachers' personal experiences, have suggested that resources—such as computers—are often used mechanically (e.g.

substituting maps with online atlas); this shows an underuse of very potent devices (Chou et al., 2012).

Promoting active models of pedagogy using ed-tech

Learning theories have addressed the general question of how we learn. Two main movements from which many theories have developed can be identified: *behaviourism*, which states humans merely react to their environment, and cognitivism, which attributes individuals an active role in planning a response to change the environment or solve a problem by organising information. Recent models describe learning as an active process where an individual's culture, context, environment, as well as socio-emotional factors and experience, influence learning (Paciotti, 2013; Zijdemans-Boudreau et al., 2013).

What current models have in common is the need for students to become actively involved in their own learning, thus leaving behind rote memory practices that were common. Active models of pedagogy require teachers to not only master the content they teach (Akyeampong, 2022; Bold et al., 2017), but also pedagogical methods specific to their subject areas, as well as knowledge of how the curriculum is implemented. In his seminal article of 1986, Lee Shulman proposed Pedagogical Content Knowledge (PCK) as a construct to describe the complex amalgam of knowledge teachers need to become proficient.

Three main components of the PCK proposed by Shulman (1986) need to be considered: first, knowledge of the contents of a particular subject; second, knowledge of instructional strategies and representations to teach certain topics; and third, knowledge of students' understanding, thinking, and learning in relation to subject matter (Howey & Grossman, 1989; Grossman 1990, 1991). PCK explains that particular aspects of the content to be taught are organised, adapted, and represented in different ways to make them more accessible to students. It is suggested that in order to make pedagogical decisions, teachers should be able to assess learning episodes, while combining situational factors, and to be able to integrate this information with their specialist knowledge on the teaching-learning process in order to take action (Cabero et al., 2017; Guerriero, 2017).

PCK models have been recently updated and expanded to include technology. For instance, Mishra and Koehler (2006) proposed the Technological Pedagogical Content Model (TPACK). TPACK research analyses the interaction between content and pedagogy, as Shulman (1986) did, but adds technological knowledge and emphasises the complex dynamics between these types of knowledge (Cabero & Barroso, 2016; Flores et al., 2018; Schmidt et al., 2009). The model is composed of three types of knowledge:

disciplinary knowledge (CK), pedagogical knowledge (PK, for teaching and learning), and technological knowledge (TK) (Kafyulilo et al., 2015: Niess et al, 2008). TK encompasses knowledge about any type of technology, whether standard (blackboard, books, etc.) or advanced (internet, digital videos, etc.) (Castillejos et al., 2016; Mishra & Koehler, 2006; Roig et al., 2015).

"TPCK involves planning, organising, critiquing, and abstracting for specific content, student needs, and classroom situations while concurrently considering the multitude of 21st century technologies" (Niess et al., 2008, p. 144). Given that education does not occur in a vacuum, a variety of circumstances need to be considered when educational planning takes place. These include the interests and potential of the student group, the individuals, their age (as a proxy to their stage of human development) and learning needs (Davis, 1993; Davis et al., 1992; Venkatesh et al., 2003). Many platforms offer resources that target specific grades or ages, but little is known about what works, where, and for whom.

While we are not advocating the TPACK model; research on ed-tech programmes in LMICs is often not clear on the pedagogical model of the programmes they study. Also, many programmes are not clear in the pedagogical model intended, nor do they explain how technology should be incorporated in classes or integrated with practices carried out in the classrooms, such as 'flipped classroom' teaching (Låg & Sæle, 2019). Research is needed to understand what is planned and what goes on in what is now the 'black box' of classrooms that use technology in LMICs. From our conversations with experts, it is clear that teachers need to be actively involved in the use and design of technology. Technological solutions that are imposed by national or regional authorities are likely to fail; in other words, 'teacher-proof' education technology models—where equipment is deployed in classrooms without a clear plan and support for its use—are unlikely to succeed[10].

In this sense, models for the inclusion of technology, as well as experts and regional studies, raise the demand for better designed apps that consider the needs and characteristics of teachers and their students. As earlier mentioned, context matters, starting with issues as evident as the language of instruction, where many times specific ethnic groups find very few resources in their mother tongue.

There is a sense that the design of resources for ed-tech is disconnected from how teaching and learning processes occur—"there's no real thought about how we teach and

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10 C. Torres (personal communication, 2023, March 31)

learn"[11]. Moreover, the educational technology industry often provides new developments without rigorous evaluations, but only provides data on how many teachers and students use a certain resource[12]. Given this, more countries have intensified their efforts to support the national ed-tech industry, as reported in Asia (UNESCO, 2019a). However, regional reviews (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023) show that financial constraints do not always allow education systems to localise or contextualise the content and make curricular and contextual adaptations. Local ed-tech faces technology's commercial imaginations that emphasise scale, low cost, and overall efficiency, promoting the dissemination of (largely Western and Northern) curricula, pedagogy, and values to a global population (UNESCO, 2021). A relevant question here is whether the disconnect between ed-tech platforms and relevant social issues in the areas they are implemented will reduce appropriation.

Finally, models like TPACK recognise that the inclusion of technology in education ultimately leads to a change in the learning dynamic, towards more active models centred on the student, in which the teacher becomes a facilitator or mediator (Ertmer, 1999; Ertmer et al., 1999; Niess, 2005). This would be a much more complex role that also requires other skill changes in pre- and in-service teacher professional education. It involves the development of teachers' digital literacy and upskilling, as well as understanding how technology can be used to create new representations or support the development of complex, higher order thinking.

Teachers as key agents for student learning

Teachers are key agents for student learning (Van Damme et al., 2006; Murillo, 2003). However, in LMICs of Asia, Africa, and LAC, they often lack knowledge on how to incorporate technological resources in their lessons. Teacher's digital skills involve understanding how technology can facilitate learning (including instruction, practice, and evaluation, among others) and knowledge of resources available that are well suited for their classrooms. It also involves having a critical perspective of the resources they use, management of the classroom, how to promote well-being in their classrooms and schools, and identification of weaknesses in understanding so that individuals or the group may be supported (Burns, 2021; Niess, 2005). Therefore, a key issue for research in LMICs is how to plan for effective pre-service or professional development programmes for the adoption of technological resources in their classrooms.

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11 K. Davidson (personal communication, 2023, February 24)

12 K. Davidson (personal communication, 2023, February 24) and P. C. Abrahim (personal communication, 2023, March 27)

Pre-service education and in-service teacher professional development (collectively referred to as teacher professional development or TPD) opportunities in LMICs remain limited according to a systematic review carried out over a 12-year period by Hennessy et al., (2022). Positive results have been found for technology-mediated TPD methods tailored to local contexts, encompassing virtual coaching, social messaging, blended learning, video-induced reflection, and the integration of subject-specific software/ applications (Hennessy et al., 2022). Effectiveness of TPD revolves around consistently incorporating a peer support element, fostering collaborative professional development, or implementing processes that stimulate and structure professional discussions such as communities of practice and networks (Twining et al., 2013). However, marginalised groups receive inadequate attention. To optimise the efficiency of technology-enhanced TPD, the pivotal role of facilitators or expert peers is key, since the interpersonal aspect of teacher and learning is sometimes overlooked (Hennessy et al., 2022).

According to the Regional Review from LAC (Castillo-Canales et al., 2023), avoiding the tendency to narrow down the focus of digital literacy to basic technological usage is key. This narrowing tendency overlooks the potential to foster critical thinking, empowerment, and creativity among users, limiting their ability to apply digital skills in diverse contexts, beyond academic settings and in their everyday lives. Accordingly, TPD needs to be developed so that teachers are flexible in their uses, according to the resources available to them, as well as the characteristics of the population they work with. According to one interviewed expert, TPD programmes should promote the development of skills that allow teachers to identify which task can be better performed with technology, defining the tool to use and why, defining when and how to use it, and selecting appropriate pedagogical resources.[13] Thus, raising the question on how to effectively include ed-tech in teachers' education curricula in LMICs seems key, but there is very little research on this topic.

