Learning, Marginalization, and Improving the Quality of Education in Low-income Countries

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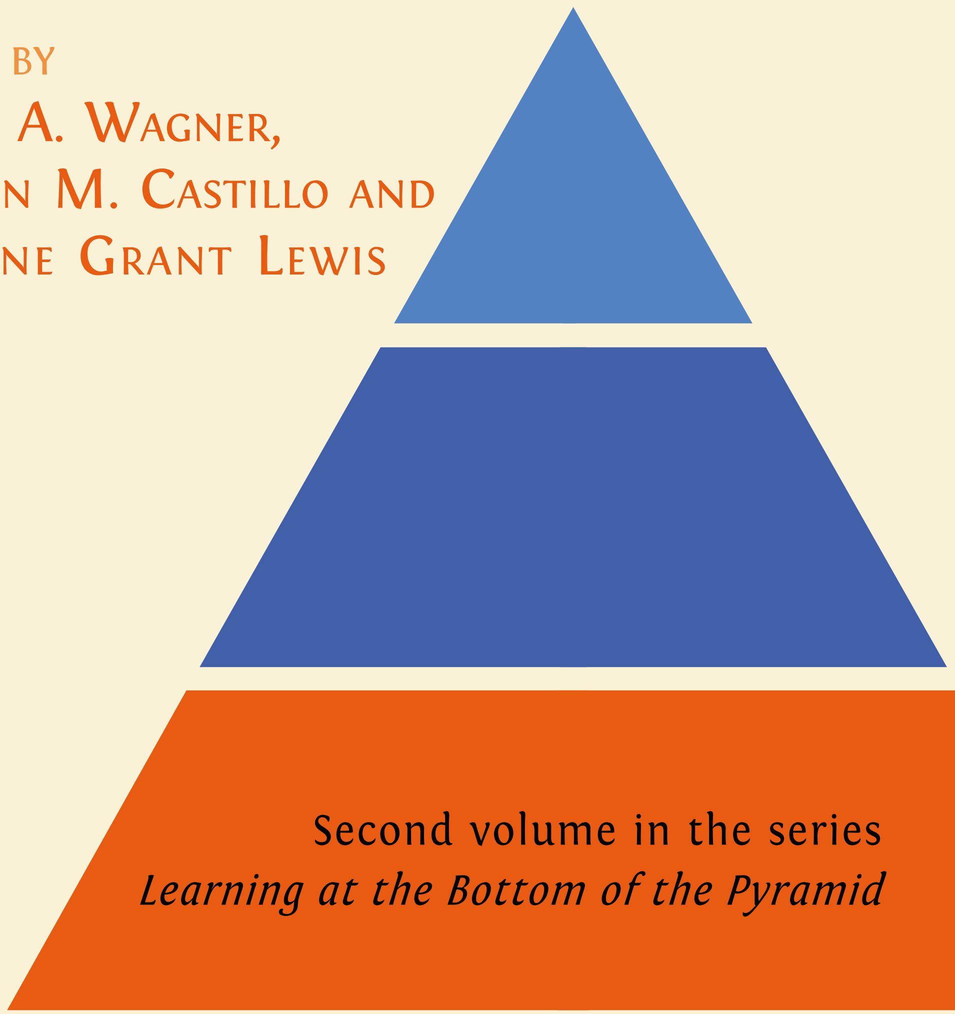

Second volume in the series
Learning at the Bottom of the Pyramid

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4. Improving the Impact of Educational Technologies on Learning Within Low-Income Contexts

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Introduction

Achieving the Sustainable Development Goal for education (SDG4) requires tackling long-standing inequalities in education systems (United Nations, 2015; Sriprakash et al., 2019; Jansen, 2019). Quality and inclusive learning that emphasizes inquiry-based pedagogies has been shown to have emancipatory powers for marginalized groups (Freire, 1970). However, material constraints such as overcrowded classrooms, limited materials, and under-resourced teachers create barriers to foundational skill development. For instance, recent estimates reveal that 50 percent of children worldwide are not achieving minimum proficiency levels in reading and mathematics after four years of schooling (Stone et al., 2019). Additionally, out-of-school learners make up one in five (262 million) children globally (UNESCO-UIS, n.d.). School closures brought on by the COVID-19 pandemic have only increased this number, and generated fear that some learners may not return to schools once they are reopened (UNESCO-IIEP, 2020). The goal of studying learning at the "bottom of the pyramid" (LBOP) is to

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address these educational barriers that have historically prevented poor and marginalized students from achieving their full potential (Wagner & Castillo, 2014).

Information and communication technology (ICT) can play a crucial role in enhancing teaching and learning quality. It can provide more efficient data analysis methods, and improve the implementation of interventions. However, ICT can only be supportive of learning if it aligns with local contexts and human capacities. ICT can help teachers be more effective, for example, but only if they have adequate digital literacy skills to make use of it. Similarly, ICT interventions can help enhance the monitoring of educational inputs, such as teacher attendance, but only if the broader educational ecosystem supports it (World Bank, 2016).

To reach our global development goals for learning, we need to disrupt the traditional learning model through experimentation with dynamic and responsive interventions. However, it is important to note that disruption as it relates to education has a different connotation than it does in other industries. For example, in commerce, disruption could take the form of replacing older practices with newer, more efficient ones (through automation, outsourcing, etc.). However, within the field of education, the goal of "disruption" is not to replace older practices (i.e., teachers) with new technologies. On the contrary, teachers are critical stakeholders who need to be included in the design and implementation of EdTech solutions. In this sense, pedagogical disruption refers to a shift towards more constructive teaching and learning, either directly through teacher involvement, or by reducing tasks that prevent them from focusing on their principal role as learning facilitators (Bada & Olusegun, 2015; Dede, 1995; Li, 2001).

In this chapter, we first provide an overview of educational technology interventions, with a special consideration for designing within LBOP contexts. We then examine relevant research on EdTech implementation and learning outcomes. The second half of the chapter contrasts constraints of educational programming with opportunities for technology to improve progress in key domains. We conclude with a discussion of new directions for EdTech research and their implications for low-income contexts.

