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EDTECH AND MARGINALIZATION: SCALING FOR LEARNING EQUITY

NATHAN M. CASTILLO, DANIEL A. WAGNER, GHAIDA S. ALRAWASHDEH, CARL MOOG

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ABSTRACT

The centrality of UN SDG4 (education) for sustainable development has foundational literacy and numeracy (FLN) at its core (Beeharry, 2021; Wagner, 2018; World Bank, 2016). Within this context, the present review considers how information and communications technologies (ICTs or EdTech) can support this UN goal, with a particular focus on low-income countries (LICs) where the need is greatest, and where educational marginalization is the most extreme. Within populations of marginalized children and youth in LICs, EdTech has been relatively under-researched up to the present, as well as inadequately designed and/or poorly implemented (Adam et al., in press; Hinostroza et al., 2014).

In this review, we explore why this has been the case, and offer some promising trends for making a positive difference, with a special focus on language diversity. In addition, we find that the push for "scaling-up", particularly within the EdTech subsector – with the promised goal of achieving greater participation with lower unit-costs – has been a source of (rather than a solution to) greater disparities in learning outcomes. In the context of EdTech for marginalized populations, we explore the contrasting notions of vertical versus horizontal scaling, and argue that an "integrated adaptive" approach to scale will be more likely to promote improved and equitable learning outcomes. We conclude that there is much that can be done to improve EdTech for marginalized learners.

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1.UN SDG4 AND THE IMPORTANCE OF FLN

The United Nations Sustainable Development Goal 4 (education) centers inclusive and equitable education for all (United Nations, 2015). Despite decades of work to expand access to education, a significant proportion of students attending school is not acquiring the fundamental skills necessary for continued learning (UNESCO, 2020). For instance, 2019 estimates indicate that fifty-three percent of children in low- and middle-income countries were unable to read and comprehend a simple text by age ten (UNESCO, 2020; World Bank, 2016).

Foundational literacy and numeracy (FLN). Overarching challenges with achieving universal literacy, stem from the complexity of defining what it is and how to measure it (Beeharry, 2021; Wagner, 2018). From a functional perspective, literacy can encompass a set of skills that include recognizing and understanding the relationship of connected text for later retrieval of information (UNESCO, 2005). However, ethnographic accounts of literacy are more connected to the cultural practices of communities through context-based inquiry (Street, 2005; Wagner et al., 1999). For the purpose of this paper, we define FLN from a multidisciplinary perspective that places it both within a set of basic skills acquired through functional practices, but as also sensitive to specific purposes within cultural context. Literacy and numeracy are therefore neither binary nor static, and operate within a continuum acquisition and use.

The ability to develop basic literacy skills provides a foundation for further education, but this need often goes unmet (Wagner, 2018). This reality is particularly true in resource-limited contexts where lack of qualified teachers, crowded classrooms, limited access to appropriate reading material, an outdated curriculum, and teacher/student absenteeism make the provision of quality learning a difficult undertaking (Akyeampong et al., 2013; Paton-Ash & Wilmot, 2015; Raupp et al., 2015).

Learning loss in the era of the Covid pandemic. The impact of COVID-19, with its associated school closures and remote instruction, has disrupted progress toward this target and SDG4 for millions of children. While the full impact of the pandemic on student learning has not yet been fully understood, early indications of the first wave of lockdowns and school closures point to severe setbacks across the globe. A recent review found that the learning losses are roughly equivalent to about half a year of learning per child (Patrinos et al., 2022). Further, the documented learning loss has disproportionately affected groups that were already disadvantaged pre-pandemic (World Bank, 2022).

In sum, the number of children in low- and middle-income countries (LMICs) who are categorized as "learning poor" today is estimated to be 7 out of 10, which means that the reduction in learning poverty since 2000 has been largely lost. Mitigating further learning loss will require innovative approaches that meet the needs of diverse, and especially disadvantaged, students, with a particular focus on technology. We turn first to one of the most important disaggregates in demographic diversity: the languages(s) that learners use in life and in school.

2.LANGUAGE, MARGINALIZATION AND TECHNOLOGY

Vignette 1: Using Tablets to Practice Reading in local languages

When nine-year-old Boyet's family immigrated to Manila, he had to join a classroom with 60 students. Boyet came from the Ilocos province where he speaks a local dialect called Ilocano. With his limited knowledge of the national language Tagalog, Boyet struggled in class. While he was already able to read in Ilocano, he had difficulty in reading and understanding Tagalog. Through the Read Philippines Foundation, Boyet's school received tablets with apps, including one that supported the use of the Ilocano language. Instead of going home immediately after class, Boyet was motivated to stay in school longer, so he could use the app every day for fun in Ilocano, and to support his learning of written Tagalog.

Language (especially those that are linked to minority communities, as with *Ilocano* in Vignette 1) forms an important factor in identifying potential sources of marginalization (Wagner et al., 2022). For students like Boyet, access to digital content that supports local and national languages can mean the difference between motivated learning and learner exclusion. Other factors, such as gender and geography, can also contribute to marginalization in pervasive ways. One key to improving learning with EdTech in LICs is grounded in identifying these and other contextual factors that contribute to, and eventually, overcome learner marginalization.