Given the need for a curricular reform beyond basic ICT to promote 21st century problem-solving skills, several frameworks of digital competencies have emerged such as the Global Framework to Measure Digital Literacy. Digital literacy competencies in this framework involve hard/software fundamentals, information and data literacy, communication and collaboration, digital content creation, safety, problem solving, and career related competencies (UNESCO, 2019a). However, it seems clear that for TPD to improve ed-tech appropriation, barriers related to teachers' beliefs and attitudes should be addressed. Implementing changes in education involves changing teachers' practices and beliefs, by gradually replacing them with beliefs shaped by positive collaborative experiences (Dwyer, 1990).

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13 M. Trucano (personal communication, 2022, October 11)

Potential of artificial intelligence to improve educational results

The use of artificial intelligence (AI) has allowed new ways of teaching and learning. For example, AI has expanded the possibilities to address educational challenges, to the extent that it promotes personalisation according to the level of mastery or learning of each student, while fostering collaborative environments or intelligent tutoring systems (such as Botta or Explainpaper) (Pedró et al., 2019). Findings from Angrist et al. (2023) showed that teaching at the right level with technology (or software) was one out of the three most cost-effective interventions in LMICs. AI also presents opportunities to improve states' capacity to manage educational systems by identifying patterns from large amounts of data to improve systems' efficacy (Pedró et al., 2019). Personalising education by adapting learning opportunities and instruction to individual capabilities and dispositions has been a long-standing objective among educators (Natriello, 2017).

Given this, ed-tech offers the potential to diversify teaching and learning strategies to deal with the educational challenges that LMICs face, since they offer the possibility of a high level of personalisation that could help adjust the learning experience to the characteristics of the individual—primarily at the level of skill development, and potentially close educational gaps for the most marginalised (Major et al., 2021). However, risks related to these systems involve the possibility of reinforcing or reproducing existing social, economic, racial, or gender biases, by worsening the level of teaching and learning expectations of some groups. Moreover, partial calculations of the assessment of the students' skills might end up shaping students' futures (Bayne et al., 2021).

Evidence in LMICs finds that overall, technology-supported personalised learning has been focused on areas considered core learning, such as mathematics and science. Also, it can include group-level adaptation or collaborative learning. Regarding impact, it has been found that more personalised learning in students aged 6–15 years, which adjusts to learners' level of math or literacy, led to significantly higher learning than those only linking to learners' interests or providing personalised feedback, support, and/or assessment (Major et al., 2021).

AI's most recent development on generative artificial intelligence (GenAI) has been the launch of Chat GPT, an artificial intelligence chatbot, which imitates human higher order thinking. Millions of people are using GenAI since it has the power to produce texts, images, videos, software codes, and music. GenAI generates content using data collected from different sources. Currently more refined models—targeted for educational purposes—are being developed. EdGPT, a GenAI improved version for education is being developed to derive smaller amounts of data, with high quality content and specific for education (UNESCO, 2023a). However, while these models continue to be refined,

efforts need to be focused on answering questions such as how to promote student-centred pedagogy and positive interactions, while ensuring not to disempower teachers. Controversies affecting its use in LMICs include data poverty and the risk of GenAI models only reflecting data and values from the Global North. Other concerns relate to ethical issues related to regulation of data ownership, plagiarism, or the provision of incorrect, dangerous, or biased information (UNESCO, 2023a; Pedró et al., 2019).

Research and policies have not been able to keep up with technology development, thus key questions remain: What should be the teacher's role in an ed-tech classroom that uses AI or AI-derivative tools? (Major et al., 2021). Questions are also raised on how to promote inclusion, equity, and cultural diversity, as well as what kind of competencies are needed among teachers and students in order to create and use safe and ethical AI. And finally, there is the need for evidenced-based use cases of applying AI in education in accordance with educational priorities (UNESCO, 2023a; Pedró et al., 2019).

Considering lessons from behavioural economics

Over the past few years, a fertile area of study has been the combination of principles from psychology, economics, and other social sciences, in what has been called behavioural economics or behavioural science. Behavioural economics studies the effect of psychological, cultural, and cognitive factors on the decisions of individuals or institutions in a variety of situations. Individual data is used to provide students and families with personalised pathways that position them for success, and which inform them about beneficial resources and opportunities that students might not otherwise be aware of (Teitelbaum & Zeiler, 2018). It is based on the idea that people do not always make rational and utility-maximising decisions.

Nudging[14] to push educational decisions or behaviours through low-cost strategies show mixed evidence on its effectiveness. Nudging interventions have been targeted to change decision environments by providing deadlines, goal setting reminders, and peer group manipulation, among others. Other kinds of nudges relate to informational nudges, such as giving assistance, social comparison or extrinsic motivation (Damgaard & Nielsen, 2018). The reported uses in education are related to the promotion of parenting skills, literacy skills, mathematical abilities, and school dropout (Berlinski et al., 2021; Haimovich et al., 2021). While there is some research in the use of messages to promote the use of

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14 Nudge Theory is based on the idea that by shaping the environment (or choice architecture), one can influence the likelihood that one option is chosen over another, altering people's behaviours in a predictable way while at the same time maintaining a sense of freedom of choice (Damgaard & Nielsen, 2018; Thaler and Sunstein, 2008).

technology (Berlinski et al., 2021; Haimovich et al., 2021), research shows that nudging effects differ on individuals' socioeconomic status, or age for example. Negative effects have also been found; for example, social comparison or non-monetary rewards can lower intrinsic motivation, and social comparison information provided with little time to adjust behaviour might be demotivating. Overall, though nudging using technology might lead to better education outcomes, it is important to determine beforehand which are the educational goals to be attained and for whom (Damgaard & Nielsen, 2018).

Behavioural economics provides insights on consumers' choices and decision-making process. Its application in education might be helpful to understand cognitive and emotional processes undergoing decision-making, especially when deciding to use technology in educational contexts by teachers (teachers have often not been included in these kind of studies). This line of research and intervention targeted to change decisions or behaviours is even more valuable in contexts of scarce resources such as LMICs, where strategies need to be cost-effective.

Looking for unanticipated negative consequences of ed-tech

Educational programmes and policies introduce changes into existing school cultures, and as such may have a positive or zero effect on learning. There have also been reports of negative effects of the introduction of equipment in specific contexts. For example, the provision of computers in Romania led to a higher use of social media and diminished the time students used to study (Malamud & Pop-Eleches, 2011; UNESCO, 2021). In planning research in LMICs, there should be anticipation for unanticipated negative consequences of the introduction of technology. In studying such issues, one particular consideration to observe would be how the introduction of ed-tech programmes does not increase inequality in learning, but hopefully diminishes it. A mix of quantitative and qualitative research may be particularly relevant to identify such results.

Research gaps and priorities

Research on ed-tech in LMICs has focused on assessing its impact on foundational skills, as well as its effectiveness in teacher professional development. Evidence has also been developed on AI's capacity to promote better learning through personalisation. Overall, both evidence from the literature review and experts' interviews suggest three key research areas that involve factors regarding ed-tech adoption: the implementation of active models of pedagogy using technology, as well as how to ensure building teachers' capacity to promote ed-tech, while taking into account LMICs' variety of contexts and ensuring inclusion and equity. Moreover, it is necessary to continue to assess AI's effects on education, since discussions on its benefits are polarised.