Overview of educational technologies and educational technology interventions

ICT in education is often referred to as "educational technology", or EdTech. Here we use the term "EdTech" to mean any digital or electronic technologies that support teaching and learning, both broadcast (e.g., radio and TV) and digital (e.g., feature and smartphones, mp3 players, tablets, laptops, and smartboards) (Power et al., 2014). Access to these technologies—and their supporting infrastructure—vary across contexts, and it is important to design EdTech programs with this in mind.[1] Figure 1 illustrates the different levels of access for different population groups. Of note, low-income populations tend to have greater access to broadcast technologies and phones than to other connected devices (see Figure 1).

However, the success of an EdTech intervention depends on far more than the technology itself. Contextualized design, stakeholder engagement, community buy-in, support structures for teachers and learners, and the ability of communities to independently maintain equipment and facilities are all elements of successful implementation and planning. Programs are most effective when they take a problem-first approach rather than a techno-solutionist approach, i.e., when they focus on addressing barriers to improved learning outcomes rather than merely digitizing the learning environment (Government Digital Services, 2019; Schurr, 2013; Centre for International Development, 2018).

EdTech programs vary in both the amount and complexity of technology used. They include broadcasting content over radio; the use of audio and video resources in a classroom setting; digital resources that support teachers' professional development; e-readers, tablets, or laptops distributed to each learner; virtual learning environments (offline, intermittently online, and fully online) and virtual reality classrooms (Power et al., 2014; Adam, McBurnie, & Haßler., 2020).

1 These technologies depend on enabling infrastructure such as electricity, connectivity, and safe storage facilities. Here, "electricity" and "connectivity" means a range of different things. For example, electricity could come from grid-connected power, off-grid solar power, or home diesel generators; these may also vary in their supply reliability. Connectivity could be internet connection—GSM/SMS, GPRS/3G/4G, broadband—or be a local connection over WiFi without internet. In COVID-19, key infrastructure also includes hand-washing facilities for safe, shared use.

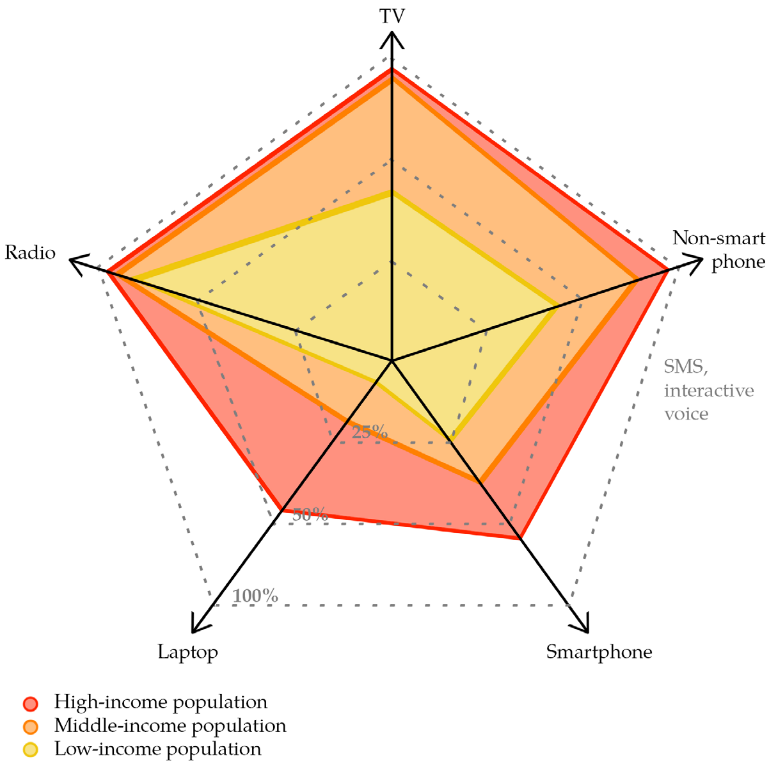

Fig. 1. Differing levels of access to devices for low-, middle-, and high-income populations. Source: Haßler, Khalayleh, & McBurnie, 2020.

Despite the variations in technology-enhanced programming, effective practices generally:

1. Address a distinct curricular focus (e.g., improving numeracy or literacy);
2. Use relevant and appropriate learning materials and modalities (e.g., use visual aids as needed);
3. For programs implemented at a school- or system-level, focus on the teachers' professional development and use of (digital) pedagogies (e.g., when and how to effectively integrate technology);
4. Focus on evaluation of program impact (e.g., was there an improvement in learning outcomes and their correlated components?);

5. Are rolled out incrementally and iteratively (e.g., small pilot programs are tested and evaluated before bringing to scale at a greater investment);
6. Use technology to monitor and evaluate factors within the education system (e.g., they monitor teacher and learner attendance, or determine schools' geolocations and their ease of access) (Power et al., 2014; Adam, McBurnie, & Haßler, 2020).

In addition to the principles above, designing for the most marginalized learners will necessarily require additional considerations. LBOP EdTech programs should prioritize cost-effectiveness, contextualized content, and alignment with existing infrastructure if they are to truly reach and support those most in need. These considerations are further elaborated below.

Further considerations when designing for LBOP

A central goal of SDG4 is to improve learning quality overall while reducing disparities in learning outcomes across populations. To improve learning outcomes for LBOP populations, solutions must take into account the multiple contextual factors and stakeholders that interact with learning within poor and marginalized contexts.

Language. Language of instruction (LOI) is a key factor in designing EdTech for learners at the bottom of the pyramid. A considerable constraint on these learners is that they often have little or no exposure to the dominant language of instruction in their schools, making their transition to school even more complicated (Ball et al., 2014). Digital solutions that deploy learning content in home languages can create better opportunities for a successful transition to a country's dominant LoI.

Local(ized) content, skills, and resources. Central to successful EdTech design for BOP settings is relevance to users' needs, digital skills, and motivation for learning (UNESCO, 2018). Additionally, leveraging home-grown technologies and innovations rather than importing foreign ICT interventions can have a positive impact on sustainability (DeBoer, 2009).

Basic infrastructure. Understanding the local infrastructure—both physical and digital—is important. Every new intervention should begin with a needs assessment and community mapping exercise to understand what possibilities currently exist for leveraging existing infrastructure (see, for instance, Highet et al., 2018). While infrastructure is a pre-determinant to access, other sociocultural factors can also lead to unequal access to resources, such as sex, age, employment status, educational background, or household income (Rohs & Ganz, 2015). Within the COVID-19 era, needs assessments are crucial to prevent governments from investing massively in interventions from which their populations cannot access or benefit (Adam, McBurnie, & Haßler, 2020; Haßler, Khalayleh, & McBurnie, 2020).