In a diverse world, the languages that children speak and use are among the variables that most distinguish marginalized learners from others. In most LICs, multiple languages exist and increase the complexity of educating children in formal school settings. Even when LICs deploy a focal language policy that encompasses common linguistic variations within country context, minoritized languages remain a strong predictor of out-of-school status (UNESCO, 2020). A key dimension of language choice policy within multi-lingual school systems involves the availability and degree of engagement with a home language (L1) to support non-home (school-connected language (L2) skills development (Castillo et al., 2023).

Broadly speaking, research indicates that children in LICs use their competence in L1 to support learning in L2 (Benson & Kosonen, 2021; World Bank, 2021). In India, for example, researchers found a considerable advantage in literacy and school graduation rates increased in districts where the medium of instruction was matched to the district's language, as compared to linguistically mismatched schools (Jain, 2017). Using historical census data in South Africa, another study compared the estimated impact of increasing L1 instruction for Black students (Eriksson, 2014). Results not only showed a positive effect on educational attainment, but also on returns to education through increased wages – with larger effects for women along both outcomes. In Kenya, Piper et al. (2016) compared the impact of an early reading program at scale that either provided learning material in English (L3) and Kiswahili (L2) alone, or with additional learning material in L1 languages. Results showed a positive impact on early reading outcomes for the L1 when compared to the use of non-L1 instruction.

Vignette 2: Reading Difficulty from Unfamiliar Contexts

In a rural Samar (Philippines), e-readers were donated to a remote school where ten-year-old Ligaya attends her classes. The e-readers contain hundreds of stories in English with varying levels of reading difficulty. Ligaya just started learning to read in English last year when she was in Grade 3. She is the top student in her class and can already read short stories with comprehension. When she was given the e-reader, Ligaya confidently mastered Level 1 which states it is "readable for 4-6 years old." Still, Ligaya struggled to understand many of the words and characters in the e-books, because she has never seen a kangaroo and is confused by how a pavlova (Manila urban dessert) tastes.

Language use in schools today is complicated by several factors. One such dimension is a tendency for some parents to prefer international languages (such as English and French) for their child's education, given their connection to economic opportunity (Benson, 2004; Wagner, 2018). Another factor is the lack of educational resources available in local languages due in part to low cost-benefit valuations of book publishers (Piper et al., 2016). A further impediment to local language use is an artifact of language of instruction policies that put colonial languages into place over decades in support of Western expansionist policies. Decisions about language choice and education policy in LICs must balance expanding economic opportunities, such as by supporting the use of dominant language competence, with preservation of local language instruction for improved acquisition of FLN skills development. A key feature of technology-enabled learning is the ability to deliver digital content that is adapted to local contexts and in multiple languages (Castillo & Wagner, 2019; Wu et al., 2021).

Most evidence to date on EdTech implementation within LICs is limited to smaller scale interventions and with mixed results related to learning impact (Hinostroza et al., 2014). In some cases, studies provide valuable insight

that help clarify learning outcomes either by implementation modality or participant characteristics. For instance, Banerjee et al. (2007) found a significant impact on math achievement in urban India through a computer-assisted learning (CAL) intervention providing supplemental instruction combined with additional class time. However, Linden (2008) later revealed that the program's effectiveness was impacted by its delivery approach, which significantly benefited students through supplemental learning and negatively impacted students as a pull-out CAL intervention. Similarly, Kam (2013) found a positive impact on a mobile phone-based literacy interventions deployed in an after-school setting in India. However, results were stronger among learners who already scored higher at baseline, revealing how technology may disproportionately advantage higher achieving students.

These examples point to some of the challenges when designing EdTech solutions for use within LICs, and why learning equity should be central to any design solution. Some of these complexities are represented in Figure 1 which is comprised of four distinct but overlapping components: intervention purposes, intended end users, devices, and language context. When this framework is applied, a design solution for effective deployment of technology in educational settings is produced (Castillo et al., 2023; Wagner et al., 2014). The three circles in Figure 1 converge in a way that considers each component of the framework with respect to their independent contributions that enable the design of educational initiatives that draw on optimal integration of technology within the broader language context.

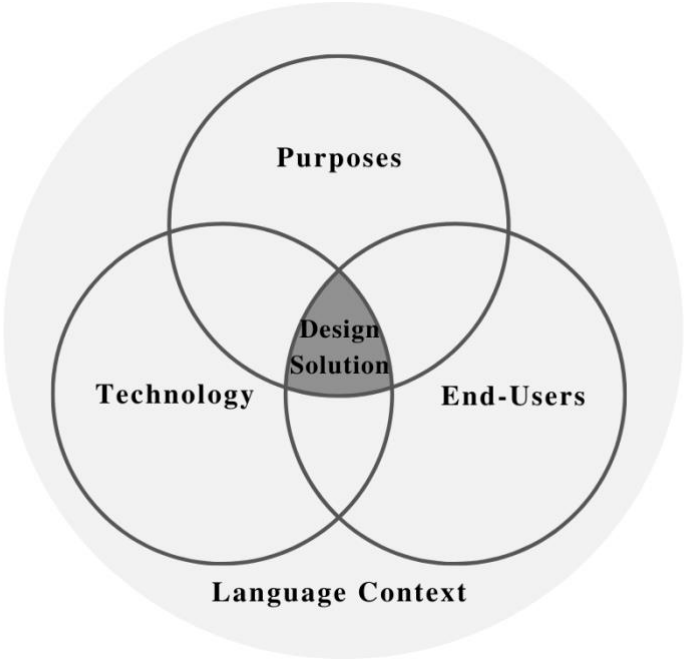

Figure 1. A Language-Centered ICT4E Framework (Castillo et al., in press; Wagner et al., 2014).