Besides infrastructure, there is a need for research that will improve understanding of what other factors promote ed-tech implementation:

- How do teachers' attitudes, individual characteristics, perceptions of social norms, beliefs, and self-efficacy towards ed-tech (variables related to technology adoption models) impact on their appropriation of different technologies? How can these be overcome? What works, where, and for whom?
- How does moderating individual, family, and community variables—such as sex, age, learning levels, language, ethnicity, beliefs and attitudes—impact on technology usage for education?
- How can nudging in education help attain educational goals in LMICs? What are the long-term effects of these interventions? Are there experiences in LMICs targeting teachers' beliefs and perceptions of ed-tech?

Research on the development of contextualised pedagogical models of ed-tech is also key, which includes the use of AI. Studies in this area could include:

- Which ed-tech models (e.g. TPACK, structured pedagogy, teaching at the right level) are more effective for promoting learning? And at what level of granularity should these models be planned for (national, regional, local, or school)? Which models have more impact on learning?
- What goes on in the 'black box' of classrooms that use technology? How are the teaching and learning processes with ed-tech in LMICs? What can be improved?
- How do AI models compare in ease of use and effectiveness to more traditional ed-tech models? Are there evidenced-based use cases of applying AI in education in accordance with educational priorities? Can AI incorporate context-relevant issues, including cultural values and contents against discrimination by gender, race, and others?
- How can AI promote student-centred pedagogy and positive interactions while not disempowering teachers? What competencies should be developed in both teachers and students for a critical and ethical use of AI in learning environments?
- How to avoid widening the gap for LMICs due to data poverty and the risk of GenAI reflecting only information and values from high-income countries (HIC)? How can ed-tech promote inclusion and equity?
- How can teachers' context, views, perspectives, and needs in the design of apps/platforms be considered in an efficient and effective way?
- How can ed-tech be promoted in school practices of LMICs to achieve sustainable societies (including for example, human rights, peace, reduction of violence, global citizenship, gender equity, renewable energies, and environmental education) or to improve general cognitive skills (e.g. executive functioning)?

- How is the decision-making process of technology inclusion adopted in a given country? What factors are considered in the assessment of alternatives—for example connectivity, devices, skills, language of the material, content adaptation? What is the decision-making process to adapt content (who takes part in that process, what are the main criteria used, to what extent this process is overseen by ministerial agencies, etc.); what works better in terms of impact? Local content produced in house (depending on local capacity), or adapted content?[15]
- Are there any negative side effects commonly resulting from ed-tech interventions and how could they be avoided?

A third line of research revolves around pre-service education and in-service teacher professional development (TPD), including the following questions:

- What are the main characteristics of effective pre-service education and in-service teacher professional development in order to promote TPACK development in LMICs?
- What are cost-effective initiatives for in-service teachers?
- What is the level of educators' digital literacy? Which frameworks of competencies of digital literacy are being used in LMICs? How do they articulate to TPD curricula?
- How can negative attitudes and resistance be overcome towards the use of ed-tech resources in LMICs?

Using ed-tech to address inequalities and vulnerability

Addressing inequalities in education is one of the main challenges that LMICs face—especially as learning inequalities have deepened due to the COVID-19 pandemic (World Bank & UNICEF, 2022). In this study, we assume a perspective for research based on guaranteeing the right to education for all (UN, 1989), understood in terms of equal educational opportunities and that all children reach at least minimum-expected levels of skills. Several international instruments and reports on the right to education have been published over the past few decades and used to show how far specific countries are from achieving it (UNESCO, 1960; UNESCO and Right to Education Initiative 2019; General Assembly, 1966; United Nations Entity for Gender Equality and the Empowerment of Women [UN Women], 1979; United Nations Department of Economic and Social Affairs, 2006).
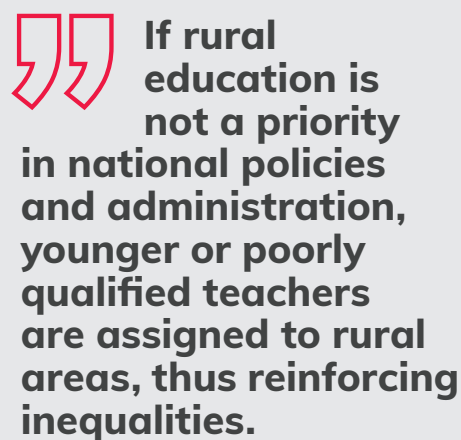
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15 These questions are also relevant when considering the governance of ed-tech.

Thinking of education as a human right requires considering the extent to which vulnerable groups have access to the support and resources that they need to be able to benefit from existing opportunities and develop their potential to the fullest (UNESCO Regional Office of Education for Latin America and the Caribbean [OREALC], 2007). In this study, we consider vulnerable groups in education to be those groups of children who are "more likely to suffer from educational inequalities and face discrimination", which impacts their right to education (UNESCO, 2023b)[16].

If rural education is not a priority in national policies and administration, younger or poorly qualified teachers are assigned to rural areas, thus reinforcing inequalities.

We understand children in these groups are frequently not able to access formal schooling, or if they do, attend a school with low educational opportunities, understood in terms of access to materials and learning opportunities fitted to their characteristics (UNESCO, 2019a)[17].

Inequality, vulnerability, and marginalisation are all multidimensional problems in which several ethnic, racial, gender, spatial, and ability related factors and dynamics exacerbate exclusion where they intersect and overlap (UNESCO, 2019a). This is assuming that such intersectionality should be the basis of any policy development, including those within the field of ed-tech. Over the next pages we discuss some of the key dimensions of inequality that need to be considered when developing ed-tech responses.

While authors have warned that the unequal availability of technological devices and internet in LMICs may increase inequality in educational opportunities and outcomes (Selwyn, 2016; Rodriguez-Segura, 2022), this report adopts the position that targeting the specific needs of vulnerable groups ought to be a fundamental dimension of the application of ed-tech in LMICs.

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16 UNESCO (2019) further defines marginalised groups as, "those who have suffered prolonged and historical discrimination, usually, but not exclusively, on the basis of identity (gender, for example), characteristics (ethnicity, race), or circumstance (refugees, migrants and internally displaced persons)" (2019, p. 86).

17 The EdTech Hub (Hennessy et al., 2021) and UNESCO's 2023 GEM Report on ed-tech background papers (Burns, 2021; UNESCO, 2021) suggest focusing equity-related strategies in LMICs on the following marginalised groups: girls; rural students; children with special educational needs and disabilities; ethnic and language minorities; refugees, migrants, and forcibly displaced children; children living in poverty or extreme poverty; and out-of-school children.

Improving the learning outcomes of vulnerable groups using ed-tech

As discussed in the previous section, the use of ed-tech appears to have a strong potential for reaching and improving the learning outcomes of vulnerable groups across the Global South (UNESCO, 2021; Berrett et al., 2020), especially when combined with other pedagogical strategies (McEwan, 2015). This has been recognised by most countries examined in the regional reviews, whether in terms of enabling access to education or responding to diverse learning needs (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023). Nevertheless, "much has to be done in order to determine which ed-tech designs can be most effectively (including cost-effectively) deployed to promote learning among those who are marginalised" (Hennessy et al., 2021, p. 9).

Current approaches call for a more flexible education, where the barriers that prevent vulnerable children from accessing educational opportunities that are pertinent to them are overcome. Given the low results of vulnerable children in education, chances are they will require higher investments and targeted programmes, although the nature of what would be required for specific groups is often not clear. Below we present some of the ed-tech interventions targeting vulnerable groups for quality education and discuss some of their related research gaps.