The role of connectivity. As of 2020, only 39.3 percent of Africans have internet access, compared to 87.7 percent of Europe and 95 percent of North Americans (Internet World Stats, 2020). The UN Broadband Commission for Sustainable Development is attempting to close this connectivity gap by 2025 with universal access by 2030 (ITU & UNESCO, 2019). Similar to internet access, the cost of data varies considerably. For instance, data costs on islands such as St. Helena are approximately $52.50 per gig in comparison to $0.09 in India (Cable.co.uk, 2020). "Internet-in-a-box" programs offer a solution for low-bandwidth communities by providing localized digital learning environments in a pre-packaged, offline suite of teaching and learning materials (Adam, McBurnie, & Haßler, 2020).

Competencies. End-user competencies include comfort with digital resources, but also more foundational competencies such as functional literacy and language ability. Digital and foundational competencies should ideally influence user interface design. A recent series of case studies showed that successful designs include attention to end-user competencies when building out a platform's user interface (Vosloo, 2018). For instance, using images instead of text-heavy menus and making button actions more intuitive led to improved utilization of the software. As learning shifts online during and post COVID-19, critical digital literacy is needed by teachers and learners to deal with the floods of information available online, as well as misinformation and online predators (Adam, 2020c; Bali, 2019).

Equity, inclusion, and ethical considerations. Importantly, EdTech solutions should strive to prevent reproducing inequalities across student groups (sociocultural minorities, struggling learners, etc.). Previous interventions using technology have produced greater benefits for higher-achieving students than for their lower-achieving peers (Kam, 2013; Warschauer, 2003). Inequalities also persist with regard to representation within digital content as well as contribution to design features (Graham et al., 2015). While equitable access is an important goal, inequality in authorship, narratives, contributions, and epistemic diversity (Graham et al., 2015; Adam, 2020b)—termed "existential inequality"(Czerniewicz, 2018)—should be considered in the design process.

Stakeholder engagement. In addition to contextual considerations for EdTech design, stakeholder engagement is essential. Stakeholders may include students, parents, teachers, school administrators, the private sector, mobile network operators, donors, and national and regional governments. Each stakeholder contributes unique needs, perspectives, and interests. For example, teachers voice important challenges related to using technological tools in the classroom, and know what aspects of their job technology could best support. Learners can provide important information about the user experience. Adding to the complexity, it may also be necessary to engage multiple government departments and NGOs within the same context. For instance, South Africa has a department of basic education, a separate department of government communication and information systems, and yet another department for higher education, science, and technology (GoSA, 2020). Each of these departments could potentially contribute to the coordination of an EdTech program, but it would require careful communication across groups so as not to unintentionally undermine or duplicate efforts.

Participatory approaches that center on social justice can be used to ensure that marginalized voices are not silenced in the process (Mertens, 2007). This means elevating the voice and needs of the various stakeholders in a tangible way that contributes to the programmatic design. Communication with stakeholders should be ongoing throughout the life of the program, allowing for collaboration at various points in the design and implementation process. This feedback is particularly important in the design of software and graphical user interfaces, where different stakeholders may require different design features.

Finally, it is important to follow ethical procedures and explain to stakeholders the risks that may be associated with an intervention and/or study, such as data collection and the creation of digital footprints that users may not have previously had. This is particularly important with the implementation of "free" software that requires registration and collects user data.

Lessons learnt from EdTech interventions

For about half a century, experimentation with educational technologies has led to mixed results for improving the quality of learning overall (Power et al., 2014; Wagner, 2018; Hinostroza et al., 2014). The next section reviews lessons learned from EdTech interventions by contrasting two prominent cases and discussing trends from recent examples.

The case of Interactive Radio Instruction

One of the earliest EdTech interventions was developed by Stanford researchers, and involved the use of Interactive Radio Instruction for math education (Searle et al., 1976). Interactive Radio Instruction combined radio broadcasts with active learning strategies and delivered specially-designed curriculum to areas where access to quality education is limited (World Bank, 2005).

Building on early success from the Stanford project (implemented originally in Nicaragua), Interactive Radio Instruction rapidly expanded to other countries and subjects (Potter & Naidoo, 2006). The approach was designed around four key principles: (1) guided support to under-trained teachers through scripted instruction, (2) development of content in local languages by curriculum experts; (3) an engaging and interactive learning environment that differed from traditional, rote-learning practices; and (4) delivery of quality learning materials to remote schools (virtually) (Ho & Thukral, 2011).

Interactive Radio Instruction has been an effective model for EdTech interventions in developing countries, and has successfully improved education quality at scale (Naslund Hadley, Parker, & Hernandez-Agramonte, 2014; Damani & Mitchell, 2020; Trucano, 2010; Anzalone & Bosch, 2005). However, there have also been challenges in some contexts. While radio broadcast has the ability to reach remote locations, radio transmission of learning content eliminates the facilitator's ability to pause or review the content. Recent versions of this approach have attempted to provide an on-demand experience by moving to pre-recorded audio, but the additional resources required (stereo, speakers, power, etc.) may still be limiting factors in some contexts. Poor supply of basic conditions to promote clear and consistent broadcasts, loosely incorporated language and cultural relevance, and limited integration into classroom practice have also been noted as barriers to success for IRI implementation (Alaro, 2007).

In response to the COVID-19 pandemic, many countries around the world revitalized their interest in delivery of educational content through technology-supported means. However, for low-income contexts, broadcast is still a prominent means of content delivery. In fact, a recent survey of 110 countries revealed that radio-based instruction accounts for 80 percent of remote learning policies, whereas internet-based instruction accounts for less than half of the learning policies deployed during school closures (Figure 2; UNICEF, 2020).

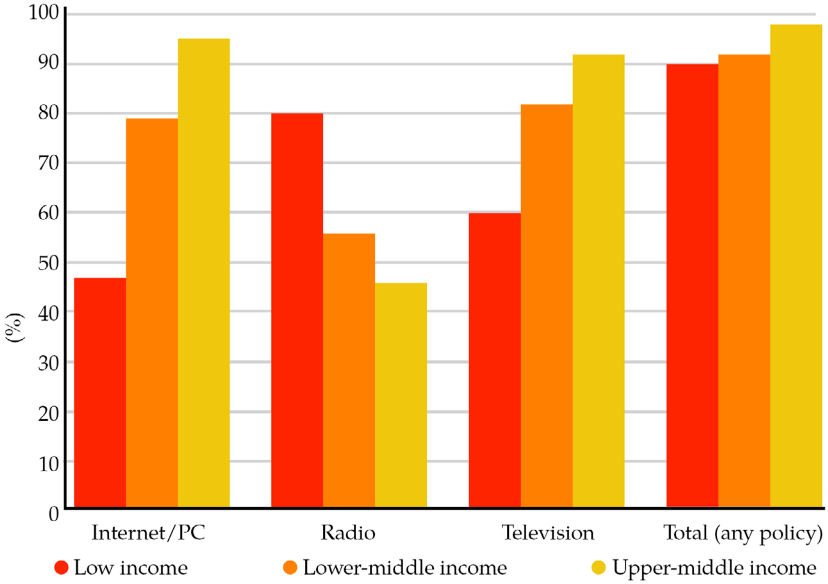

Fig. 2. Share of countries implementing remote learning policies at the pre-primary to upper-secondary levels of education, by technology and country income group, during COVID-19. Sources: UNESCO-UNICEF-World Bank Survey on National Education Responses to COVID-19 School Closures (2020) and UNICEF country offices (2020). Note: Figures are estimated using simple averages across countries.

The case of the One Laptop Per Child Initiative

Another widely-known EdTech experiment is the One Laptop Per Child Initiative. This project has provided laptops (and software) to roughly 2 million children across 42 countries (OLPC, n.d.). Learning outcomes have been mixed. A large-scale randomized evaluation in Peru concluded that One Laptop Per Child dramatically increased access to technology and digital learning content, but showed a limited effect on academic achievement (Beuermann et al., 2015). Limitations associated with the early One Laptop Per Child model in Rwanda were: (1) insufficient attention to teachers' professional development to properly integrate the devices into classroom practices; (2) lack of training in device maintenance; (3) mixed visions between international partners and local implementers; and (4) the decontextualization of the digital content pre-loaded onto the devices (Adam et al., 2016). Uruguay and Nepal are two other well-known implementations of One Laptop Per Child at scale. Both interventions similarly had a non-significant impact on academic achievement, which was attributed to improper use of the devices and limitations associated with maintenance (de Melo et al., 2014; Sharma, 2012).

Both Interactive Radio Instruction and One Laptop Per Child present important considerations for the design and implementation of technology-enhanced programs. The contextualized content and integrated instructional support provided, through IRI, improved learning outcomes across subjects and age groups, despite its use of relatively low-tech devices. Conversely, One Laptop Per Child's limited emphasis on teacher development and classroom integration has led to little impact on academic achievement in a variety of contexts. Such mixed outcomes from technology implementation—and the significant opportunity costs—have led to skepticism about the role of EdTech in low-income contexts.

Recent trends and examples

Recent experimentation with EdTech has focused on promoting inclusivity among sociolinguistic minorities (Castillo & Wagner, 2019), providing teacher support through professional development and coaching (Piper & Kwayumba, 2014; Haßler, 2020), and generating evidence-based management approaches to improve data collection and utilization for policy planning (Castillo & Vosloo, 2018).

Technology is becoming cheaper and more powerful each year, with access expanding to nearly every sector. Particularly, mobile phones are outpacing every other form of technology—even in low-income contexts (ITU & UNESCO, 2019). For school-based learning, this phenomenon opens up opportunities to move away from "traditional" teaching materials (textbooks, chalkboards, notebooks) towards technology-enhanced instructional supports. These new developments allow children to access learning materials in their home languages, offer tailored lesson plans that reinforce skills at the student's own pace, and support teachers' ability to track their students' progress, so that they can provide faster and more accurate feedback.

Despite decades of research illustrating the advantages and limitations of using EdTech to improve learning outcomes (Kimmel & Deek, 1996), particularly in light of the digital divide (Selwyn, 2002), the recent pivot to online and broadcast learning in the COVID-19 era has neglected to acknowledge previous findings (Burns, 2020). For instance, while 90 percent of governments enacted digital or broadcast policies for remote learning in response to school shutdowns, 31 percent (463 million learners globally) are not accessing remote learning programs, while in Africa the proportion increases to about 50 percent (UNICEF, 2020).

Early failures with digital learning interventions were often predictable due to poor planning. In 2015, an international group of informed stakeholders put forward a set of recommendations for the planning and design of digital resources, specifically for international development, referred to as the Principles for Digital Development (PDD, n.d.). Each principle is complemented with additional resources and case studies to plan, design, deploy, and monitor the use of technology for development programming.[2] Increased attention to the PDD and similar frameworks will help circumvent earlier failures of EdTech design and implementation.

2 The principles include: design with the user, understand the existing ecosystem, design for scale, build for sustainability, be data-driven, use open standards, reuse and improve existing research, address privacy and security, and be collaborative. For further detail see www.digitalprinciples.org/principles.

Constraints and opportunities for LBOP

This section contrasts some pervasive constraints of education interventions with opportunities for emerging applications of technology to support LBOP. The scope of the review considers teaching and learning, data collection, and implementation and evaluation practices.

Teaching and learning

Teachers play a pivotal role in student achievement and wellbeing (Evans & Popova, 2016; Popova et al., 2018). However, recruiting strong educators and sufficiently supporting their efforts has not been a straightforward task in many parts of the world.

Constraints

Limited personnel. There is a dearth of skilled teachers necessary to reach the expanding global student population. In 2015, an estimated 1.6 million additional primary-level teachers were needed in sub-Saharan Africa alone (UNESCO, 2014). Teachers working in low-income contexts are often underpaid and undervalued in society, which leads to a lack of motivation and escalated teacher absenteeism (Haßler, Khalayleh, & McBurnie, 2020). At the policy level, there is often a lack of long-term vision for education (Andrews et al., 2017). Therefore, national curricula are constantly being revised, usually aligned with changes in political powers. With each revision, teachers are expected to learn additional content and modify their methods with little attention to the costs and impacts of such extensive training campaigns (Botha, 2002; Chisholm et al., 2000).