Ed-tech and girls' education

Girls' education is generally recognised as a priority for the development agenda in the Global South. The specific situation of girls and boys is different depending on the country. While girls find it difficult to access secondary or higher education in some countries for a variety of reasons, including economic, cultural, and religious, others may have more equal access to education but are exposed to traditional, rigid gender roles (UN Women, 1979; Cusack, 2013). It appears that ed-tech interventions targeting girls and research on gender and ed-tech are still at an early stage across LMICs. For instance, in Kenya, *iMlango* places a specific emphasis on enhancing the educational achievements of marginalised girls by using technology to tailor educational content for students in rural and semi-urban areas, impacting 180,000 students (Vegas et al., 2019; Adeniran et al., 2023). In LAC, reducing gender disparities through ed-tech has been largely neglected in contrast to the substantial attention and efforts dedicated to tackling inequalities such as the urban-rural gap (Castillo-Canales et al., 2023). The prioritisation of this issue is influenced by political, cultural, and socioeconomic factors within each context, even at the subnational level (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023).

Another key topic that deserves further research is how social norms in cultural, religious, and labour divisions impact the ed-tech absorption in girls' education in LMICs—both at home and in school—and its potential to the reinforcement of gender stereotypes (Nicolai et al., 2023). Hennessy et al. (2021) note that cultural biases and gendered assumptions regarding girls' competency and interest in technology, as well as the associated benefits and risks of its use by them, often result in girls having significantly less access to technology than boys. In this context, they suggest bridging this digital gender gap through the active involvement of caregivers and teachers in ed-tech programme development and their continuous training in both technology-oriented and gender-responsive terms. The need for more knowledge on possible measures to address this issue is particularly critical in a context where the existing literature shows that when girls are provided access to ed-tech, they not only seem to "perform better than or as well as boys" (Nicolai et al., 2023, p. 32), but, as a result, also experience a greater sense of empowerment that extends beyond their education (Hennessy et al., 2021).

Rural students

Within LMICs, rural areas often face challenges such as a lack of infrastructure, poverty, and armed conflict (World Bank, 2009; Østby et al., 2009; Rodríguez-Pose & Hardy, 2015). If rural education is not a priority in national policies and administration, younger or poorly qualified teachers are assigned to rural areas, thus reinforcing inequalities (Mulkeen, 2005; Adedeji & Olaniyanm, 2011; Crawfurd & Pugatch, 2022; Evans & Acosta, 2023; UNESCO, 2023a). In this context, the limited access to ed-tech can contribute to increasing the urban-rural gap, which makes it critical for interventions to prioritise the needs of rural students. However, there are initiatives geared towards assisting this demographic. For example, in South Asia, the Nenasa Smart Schools project in Sri Lanka is dedicated to making educational content available to rural students through satellite television-based distance education and a mobile app; teacher training in digital pedagogy skills is also provided via such means (Vithanage et al., 2023). Literature also suggests that tech-supported teacher professional development programmes can be effective in rural and remote settings, thus contributing to reducing educational gaps (Hennessy et al., 2022).

Moreover, the LAC regional study (Castillo-Canales et al., 2023) highlights another emerging trend in ed-tech and rural settings: the engagement of diverse stakeholders to empower rural community groups to develop digital inclusion initiatives through collaborative and participatory efforts. Following a decolonial lens, these strategies aim to align the design and implementation of ed-tech interventions with local narratives and perspectives and make the design culturally-relevant in pedagogical terms, as well

as appropriate for learners and teachers who often have less experience with the use of technology (Hennessy et al., 2021). Further research might provide critical insights about these experiences and how they could be adapted in other settings.

Children with special educational needs and disabilities

Ed-tech has the potential to play a pivotal role in enhancing both the access and quality of education for children with disabilities (Kuper et al., 2018). Regional teams reported experiences showing this in LMICs (Vithanage et al., 2023)—for instance, Wondertree in Pakistan, a programme that caters to the educational needs of children with motor and cognitive difficulties, and Sghartoon in Tunisia, a digital teletherapy platform designed to support children with learning disabilities such as dyslexia through educational games.

Nevertheless, a recent systematic literature review (Lynch et al., 2022) revealed how there is little published research in LMICs focusing on "how, when and what type of technology should be introduced to the learning process of children with disabilities", as well as "identifying new approaches to how learners with disabilities can access information to develop their knowledge, confidence and diverse skills" (p. 21). This corresponds with the findings of the regional teams (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023), which called for the need for more research on ed-tech and children with special educational needs and disabilities, as well as greater prioritisation by policymakers in the region to address the educational inclusion of this group through technology.

Consulted experts also drew attention to the importance of fostering interdisciplinary work and close collaboration with learners with disabilities and their teachers and families when designing ed-tech projects and assistive technology solutions. This aligns with what Martinez & Scherer (2018) call the "match of person with technology" (MPT) model, which "takes a person-centred approach to identify the personal and psychosocial characteristics, needs and preferences; environmental factors; and functions and features of the technology" (Lynch et al., 2022, p. 2-3). This approach appears to be well-suited for ensuring that technology is effectively adopted by learners with special educational needs and disabilities, thereby proving the value of ed-tech in their learning processes.

An approach to this group requires adopting adaptive pedagogical strategies. For example, the Universal Design for Learning (UDL) has often been used in planning special education programmes, aiming at including children with disabilities in "regular classes" (Alba Pastor, 2018; CAST, 2008). Further research is needed on how to adapt UDL designs for ed-tech in LMICs.

Ethnic and language minorities

Language issues related to ed-tech solutions in LMICs are a critical topic in order to address the needs of children who are not taught in their mother tongue. This is particularly the case when considering children who belong to ethnic or linguistic minority groups, as they are "less likely to have mastered second or third languages supported by national education ministries" in a scenario where "research strongly shows that children's ability to access (orally or in writing) learning materials in their mother tongue has a major impact

> " **Given that countries in the Global South often have very limited financial resources, promoting research on how to develop solid policies and programmes is an issue of great importance if the right for education of all children will gradually become a reality.**

on learning outcomes" (Hennessy et al. 2022, p. 26). Beyond the discussion regarding the tension between adapting ed-tech to address these needs and the scalability of these solutions in resource-constrained settings, literature has pointed out some approaches to use ed-tech in supporting the literacy of these groups. These range from providing digital content that facilitates interaction and learning for individuals with limited reading skills and incorporating local languages to ensure their comprehension, to the close attention of the cultural context of learners to promote their engagement (Hennessy et al., 2022).

Authors also suggest the potential of articulating stakeholders in order to create ed-tech solutions that respond to localised needs and are culturally relevant (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023). The LAC regional team highlighted experiences where indigenous groups have been included in processes of design and implementation of ed-tech interventions, so that the latter can be aligned with "self-determined" interests (Castillo-Canales et al., 2023). The review gives the following example:

Indigenous and rural community groups in Mexico and Brazil have collaborated to lead digital development initiatives that respond to their needs. These groups have been actively involved in establishing and managing digital infrastructure, services, and applications through various deployment initiatives. Additionally, they have made significant efforts to create and implement suitable digital literacy programmes. Many of these projects (e.g., REDES AC and Rhizomatica in Mexico,

and the work by Leal & Brant, 2012, in the state of Roraima in Brazil) adopt a non-profit or cooperative organisation model, facilitating community networking and addressing market failure challenges. (Castillo-Canales et al., 2023, p. 26)

In this context, Mendez Cota and Lopez Cuenca (2020) advocate for the prioritisation of indigenous, multilingual, and intercultural literacies in the research agenda on ed-tech and digital literacy in LMICs.