Lack of teacher support in diverse contexts. Teaching quality in low-resource contexts is impacted by several systematic problems. In many cases, teachers are not adequately prepared, schools are under-resourced, and classrooms are overcrowded with students representing a variety of language and learning skills (Bennell & Akyeampong, 2007; Education Commission, 2019). For instance, less than two-thirds of primary school teachers in sub-Saharan Africa are trained (United Nations, 2019). Such circumstances inhibit teachers from adequately responding to the magnitude of complexity in learning spaces and individual student needs. Differences in economic circumstances, home environments, and other sociolinguistic characteristics further complicate teachers' ability to create quality learning environments.

Opportunities through EdTech

The constraints presented above can, in some ways, be addressed through appropriate integration of educational technologies. As with all tech-based solutions, the primary objective should be improving learning outcomes. Technological interventions for teachers can provide the most benefit when they support overall classroom function by automating routine tasks (data capture and marking, skills classification, etc.) so teachers can focus on broader pedagogical tasks (Power et al., 2014).

Tech-supported professional development. The effectiveness of EdTech for teachers in low-income contexts has varied. Limiting factors include device access and usage, costs, attitudinal factors, technical challenges, and pressures that teachers face in other areas of their jobs (Allier-Gagneur et al., 2020; Boitshwarelo, 2009; McAleavy et al., 2018; Haßler, Hennessy, & Hofmann, 2018). Effective use of EdTech in teacher education programs should empower teachers to be reflective practitioners, and structure teacher professional development around cycles of continuous practice, reflection, and iterative improvement (Allier-Gagneur et al., 2020; Lawrie et al., 2015).

Some technology-supported professional development programs include the use of platforms that teachers are already familiar with for communication and exchange of ideas. For instance, WhatsApp and Facebook have been used to build virtual communities within and between schools (Mendenhall, 2017); provide open educational resources (OER) to reduce the costs of teaching and learning materials (Haßler, 2020); and transfer video recordings of lessons to enable teachers to critically reflect on concrete examples of effective practices (Borko et al., 2008).

Cost effectiveness of teacher education with technology is an important consideration to monitor. One-tablet-per-school models implemented in Zambia and Zimbabwe through OER4Schools demonstrated the potential to reach marginalized communities at a very low cost while preparing the ground for more complex interventions (Haßler, Khalayleh, & McBurnie, 2020). Mobile applications that can be downloaded to smartphones or tablets are also relevant for ongoing teacher professional development. iAct, developed by the Roger Federer Foundation, delivers participatory teaching modules for untrained teacher volunteers in Zambian primary schools.[3]

Rethinking pedagogies. One of the greatest opportunities that EdTech provides is the possibility to rethink pedagogies and practices in teaching. When used effectively, technology-supported teaching has encouraged a shift from uni-directional, instructivist pedagogies to collaborative, constructivist ones that emphasize learner-centered classrooms (Bada & Olusegun, 2015; Dede, 1995; Li, 2001; Sims, 2006). In fact, Bulman and Fairlie (2015) found positive effects of ICT interventions in developing countries due to their ability to substitute it for lower-quality traditional instruction. Consequently, the diversity of learner needs can be better supported than with the traditional curricular model (Banerjee et al., 2016). The Universal Design for Learning (UDL) is one example of a learner-centered model that is often coupled with EdTech (CAST, 2018). The UDL framework emphasizes the importance of individual differences for effective instructional design (Morin, 2020). Other relevant frameworks have documented strategies for effective digital learning design (Conole, 2015; Conole & Weller, 2008; Schurr, 2013; Wagner et al., 2014).

Multilingual content. Language of instruction plays a prominent role in foundational skill development, especially within multilingual settings. Evidence shows that, in many developing country contexts, there is a misalignment of the language spoken at home and the official language of instruction in formal school settings (Ball, 2010; UNESCO, 2020). Research promoting the benefit of learning in home languages has prompted support of full proficiency in home language skill development before learning in a first additional language (Pinnock, 2009; Cummins, 1981; see also Cortina, 2014).

However, moving from policy to practice has proven more elusive for many school systems around the world. A considerable advantage of EdTech solutions is the ability for content to be deployed in multiple languages based on learner preference (Castillo & Wagner, 2019). Same-language captions of video content and downloadable audio transcripts can provide additional support to learners who are hard of hearing and

3 iAct stands for "interactive learning and teaching". See http://iact.info/ for more information.

those who are learning in a second language (Adam, 2020a; Kothari & Bandyopadhyay, 2020).

Printed and digital OER. Learners at the bottom of the pyramid often come from homes with limited parental involvement in their reading practices as well as limited exposure to written text (Wagner et al., 2016). Investment in OER provides an opportunity to address the lack of teaching and learning materials at home and in school (Hodgkinson-Williams et al., 2017).

Increased attention to OER content has already produced a vast online repository, albeit overwhelmingly representative of Global North contexts (Santos-Hermosa et al., 2017; Adam, 2020b). As such, the resources often need to be adapted in order for them to be culturally appropriate. For instance, the African Storybook Initiative aims to address the shortage of books for early grade reading in the languages and contexts of Africa. To date, the initiative has produced over 1500 user-generated books in more than 200 languages.[4]

While OER are often used in their digital form, they may have a greater impact in low-income contexts in printed form. Use of OER material—as opposed to costly proprietary content—offers a considerable reduction in the cost of printed educational material.

E-learning platforms. Given that learners have diverse needs, a tailored approach has the potential to reach each learner at their respective level. E-learning platforms offer a range of functionalities (Adam, McBurnie, & Haßler, 2020), such as:

- curated educational resources in different formats (text, audio, or video);
- scaffolding and the ability to schedule learning;
- facilitating communication between students, parents, and teachers;
- facilitating discussion between users in discussion forums;
- administering exercises and quizzes;
- conducting formative and summative assessments;
- monitoring student progress;

4 See https://www.africanstorybook.org/ for information.

- providing infrastructure for synchronous virtual lessons.

These functionalities can allow for learning to happen at a student's own pace, and be tailored to their specific needs. Moreover, since virtual learning environments can assist in marking assignments and tests, they can give teachers more time to focus on areas where learners are struggling. Through data analysis and dashboards, teachers are able to more easily see where students need support.

In LBOP contexts, e-learning platforms should be designed to function without continuous connectivity. Presently, a variety of offline e-learning platforms are emerging, such as Kolibri, eGranary, Rachel Plus, Kiwix, Bibliothèques Sans Frontières, and Internet-in-a-Box. These platforms work over a local area network, and thus no internet connection is needed. Traditionally online virtual learning environments like Moodle are also developing better offline capabilities. Other platforms such as Coursera, a Massive Open Online Course provider, have mobile apps that work offline and synchronize answers when there is connectivity. A key feature of offline virtual learning environments is being able to adapt and curate the content provided. The Kolibri platform, for instance, offers a user-friendly content curation studio.

Data to improve education

The ability to assess and make claims about learning impact is perhaps one of the more important outcomes that has resulted from the increased scrutiny of educational inputs and funding. However, the push for more accountability in terms of meeting SDG4 faces certain constraints. Aspects of data planning and its utilization for both policy and teaching present barriers to making timely, evidence-based decisions to improve education.

Constraints

Data for decision-making in policy. Policymakers must make important decisions about the types and amount of data to collect, and how it will be stored. One challenge surrounding this process is predicting the "right size" of data to collect within a program's scope of resources (Braun & Kanjee, 2006). Similarly, data collection efforts within international education projects are limited by funding availability for monitoring and evaluation activities. For instance, the United States Agency for International Development (USAID) allocates approximately three percent of total program dollars to fund external performance and impact evaluation of funded projects (USAID, 2017). Consequently, data management systems do not exist universally in all school systems. For instance, as seen in Figure 3, by 2013 just over 70 percent of developing countries reported data across select global development indicators for education (Abdul-Hamid, 2014). Other findings point to even greater "data deprivation" along key development indicators (Serajuddin et al., 2015).

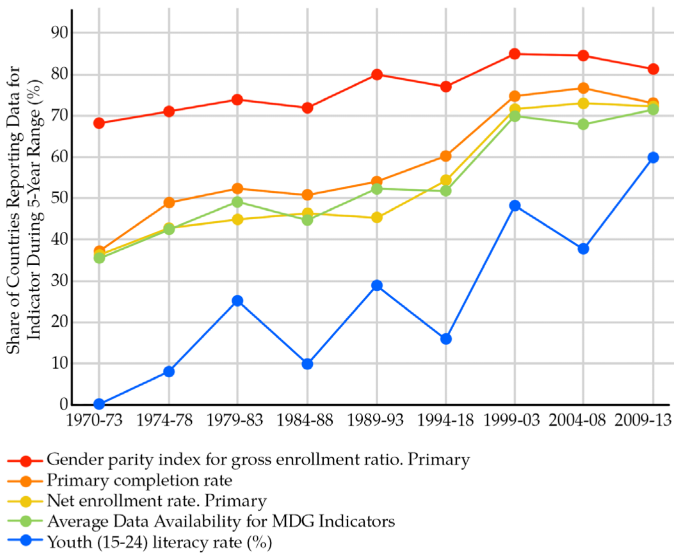

Fig. 3. Percent of countries reporting data for select education indicators at five-year increments, 1970–2013. Source: World Bank EdStats calculations based on UNESCO Institute for Statistics data, in Abdul-Hamid (2014).

Another challenge for policymakers is data access. When data is collected, it is often scattered, decentralized, or collected without regard for disaggregated analysis. One effort to improve data-driven decision-making was the promotion of Education Management Information Systems (EMIS), led by the World Bank. While EMIS activities have increased considerably, a recent review found that roughly 50 percent of projects had been rated less than satisfactory, due in part to operational challenges and limited data utilization (Abdul-Hamid, Saraogi, &

Mintz, 2017). EMIS can be challenging to implement due to the level of complexity that the system requires to produce results. In its current format, an EMIS requires multiple stages of development over a variety of management units, with an average project cycle of four to seven years (2017). While EMIS has produced important contributions to the data revolution for education development, a more feasible approach may be to shorten the distance between data scientists and classroom practice.

Data to support teaching. As noted above, teachers in low-income contexts face several challenges that impact their ability to promote quality learning environments. Large class sizes, lack of contextualized content, and limited training are among these challenges. However, an implicit constraint related to teaching is how classroom assessments are conducted. Around the developing world, teachers engage primarily in summative assessment of their students' ability to grasp curricular content. These assessments generally take the form of annual exams that require hand-grading, with delayed feedback that is rarely incorporated into pedagogical change to support individual skill development. Oftentimes, outcomes are unknown until too late in the school year, and in some cases, reports are not provided until students have already moved along to the next level in the schooling cycle. If pedagogical agility is expected for improved learning outcomes, data processing and utilization must be improved to support better classroom practices.

Opportunities through EdTech

Data for policy decisions. Perhaps the easiest way that data can support policy decisions is through real-time input monitoring. Technology is creating new opportunities to capture, disseminate, and increasingly, automatically analyze data to this end.

For example, the Sierra Leone Education Attendance Monitoring System (SLEAMS) is a pilot project led by the Teaching Service Commission (TSC) that monitors teacher attendance in schools.[5] The 2020 pilot was implemented in over 40 schools across five districts using mobile devices. Data were validated using daily self-reporting by school administrators, combined with teacher fingerprint data and monthly visits from district deputy-directors. The data were then uploaded to a

5 https://sleams.org/.

server for monitoring by the central government as well as a public data dashboard that parents and other stakeholders could view. A future iteration of the software plans to incorporate data capture for students, as well as COVID-19 indicators. Sierra Leone's Department of Science and Technology has also built an education data hub and digital census, which mapped the location of all schools, along with other factors (Namit & Thanh, 2019).

In Peru, the EduTrac program sought to improve teacher and student attendance, increase the availability of educational material, and improve the use of local funding to maintain education infrastructure in two remote regions of the country.[6] Each week, community volunteers traveled to project schools to record observation data based on a set of input monitoring prompts via text messaging on feature phones. Data processed from a central server was used to generate routine reports and distributed among community members for tracking progress along project indicators through monthly planning meetings. This effort helped mobilize parental participation, citizen monitoring, and local decision-making in a cost-effective way via technology (R4D, 2016).