Refugees[18], migrants, and forcibly displaced children

Technology has proven to be helpful in addressing the difficulties related to the education of refugees, migrants, and forcibly displaced children on the move, both in formal and informal settings, particularly in the MENA region and sub-Saharan Africa. As Ashlee et al. (2020) put it:

> The literature suggests that technology is being used in refugee contexts to complement formal education in classrooms, to enhance or provide non-formal learning in education or community centres, and to provide location-independent learning when refugee children are unable to be physically present at schools or education centres. The advantage of ed-tech appears to be its flexibility and ability to provide education at a distance, move with refugees on their displacement journeys, and reach remote locations (Ashlee et al., 2020, p. 31).

A key contribution of ed-tech towards this objective is the role played by mobile devices in providing access and learning during periods of displacement and disruption of formal education. In Africa, for instance, the successful use of mobile phones in sub-Saharan Africa has helped to provide teachers in refugee settings with access to curriculum, language instruction, lesson plans, SMS support, content delivery, virtual coaching, and even their salaries (Adeniran et al., 2023). Similarly, in the case of the MENA region, the Digital Learning Platform (DLP) in Palestine, developed by the United Nations Relief and Works Agency for Palestine Refugees (UNRWA), has provided uninterrupted access to digital learning materials and resources for refugee children (Vithanage et al., 2023).[19] Given this context, there is an urgent need for more research into the effectiveness of mobile devices and digital platforms in enhancing the educational

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18 Refugee' is a legal concept, defined under international law, and refers to "people outside their country of origin because of feared persecution, conflict, violence, or other circumstances that have seriously disturbed public order, and who, as a result, require 'international protection'" (United Nations High Commissioner for Refugees, 2016, paragraph 2).

19 This reference corresponds prior to the Fall 2023 conflict in the Gaza region with Israel.

opportunities of this vulnerable group. Such research should also explore how these technologies have addressed other biases prevalent in refugee camps, including those related to gender and ethnic minorities.

Incarcerated students or long stay patients in hospitals

Children are often unable to attend formal schools if they are incarcerated or are admitted to stay in hospitals for a long period[20]. This should not mean that they have to waive their right to education. The state is primarily responsible for providing access to education for such children, although often they do not. Ed-tech presents an opportunity for these children to access education. For instance, in the last decade, researchers have increasingly delved into the potential of digital technology to mitigate the educational challenges of children and youth with chronic health conditions in long-term hospitalisation (Liu et al., 2015; Wadley et al., 2014; Hopkins et al. 2014; González et al., 2011; Mintz et al., 2018; Powell et al., 2021). These benefits primarily centre around creating mediated connections between young patients and their schools and peers, thus providing not only ways to continue their engagement in learning but also contributing to their emotional well-being.

Research on incarcerated learners, on the other hand, has analysed e-learning effects on re-entry, reduction of recidivism, and promotion of a better post-release life. A systematic review by Mahlangu and Zivanai (2023) found that online education promoted learning new information and the development of abilities. However, the authors concluded that technology cannot replace good teaching and that technology for incarcerated students should be highly contextualised to ensure results for isolated students.

Most research on this topic is initial and has taken place in the Global North, and our team has not found research on this topic that involves ed-tech use conducted in LMICs, nor have we found studies using ed-tech for incarcerated children or adults.

Orphans

The recent COVID-19 pandemic has generated an increase in the number of orphans, who are sometimes under the care of relatives, government agencies, or non-governmental organisations. From the start of the pandemic to the end of 2021, a total

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20 These children might be part of marginalised groups on the basis of "circumstance" as defined by UNESCO (2019).

of 147 million children worldwide between the ages of 0 and 17 were estimated to have lost one or both parents due to any cause of death (UNICEF, 2022). This figure included 57.2 million orphans living in sub-Saharan Africa, 34.4 million in South Asia, 25.3 million in East Asia and Pacific, 9.76 million in Latin America and the Caribbean, as well as 6.26 million in the Middle East and North Africa region. Moreover, a recent review calculated that between March 2020 and January 2022, more than 6.7 million children lost a parent or caregiver due to COVID-19, with two out of every three children being adolescent (Hillis et al., 2022). This fact points to this population not only being largely school-aged, but also particularly vulnerable to "sexual violence, exploitation, HIV, suicide, and dropping out of school, often to work or care for younger siblings" (Hillis et al., 2022, p. 24). While in any of these cases their right to education must be ensured, we have not found any research on ed-tech use in interventions related to the formal education of orphans in LMICs.

How does inequality operate? How can it be reversed?

While the above discussion suggests that policies or programmes to reduce inequality through ed-tech should be strengthened or created, the question remains as to how it is generated in the first place. There could be several mechanisms. The first one is through a differential provision of services from the state; indeed, there is some evidence that this occurs, for example for rural areas, with the argument that it is more difficult and expensive to reach them, compared to their urban peers (Echazarra & Radinger, 2019).

The second mechanism could be through families themselves; for example, poor families are likely to provide poor health and nutrition to their children, which limits their potential (Black et al., 2017). Also, poorly educated parents may be unable to help their children with their homework or engage actively with teachers at school (Britto et al., 2016; Balarin & Cueto, 2007).

A third mechanism could be social: for example, in some contexts, students who are poor, from certain ethnic groups, or with a disability are discriminated against by their peers and other members of the community (Baysu et al., 2023).

A fourth mechanism could be institutional: when planning the provision of education services and treating all students the same, more educated, and wealthier families could take advantage of existing resources better than poorer families. This risk calls for a well targeted, multisectoral approach when planning and implementing interventions (Richter et al., 2017). For example, students from relatively wealthier families are more likely to access government scholarships for higher education studies.

Understanding how inequality works in education would be of great service to design programmes and policies with an egalitarian focus, and also to monitor that the implementation does not result in further inequality.

Research gaps in inequality

Education systems in LMICs often have to boost performance across various education indicators, particularly in learning, while simultaneously reducing disparities between disadvantaged students and their peers. Ed-tech may be a double-edged sword in this sense: if used with equity as an overarching principle, it could help bring down some barriers. If not, inequality may increase. For example, Bayne et al., (2021) have noted: "Children's capacity to engage with technology and content is marked by socioeconomic and cultural factors which need to be taken into consideration when designing equitable ed-tech policies" (p. 2-3). Also, there is a need to target programmes to vulnerable groups considering their characteristics and potential. Below, we list some of the research gaps that emerge from this discussion:

> **Rather than burdening the education sector with the logistics of technology distribution, the focus should be on enhancing pedagogical support in countries of the Global South.**

- What are examples of effective interventions for vulnerable groups such as those mentioned above? Why do they work and how could they be adapted to other contexts?
- What are the costs of implementing such interventions and what economic and social benefits could be expected?
- How can local stakeholders (e.g., teachers, principals, other members of the community at large) be trained and empowered to participate and develop programmes for vulnerable groups in their communities?
- What are effective methods to use Universal Design for Learning (UDL) principles in ed-tech interventions targeting vulnerable groups, particularly children with disabilities?
- What are the mechanisms that explain existing inequalities in specific countries or local contexts and how could they be overcome?
- What are effective communication campaigns to overcome traditional stereotypes and negative attitudes towards the right to education of vulnerable groups?