Emerging applications of learning analytics are revolutionizing data practices, with some exciting possibilities on the horizon (see 'New Directions' section below). Learning analytics gather and interpret data from environments with built-in modes of assessments (like intelligent tutors, adaptive quizzes/assessments, or peer review) to help measure students' progress over time (Cope & Kalantzis, 2015a; 2015b). Technology-mediated learning environments can also provide fine-grained insight into learner activities and offer a better understanding of progress in skill acquisition for teachers, parents, and other stakeholders (DiCerbo & Behrens, 2014). Learning analytics do not focus only on the cognitive effects of learning, but help shift attention to actual representations of knowledge and the knowledge processes that learning causes (Cope & Kalantzis, 2015b). Several EdTech applications are supported through learning analytics in order to produce data to support policy and practice in low-income contexts.

Brazilian startup *Letrus* is applying learning analytics to improve writing and literacy by combining an artificial-intelligence-to-human

6 https://www.educationinnovations.org/p/edutrac-peru.

feedback loop with linguistic knowledge and teacher support.[7] Students write essays on the platform where the AI identifies writing patterns and provides immediate feedback on their writing. Upon automated feedback, the writing samples go to an interface where teachers make additional comments and assign grades in real-time. An evaluation of the innovation across 178 secondary schools is currently underway (J-PAL, n.d.; Bruno, Lima, & Riva, 2021).

Peer assessment applications of EdTech have also proven feasible within low-resourced classrooms with high learner-to-teacher ratios. In South Africa, findings showed support for a hybrid natural language processing (NLP) peer-assessment system using mobile phones for second-language learning among high-school students in an urban setting (Molapo et al., 2019).

Learning analytics can also help with understanding students' patterns of engagement. This technique involves collecting user metadata to assess use patterns on the platform and other conditions that affect proper use (software crashes, students lingering on a particular part of the platform, etc.). Data can also help identify patterns of "wheel spinning" that could indicate difficulties in understanding the educational content. Importantly, developers can use this data to refine and iterate the platform to improve the overall user experience.

Implementation and evaluation

Early efforts to bring technology into the classroom were grounded in the assumption that the devices would stimulate motivation and improve learning outcomes. Another assumption was that implementation would neatly reflect program planning. However, in some cases, school administrators were more concerned with keeping their devices in "like new" condition and kept them stored to avoid damage or theft. Consequently, they were under-utilized. These parallel assumptions have led to what some have referred to as the "last mile problem" (Banerjee & Duflo, 2012). The term refers to the fact that good designs may fail due to poor implementation, rather than the idea behind the intervention itself.

Implementation involves other programmatic components as well. Decisions concerning where data are stored, who manages the data,

7 https://www.letrus.com.br/.

and how content is updated according to evolving needs are all key to a sound implementation framework. Learning design and measurement requires care and technical skill, as well as knowledge of the sociocultural context within participating communities (Wagner, 2018). Combining each of these skill sets has been challenging for social science research to date.

Constraints

Lack of cultural and contextual awareness. A major factor that affects success or failure at the last mile is how much (or little) consideration is given to the socioeconomic, cultural, sociotechnological, political, and geopolitical contexts. Similar to digital design considerations for LBOP, poor implementation designs fail to account for programmatic characteristics grounded in cultural awareness, such as local language needs, end-user competencies, and infrastructure to name a few.

Complex rollouts and distribution activities. Another implementation challenge is rolling out interventions to hard-to-reach areas, as well as updating content and distributing new materials as program needs change. Generally, distribution tasks are bottlenecked within a particular project unit and are accompanied by costly training workshops to teach teachers and administrators about updated content. These should be integrated into the revised implementation plan. Delays in distribution have direct and adverse implications for last-mile service delivery, especially for marginalized learning sites.

Limitations in program oversight and research. Proper oversight through routine implementation monitoring poses an additional challenge for BOP contexts. Cost and safety implications of physical travel to project sites often result in unequal program support, where remote and otherwise hard-to-reach communities are most adversely affected (Ho & Thukral, 2011). Without proper implementation monitoring, it becomes difficult to assess progress along intended objectives, and what improvements or adaptations need to be made.

A popular approach of analyzing the impact of educational inputs at scale is the application of randomized controlled trials (RCTs), which require advanced methodological expertise and abundant operating costs (see Castillo & Wagner, 2014 for a review of cases; also Pritchett, 2020). Meanwhile, the rigor with which RCTs are deployed often leads to marginal or inconclusive impacts for the amount of money invested (Lortie-Forgues & Inglis, 2019). Where RCTs have shown an impact, replication studies have produced an alarming amount of null findings (OSC, 2015; Kerwin & Thornton, 2020). Thus, deep consideration needs to be given to whether an RCT is the most effective way to evaluate a project. Other simpler, less expensive methods that produce faster results should be explored.

Opportunities through EdTech

Taking a problem-first approach. A common source of failure in EdTech interventions is that a problem is often defined as lack of some other, more preferred solution, e.g., poor learning due to a lack of tablets at school (Adam et al., 2020). Shifting from a solution-driven approach to a problem-focused approach could help offset implementation failure. One widely used problem-focused approach is the Problem Driven Iterative Adaptation (PDIA) method designed for governments to unpack complex problems (Centre for International Development et al., 2018).

Before jumping to a particular solution, PDIA guides implementers to fully understand the problems that need to be addressed. This is crucial to ensure that technology is not being added without purpose. The PDIA framework is a step-by-step approach that helps break down problems into their root causes, identify entry points, search for possible solutions, take action, reflect upon what has been learned, adapt, and then act again (Centre for International Development et al., 2018). PDIA is a dynamic process with tight feedback loops that allow program developers the ability to build a solution that fits the local context.

Agile development. Implementation at scale can be challenging for some education systems. Rapidly evolving technologies and processes that are contextually dependent limit static distribution strategies. However, EdTech can allow systems to operate within a dynamic delivery model that responds to local needs.

Historically, the education development approach has operated within a paradigm that seeks to reach a desired end goal—such as a certain level of literacy after six years of schooling. An overemphasis on the end goal creates a static deployment approach that may limit the ability to iterate and optimize *en route* to the end goal.

Agile development, by contrast, deploys an iterative, flexible, and adaptable approach. Rather than building the parts of the whole, agile development creates a sequence of "minimal viable products". A minimal viable product is the most basic version of the product needed to provide feedback for further development. It helps to assess and evaluate whether the intervention is developing in the right direction, towards a product that will be as useful and impactful as possible (Adam, McBurnie, & Haßler, 2020).