The governance of ed-tech ecosystems

The growth in ed-tech and its spread across the globe, especially after the COVID-19 pandemic, has deepened the ongoing reconfiguration of educational governance taking place over the past decades, as both the scale (local, national, regional, global) and actors involved in education decision-making processes have changed drastically (Jessop, 1997; Jessop, 2016; Robertson et al., 2002). Education governance is now a multiscalar affair, where global guidelines shape national policies, and private (for- and not-for-profit) actors have an increasingly important role in shaping educational decisions. Some suggest that governance has become "fragmented" (Rosenau, 2017a; Rosenau 2017b), while others (Keast et al., 2006, p. 27) speak of "governance complexity" and the fact that policy has become a 'crowded domain', with multiple actors, institutions and guidelines competing with one another. Ed-tech policy spaces have become "opaque and dissociated" (Peruzzo et al., 2022, p. 12), especially as ed-tech providers have expanded their 'territory of influence' over policy (Mackenzie & Lucio, 2005). At the same time, there is now greater clarity as to "the human rights obligation of States to provide public education and regulate private involvement in education" (International Human Rights Law Review, 2019).

While the governance of ed-tech involves a number of aspects, we could summarise its main goal as that of ensuring the alignment of all the different actors (from policy makers, to producers, brokers, researchers, and final users) and processes (innovation, purchasing, implementation, administration, etc.) around desirable education outcomes. If, as discussed in the previous section, learning and equity are the key goals towards which all educational actions should be oriented, then the governance of ed-tech should also be geared in their direction. The notion of the ed-tech ecosystem[21] (Pellini et al., 2021; Bapna et al., 2021)—with different actors, at different levels, performing different roles, but all contributing to the system's functioning and movement towards such goals—is particularly relevant as a starting point for thinking about governance arrangements.

Existing research, however, suggests that goals in ed-tech ecosystems in the Global South are often loosely-, poorly-, or ill-defined [Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023]. Thus, the hype of new technology can end up driving decisions without much consideration given to questions of purpose, scalability, or sustainability (Selwyn, 2016; UNESCO, 2019a; Wagner, 2018a; Wagner, 2018b), and with

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21 A. Pellini (personal communication, 2022, October 12) and J. Wolf (personal communication, 2023, March 23)

tech often taking precedence over educational goals[22]. This lack of clarity in terms of goals is paired with, and often derived from, the poorly understood nature of existing problems that ed-tech is called to address – whether they are related to specific populations or learning goals[23]. Such a lack exists also in relation to questions of context, and of how cultures (of innovation, pedagogical practice, etc.) need to be considered.

Available research also suggests that such ecosystems are very diverse in terms of how actors and their roles are organised—with anything from ministries and specialist independent agencies to the tech industry and civil society organisations leading ed-tech agendas in different contexts. Local ed-tech ecosystems also vary greatly in terms of capacity (e.g. funds, knowledge, etc.) [Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023].

International research has shown some of the complexities of ed-tech markets themselves, which could be said to have their own production eco-systems, made up of a variety of investors and producers which have different interests and respond to different business models (Hillman, 2022). Understanding the complexities at this level is crucial when seeking alignment to public policy goals. The tensions that emerge from these opposing demands of "capitalisation" (i.e. the drive to capitalise on an investment) and delivering public goods, may be hard to resolve and may end up working against public policy aims. Such tensions, as Birch and Muniesa (2020) argue, are especially high in the current global regime of "technoscientific capitalism", in which tech markets (ed-tech markets in our case) are particularly attractive as potential sources of capitalisation.

Moeller (Patil & Stipanovic, 2023), for instance, explores the tensions between producers having to respond to the demands of venture capitalists, whose focus on capitalisation leads them to invest in a number of products with the expectation that only some of them will be developed in the long term; and those of policy makers or schools, who purchase products with the expectation that their relevance and supply will endure. Motivations to produce may be equally varied, with some products being developed and distributed at low cost as a strategy to attract investment into other products or business areas (Hillman, 2022). To further complicate matters, research conducted by Williamson and Komljenovic (2023) shows how ed-tech producers, as part of their branding, marketing, and 'assetisation' strategies, actively contribute to imagine and shape educational futures in ways that will necessarily permeate and influence the definition of public education goals. Finally, the influence of large global corporations

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22 M. Faul (personal communication, 2023, January 18)

23 M. Faul (personal communication, 2023, January 18) and A. Pellini (personal communication, 2022, October 12)

(e.g. Microsoft, Huawei, Meta, Alphabet, etc.) may supersede more local and context-relevant developments.

The challenges faced in the governance of ed-tech ecosystems go beyond the education system and include the challenges generated by the new dynamics of the ed-tech market. If such challenges are hard to address in general, the difficulties may deepen in the Global South, where the institutional weaknesses of many states add a degree of complexity to the political economy of ed-tech ecosystems, as actors and actions are less bound by institutional mechanisms. Problems of discontinuity, unstable bureaucracies, low quality public debate, informality, and corruption can all derail policy agendas (Balarin & Saavedra, 2023). While the question of ed-tech governance is urgent, existing research suggests that very little thought has generally been given to questions of ed-tech governance in the Global South, and to how governance mechanisms could enable different actors to collaborate in achieving desired goals (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023).

Making ed-tech ecosystems work

Moving beyond the definition of goals, understanding the nature and arrangements of existing ed-tech ecosystems is a necessary step for designing and improving governance. This involves the identification of actors, processes, and problems (Pellini et al., 2021).

Existing research (Bapna et al., 2021) shows that ed-tech actors may operate at different scales (global, regional, national, and local) and may involve government actors (education and other ministries, different level administrators, legislators, regulators and governmental agencies), independent agencies (such as tech hubs, etc.), private for-profit and not-for-profit actors (from tech developers, venture capitalists, and private foundations), to end users (students, teachers, and families).

The regional reviews (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023) show that there is great regional variance in terms of the range of actors and the leadership and influence that they exert over ed-tech ecosystems. In Africa, for instance, private actors seem to be leading the ed-tech agenda, while in Latin America this is more often done by ministries of education, whose leadership in terms of goal setting and coordination is often weak (Adeniran et al., 2023). However, there are also cases where national level coordination agencies, like the Ceibal Foundation in Uruguay, CIEB in Brazil, a2i in Bangladesh, and the National Information Technology Development Agency (NITDA) in Nigeria, have played a key role in structuring and organising national ed-tech ecosystems (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023).

While there is some evidence suggesting that such independent (extra-ministerial) agencies might be well positioned to structure and lead ed-tech ecosystems in desirable directions, there is little research on the strength of different models of governance and their appropriateness to different countries and regions (with different institutional capacity, budget availability, etc.). More often than not, the current organisation of ed-tech ecosystems in the Global South does not seem to respond to clear intentions with regards to how the systems should be organised (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023).

The lack of clear (educational and public) purpose, the loose systemic organisation, and the lack of clear articulation around clearly-identified educational issues or problems, has meant that the focus of many ed-tech initiatives in the Global South has been on "getting something going"[24]. This has led to an abundance of specific programmes solving equally specific problems, which are often discontinued due to a lack of political interest when administrations change, a lack of planning to ensure programme sustainability over time (budgeting, maintenance, etc.), and a lack of appropriate actions (from adaptations to local context, to long-term funding) to ensure relevance and use of different ed-tech initiatives (Balarin, 2013; Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023). Research suggests that a key aspect for policy sustainability is to ensure local appropriation of initiatives through strategies to strengthen democratic and deliberative policy making, which may also help ensure that programmes and initiatives are relevant for specific contexts and address local needs (Papadopoulos & Warin, 2007; Selwyn, 2012).

While governance arrangements may seek to shape and regulate a wide range of processes, our reviews (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023) and expert consultations point towards four key areas and processes where research may need to focus: formal governance structures and mechanisms, capacity development, knowledge generation, as well as privacy and the containment of privacy and other risks. Some specific issues, such as those around procurement, may fit in more than one of these categories as it relates to questions of quality assurance, transparency, as well as questions to do with the understanding of technology itself.

Formal governance structures and mechanisms to ensure adequate coordination, alignment, continuity, and transparency

Formal governance practices are fundamental to ensure adequate coordination and leadership of the ed-tech agenda, to guide procurement practices and to ensure

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24 J. Wolf (personal communication, 2023, March 23)

adaptation, continuity, and goal orientation. Existing evidence shows that procurement practices are often guided by "commercial actors with off-the-shelf offerings", and that policy makers procuring ed-tech often lack clear processes for selecting products and do not perform adequate due diligence to ensure quality (Patil & Stipanovic, 2023). During the 2023 UNESCO consultation, participants noted that the pandemic may have deepened this trend as it introduced the "wild west" of procurements (Patil & Stipanovic, 2023). Questions of procurement go beyond those specifically related to ed-tech and extend to the public processes related to the development of the infrastructure required for the implementation of ed-tech, which have been shown to be a key area in which corruption can emerge (IMCO et al., 2021).

While there is no specific institutional design that can guarantee the alignment of all actors, institutions, and initiatives around clear educational goals, most experts suggest that it is fundamental to develop adequate institutional structures to ensure coordination among stakeholders from all incumbent groups (policy makers, developers, educators) at the decision-making table (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023). Cases like those of Ceibal in Uruguay, CEIB in Brazil, a2i in Bangladesh and National Information Technology Development Agency (NITDA) in Nigeria, suggest that having an ed-tech agency in charge of coordinating the system may be a good path to follow; they enable knowledge exchange, standard setting, and adjusting aims by bringing different actors together. Such agencies, which are usually inter-ministerial, might be especially suitable to lead national ed-tech ecosystems, leading and coordinating the actions of local decision makers to ensure that they align to common goals while also promoting necessary adaptations to local needs.

Regional spaces for coordination and knowledge exchange may also play a key role in developing common understandings about goals and potential actions to reach them, containing national tendencies towards discontinuity and more ad-hoc decisions.

Apart from official government agencies, models such as that of the EdTech Hub, which seeks to provide independent knowledge and evidence to guide decision-making may be important, especially in contexts where weak governance may lead to unsubstantiated decisions and corruption—like in much of the Global South. There is a potential for partnership with such agencies that already operate in some regions of the Global South (Hennessy et al., 2021).

Beyond institutional spaces for coordination, there is a need to identify and develop adequate governance mechanisms to ensure purpose, transparency, continuity, and the necessary knowledge base for decision-making. One particular area in which

this is needed is in government procurement of ed-tech. While there is an element of capacity building around this (discussed below), experts suggest that there are specific mechanisms such as standard setting or the use of key performance indicators (KPIs) that could help align ed-tech actions around desired needs (Faul, 2023). Such KPIs should be aligned with existing research on ed-tech in general, but with a special focus on responding to the challenges and needs of LMICs. KPIs can be the basis for government officials to negotiate with private providers as well as for assessing the quality and results of different products and initiatives. National-level guidelines with clear criteria for governments to follow when assessing the quality of products and initiatives can also strengthen procurement capacities, and these could draw from a growing literature on how to govern public-private partnerships (Andonova, Faul & Piselli, 2022). Developing guidelines for parents to help them better understand the value, contribution, and potential risks of ed-tech (e.g. privacy) is another mechanism to foster goal alignment (Loble & Hawcroft, 2022).

Building capacity throughout the ed-tech ecosystem

Capacity building, especially within the public sector, is the other key to ensure adequate decision-making-processes with regards to ed-tech initiatives. Such capacities should be developed throughout the ed-tech ecosystem, including central and local administrators, but it may be more necessary among those in charge of leading and developing the ed-tech ecosystem.

Three areas of attention have been identified through the literature and expert advice:

- The first is building capacity for strategic planning, coordination, and monitoring, as well as understanding and setting standards for quality and equitable ed-tech initiatives.
- Second, strengthening mechanisms and capacity for procurement has been raised as one of the most important issues in ed-tech governance. The multiplicity of actors in the ed-tech ecosystem and the existence of potentially competing or even opposed aims (profit vs. public value) may create conflict with or obstruct public objectives. Procurement mechanisms need to ensure that decisions are made in light of established public goals; that products are relevant to address policy priorities; that they are procured in a timely manner, and that existing budgetary capacity is sufficient to ensure later maintenance and support. Procurement guidelines, such as those mentioned above, can also include provisions for making ed-tech products adaptable to local needs by requiring

developers to consider this in their proposals. Procurement practices should also consider how to promote transparency and limit the scope for corruption[25].

- Third, it is fundamental to develop systemic capacity to produce and adapt programmes and content to local context to ensure relevance. Various experts highlight the lack of context- and language-relevant content, as well as the lack of consideration of specific problems affecting certain populations, which ed-tech initiatives could help address. Developing capacity not only among local decision makers but also among teachers to assess needs and relevance of different products and programmes is important in this respect[26].

Knowledge generation

Available research and expert views highlighted the testimonial nature of much of the evidence on ed-tech programmes. In response, developing systemic capacities for independent knowledge generation that could guide decision-making becomes crucial. From independent quantitative and qualitative evaluations to research exploring the role of ed-tech in key areas (pedagogical, fostering equality, and best practices in governance that are relevant to specific contexts), knowledge generation is fundamental to advance desired goals. Some experts highlight the risk of narrow models of evidence-based research which may lead to the discontinuation of programmes without allowing for necessary learning and adaptation—it is learning from those failures that might lead to more robust programme designs[27].

Partnerships with academia and research organisations in LMICs may play a key role in ensuring the generation of rigorous, independent policy-relevant knowledge.

Containing privacy risks

The question of risks around private data use and personal security—especially among children, but also among teachers—has emerged prominently as one of the central issues in ed-tech governance. Various "high profile data breaches" in other sectors have highlighted the need "for stricter and more comprehensive student privacy laws" (Peterson, 2016, p. 962). The acceleration of ed-tech expansion during and after the COVID-19 pandemic brought the problem to the forefront, when many companies

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25 M. Jamieson Eberhardt (personal communication, 2023, June 8)

26 M. Jamieson Eberhardt and F. Ripani (personal communication, 2023, June 8)

27 A. Pellini (personal communication, 2022, October 12)

approached governments to freely offer their services and assistance (Peterson, 2016). There is a clear need for governments and international agencies to develop legislation and policies "to promote standards, regulation and legal protection for privacy, security and safeguarding" (UNESCO, 2021).

One of the key tensions in relation to student data protection is between "the need to protect students' data privacy" and the need of both ed-tech companies and schools to access student data to "innovate", "evaluate and improve education programmes", and "ed-tech companies' ability to innovate" (Peterson, 2016, p. 962).

While formal governance, regulation, training, and monitoring is key in this area, researchers have also highlighted the crucial role of developing students' critical digital literacy and for schools to promote digital citizenship education (Sayed, 2022). This would lead to the development of necessary understanding and skills and among students around "issues of privacy" and to "be mindful of protecting their own and other's digital wellbeing" (Sayed, 2022, p. 44).

Research gaps and priorities

Overall, research on ed-tech governance is very underdeveloped in LMICs. While our regional reviews (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023) have raised questions around governance, they show a marked lack of literature around it. We therefore suggest three key research areas for further development, mostly concerned with gaining a better understanding of how ed-tech ecosystems are currently being governed, and how they could improve with the identification of best practices that are relevant to these contexts.