The agile development process emphasizes a strong discovery phase where the problem and its assumptions are thoroughly investigated. Further, it emphasizes reflection and redesign after each iteration. The different phases of development of a product or service are sometimes labeled as based on their deployment maturity levels from a baseline discovery phase where the problem is fully unpacked, to an advanced, live phase where the product is supported at scale (Government Digital Service, n.d.).

Design Based Implementation Research (DBIR) is another common approach to agile development. DBIR is a collaborative, iterative, systematic method for refining interventions for large-scale roll-out that follows a method of grounded systematic enquiry, and acknowledges that while an intervention may work in one setting, successful implementation may not be transferable to another (LearnDBIR, n.d.). Through a tight connection between research and practice, DBIR assists interventions to be more effective, sustainable, and scalable (Fishman et al., 2013).

New directions for learning with EdTech

While the need for radical changes in schooling has been discussed for decades (Illich, 1971), COVID-19 has ushered in renewed global efforts to reconfigure formal education. It has required stakeholders to reconsider how to provide equitable support to learners, and has accelerated experimentation with technology. In many parts of the world, formal schooling has been delivered with relatively little modification since its inception (Winthrop & McGivney, 2015). One outcome of the crisis is that it has changed how children, teachers, and parents interact. However, this disruption also has the potential to widen the learning gap between the rich and the poor, and deepen educational divides along access to digital resources (Vegas, 2020). Therefore, to support education in the face of the pandemic is as critical as the adoption of the SDGs for improving learning quality. This shift in thinking must consider pedagogies, evidence-based practices for remote learning, as well as new approaches through emerging technologies.

For instance, ever-increasing computing power makes technologies such as machine learning (ML) and artificial intelligence (AI) feasible for day-to-day applications. In fact, over 80 percent of the targets within the society grouping of the SDGs (including education) could potentially benefit from ML/AI integration (Vinuesa et al., 2020). However, there are major drawbacks to consider. One is the massive computational resources required and the subsequent negative environmental impact (as discussed in Unwin, 2020). Also, more advanced technology could require the already-stretched teacher workforce to upgrade their job skills. While experimentation with emerging technologies is nascent and the benefit for BOP learners is far from clear, some recent applications for education are encouraging. (Kharas & Cohen, 2018; Paul et al., 2019; Pedro et al., 2019).

Processing power combined with ML techniques allows computers to analyze multiple datasets simultaneously and identify complex patterns within the data. Similarly, deep-learning approaches use artificial neural networks (as in brain science) to evaluate characteristics in multiple layers of data and iterate on historical trends. Within international development, data-processing methods that incorporate neural networks have been used to combine nighttime satellite imagery with national survey data to improve forecasting along poverty and mortality indicators, and even extend predictions to areas not covered through existing survey data (Jean et al., 2016). Applying a similar approach to the field of education development could have important implications. Satellites mapping school placement combined with ministry data on student enrollment can help allocate resources to schools to address digital connectivity gaps, as was recently done in Kyrgyzstan (Kumenova, 2019). This example is part of UNICEF's broader Innovation initiative to use satellite imagery to map every school in the world.[8]

Cloud storage services and analytic systems are another emerging application of technology. Cloud services have been driving commerce, higher education, and governance activity in countries across the Global South (Kshetri, 2011). An attractive component of cloud services is the ability to overcome IT infrastructure barriers and integrate with ubiquitous devices for enhanced information flow (Kshetri, 2017). Within a locally connected environment, EdTech solutions can leverage cloud services to push software updates across school sites, eliminating costly distribution campaigns and delayed delivery to remote communities. The Internet of Things, combining connected devices and cloud services, can now play a greater role in a school system's ability to provide continuous oversight and make use of data for policy decisions.

Although emerging technologies can expand analysis across robust amounts of information, it is important to consider ethical concerns associated with their implementation. Profiling of students leading to discrimination (O'Neil, 2016), compromised privacy, and the institutionalization of social inequality mechanisms are some issues that require further attention when engaging in analysis with big data (Cope & Kalantzis, 2015b).

Reports from The Institute for Ethical AI in Education highlight important considerations for ethical AI use (2020a; 2020b). Some considerations include ensuring no limitation of human agency and autonomy, technological robustness and safety, non-discrimination and fairness, privacy and data governance, transparency, societal and environmental wellbeing, and accountability. Similarly, UNICEF considers ethical issues to be an integral part of program design with emerging technologies through their multi-stakeholder Generation AI initiative (Kochi et al., 2018).

Deploying emerging technologies in low-income contexts requires serious groundwork to determine a design's appropriateness and feasibility along multiple contextual parameters (network availability, technical literacy, community buy-in, etc.). Ultimately, the focus should be on enhancing data processing and utilization while increasing

8 https://www.unicef.org/innovation/.

access to inclusive, high-quality content that addresses student needs along the full spectrum of the achievement distribution. This perspective is in contrast to the broadly implemented one-size-fits-all approach. Central to the implementation of emerging technologies is a reciprocal model whereby student input helps optimize the model and the model, in turn, helps optimize user skills through continuous, formative analysis.

Conclusion

This chapter has presented new perspectives for improving progress toward SDG4 targets that focus on the use of data and digital solutions to improve pedagogical practices and policy planning within complex low-income contexts. LBOP EdTech design should acknowledge the intersecting characteristics that interact with learning. Understanding local needs and realities related to language, cultural relevance, digital and physical infrastructure, and local competencies will help inform more appropriate design features and increased chance of sustainable success. Central to a learning-equity approach is moving beyond a single-curricular approach and creating policies that focus on bottom of the pyramid populations. Therefore, the best use of educational technologies can be mapped out along the following areas:

- Providing resources to teachers and students to improve pedagogical practices and personalized learning opportunities through continuous feedback.
- Supporting data collection and analysis with formative assessment and better resources for data reporting and utilization.
- Creating dynamic implementation ecosystems that adapt to local contexts and facilitate distribution and oversight efforts, especially for the hardest-to-reach schools.

Global megatrends such as climate change, migration, or pandemics like COVID-19 are altering how we think about education. If we are to truly accomplish the targets set forth by SDG4, we must redirect our focus toward solutions for BOP populations and leverage emerging applications of technology to improve those efforts.

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