There is a fundamental need to better understand existing ed-tech ecosystems. Most research in LMICs, such as the reviews (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023) showed, focuses on specific programmes and initiatives, without offering a comprehensive view of how ed-tech ecosystems actually work and how they work in relation to broader education systems. Studies in this area could include a focus on:

- Mapping actors, actions, motivations, understandings of their roles and that of technology in education, to understand where alignment exists and does not, as well as how it could be promoted. This should include actors in the private and public sector, as well as parents, students, and non-governmental organisations, etc.
- Identifying capacity development needs among different actors
- Identifying problems and areas for improvement in different countries

- Identifying and comparing existing ed-tech policy frameworks (national policies, specific regulations, etc.) and analysing how they define their purpose, how they align with global policy frameworks or key quality and equity aims, how they diagnose national and local needs, etc.
- Comparing different ed-tech ecosystems (with regard to purpose, planned actions, understanding of national and local needs, ensuring contextual relevant responses and local initiatives, etc.).

Research on capacity development is another key area to identify and develop adequate and innovative strategies to improve capacities at different levels of the system—e.g. teachers, school managers, district administrators, or civil servants and politicians negotiating contracts. This could be done through:

- Research to identify good practices in capacity development of officers at different levels.
- Working with stakeholders, for instance through action-research studies, to design and test capacity building strategies.
- Experimental research on policy innovations to strengthen governance, including innovations to strengthen local capacity for governing and developing context-relevant programmes and solutions.

Drawing on existing IDRC work in this area, including work done from the KIX Hubs[28] is recommended.

Identifying and developing global, regional, and national level benchmarks, indicators, guidelines and other instruments seeking to guide the actions of policy makers and other stakeholders (teachers, parents, etc.) which could serve to benchmark processes comparatively. This could be done through comparative case studies involving desk reviews, interviews with key actors, and field visits to better understand how such instruments have been developed and how they have worked in practice.

The development of national and regional level benchmarks and indicators should seek to relate to existing global level guidance, from the Sustainable Development Goals to the Abidjan Principles on the human rights obligations of States, to provide public education and to regulate private involvement in education (International Human Rights Law Review, 2019), to UNESCO's (2023) *Recommendation on the Ethics of Artificial Intelligence and UNESCO's* (2023) *Guidance for generative AI in education and*

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28 For more details see https://idrc-crdi.ca/en/research-in-action/kix-regional-hubs

research. The results from UNESCO's Expert Consultation conducted as part of the 2023 GEM report would also be an important resource (Patil & Stipanovic, 2023).

Looking forward: Research on ed-tech for low- and middle-income countries

Technology has permeated all aspects of life in the modern world and will continue to do so. Education is not an exception, yet research shows that our knowledge on how best to use it to promote learning for all children, particularly for vulnerable children in LMICs, is still in its infancy or in some areas or for some topics, non-existent. Even in industrialised countries, research shows that ed-tech programmes do not always have a positive impact or even worse, have negative consequences on the life of children. Given that countries in the Global South often have very limited financial resources, promoting research on how to develop solid policies and programmes is an issue of great importance if the right for education of all children will gradually become a reality.

This study is not a systematic review, but a study on ed-tech in LMICs, based on a review of the literature, interviews with experts, site visits, and the findings from three regional reviews on Africa, Asia, and Latin America/the Caribbean (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023). Our results show that we still do not know enough about the access children in many contexts have to digital devices and the internet, their ability to use it, and the skills of their teachers to incorporate technology into their lessons to promote learning. Thus, systems to monitor access, use, and abilities linked with technology are needed if countries want to make solid policy decisions.

Second, our review has shown that too often countries have rushed to provide equipment and internet to schools, without first having a plan. Technology by itself will not improve education; it promises to do so only if it is part of a larger plan aimed at improving learning for all children. Our section on pedagogical issues discussed models for the appropriation of technology, for theoretical models on how to incorporate them into classrooms, and the need to consider attitudinal and sociocultural issues in ed-tech programmes, making it clear that there is much to learn in studies carried out in the Global South on these topics.

Third, we discussed issues related with the adoption of ed-tech to improve learning among vulnerable children in LMICs. This topic lies at the heart of the right to education approach that we have adopted in this study. It is an area where very little research exists, even though there are a few experiences worth discussing (see regional reviews) (Adeniran et al., 2023, Vithanage et al., 2023, Castillo-Canales et al., 2023).

Finally, our section on governance highlights the crucial need to consider effective strategies and governance mechanisms to organise and nurture strong and functional ed-tech ecosystems. This means aligning interventions and actors around key educational (rather than technological) goals, as well as safeguarding the privacy and safety of students. While the definition of global, regional, and national policy goals plays a key role in facilitating such alignment, and in creating more cohesive and functional ed-tech ecosystems, governance practices should also enable systems and individuals to address and adapt to the local needs and to address specific inequalities and vulnerabilities through relevant contextualisation. Experts advocate for a perspective that views technology integration as a facet of a policy agenda that extends beyond the realm of education[29]. Rather than burdening the education sector with the logistics of technology distribution, the focus should be on enhancing pedagogical support. As an alternative, there is a proposition to manage digital infrastructure externally to the education ministry. This external management would encompass coordination, design, and implementation, even extending to providing disadvantaged families with funding to acquire necessary devices.

Above we identified a few topics for research that would be needed in LMICs, as an input for policy decision-making. However, in Annex 1 below we take a step further and identify a few general research questions that require attention, linked with frequent policy decisions around programme planning, design, or revision.

As stated throughout this study, the introduction of technology in LMICs has the potential to improve learning and inclusion among students. However, if policies and programmes are designed without consideration for existing research and indicators, it may only favour a few. We trust that the discussions above will serve as inspiration for governments, agencies, foundations, and other stakeholders to promote policy-relevant research on ed-tech in LMICs, and for governments and implementing organisations around the world to use such research.

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29 C. Steinberg (personal communication, 2023, February 15)

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Appendices

Appendix 1. Programme implementation and ed-tech research

Domain of issues	Programme implementation issues	Ed-tech research questions associated with implementation issues
Vision, goals, and objectives	What does the programme want to achieve (is it based on current knowledge and the characteristics of the context? Where it will be implemented?)	None*
Pedagogical	What pedagogical resources are needed to implement the programme?	What are the most convenient ed-tech resources for the programme (if any)?
	How can teachers, school directors, students, and other stakeholders be prepared to use the pedagogical resources autonomously?	How could ed-tech resources help stakeholders develop skills in the use of resources, and how can we know that stakeholders have become autonomous in the use of ed-tech resources?
	What is the pedagogical model implemented by the programme (e.g., what is the expected use of pedagogical resources, inside and outside the classroom, and by different stakeholders?)	Do ed-tech resources used in schools promote active student involvement in pedagogical activities? Is there sufficient teacher readiness in the context where the programme is being implemented to ensure that it will be adequately used and that it will promote student learning?
	What is the model for student evaluation sponsored by the programme?	Do ed-tech resources help provide individualised as well as group information on how students are advancing, and how is this information used by teachers?
	Was the schedule of activities and services provided in due time by the programme?	Did the use of ed-tech resources increase the impact and efficiency of the programme, compared to more conventional, less expensive alternatives? Are savings in costs sensible in relation to broad educational goals (e.g. at the expense of teachers who are considered key for meaningful educational relations)?
Governance	What are the normative and context considerations that the programme should observe?	How does the governance ecosystem facilitate or hinder the use of ed-tech resources that positively impact learning and inclusion? Are ed-tech resources used which follow international ethical standards (e.g., protecting privacy of users or only with explicit consent from adults)?
Equity	Did the programme have an inequality focus or component, and was it implemented?	Did the use of ed-tech resources contribute to increasing population averages while diminishing gaps between vulnerable and non-vulnerable groups, and how did it do it?

Note. *Ed-tech considerations should not define the goals of an educational programme. Having said this, ed-tech researchers could contribute to analysing whether the programme is aligned with national or global goals, and how ed-tech research could contribute to a variety of possibilities being considered for the vision of the programme.