EdTech offers the potential to provide learners with authentic and culturally and linguistically relevant materials to work on at their own pace, wherever they are. Digital learning solutions can also assist in differentiating instruction,

monitoring student progress, and providing real-time feedback. A number of Web 2.0 technologies, such as blogs, wikis, and social networking sites, fit seamlessly into curricular structures and programs (Castillo et al., 2023). Several other innovations are slowly gaining attention in the field of education, such as augmented and virtual reality, chatbots and robots with text-to-speech and speech-to-text capabilities and will likely see increased use over the next decade (Adam et al., in press). However, a sustainable technology design involves working within the constraints of a particular learning environment, the existing infrastructure capacity, and the end-user's digital literacy competencies (including their language skills and aspirations).

Another key factor affecting sustainable EdTech deployment in LICs is cost. In Kenya for instance, Piper et al. (2014) sought to compare the impact to cost benefit for a medium-scale literacy intervention that made use of technology among a set of government schools. Sites were randomly assigned to one of three treatment arms or a control group. Treatment arms differed in terms of technology use, but each incorporated a tablet device either at the school cluster-level, the classroom-level, or the individual-level. Results showed that students in all three treatment groups scored higher on key learning outcomes as compared to the control, but no significant differences were detected between ICT interventions by level. It should also be noted that language fluency (Kiswahili and English) had differential impacts on the results, and showed that students with near-bilingual mastery in both languages resulted in higher reading outcomes.

Overall, research suggests that language is not only a major predictor of FLN outcomes in LICs, but also for EdTech interventions. This broad conclusion is not unrelated to matters of context, which have been the subject of theoretical and practical efforts over many years.

3.CONTEXT AND PERSONALIZED LEARNING

There is a long history of education and learning that describes the importance of "meeting the learner" where they are cognitively, perhaps best exemplified in the work of Vygotsky (1978), and scaffolding practices deployed by teachers worldwide every day. More recently, this notion has been adopted by approaches such as Human-Centered Design (Holeman & Kane, 2020), Universal Design for Learning (CAST, 2022), and Teaching at the Right Level (2022). Broadly speaking, the use of EdTech requires design to be shaped by these same general principles (Wagner, 2018).

One learner-centered approach that has been gaining ground in many educational circles is differentiation. Differentiated instruction employs varying educational practices tailored to the individual's unique needs, strengths

and preferences. This approach is more effective than the traditional approaches to instruction that target the average student (Bondie et al., 2019).

The key to effective differentiation is to keep students in the sweet spot where they are challenged and motivated, but not overwhelmed. Vygotsky termed this approach as keeping students within their *zone of proximal development* (ZPD; Vygotsky, 1978). Students thus benefit from the assistance given by a "knowledgeable other" to develop a more independent understanding. While the idea of the "more knowledgeable other" was originally used to refer to a teacher or a parent or more knowledgeable peers, it has been extended to include the learning support provided through technology (Phelps, 2019). In this approach, each student needs to be guided through learning material, tasks and support appropriate to their current skill level, what Vygotsky and others termed "scaffolded learning" within their ZPD (Lave, 2009; Wass & Golding, 2014).

However, teachers may not always have the training or resources to assess student performance, and provide effective reinforcement of skills in the ZPD (Bettinger et al., 2020). This is particularly true in large and/or diverse classes where there is greater variability in students' interests, abilities and languages (Turner et al., 2017; Van Schoors et al., 2021). A lack of proper diagnosis and support may result in students' inability to participate in EdTech grade-level (targeted) learning activities (Kim et al., 2017).

Digital FLN solutions that leverage technology to improve the understanding of user needs, skills, and motivation for learning has been termed personalized and adaptive learning (PAL; Adam et al., in press; Kem, 2022). Digital approaches to PAL enable teachers to teach at the right level and improve individualized instruction for learners who struggle to develop strong FLN skills. EdTech design solutions (as in Figure 1) also need to assure sustainability. For instance, *Maths Whizz*, deployed in Kenya, is an adaptive virtual tutoring platform (Whizz Education, 2019). The virtual tutor serves to guide the student through mastery-based principles of interactive content along an individualized learning path by first diagnosing each student's knowledge gaps across several topics. With a digital library of over 1000 lessons and more than 20,000 embedded assessments, the virtual tutor continually tracks students' progress and adapts lesson activities to their unique needs and pace of learning while providing supplementary support resources to both the student and teacher.

Over the years, various efforts have been made to find ICTs that are appropriate for marginalized learners of varied ages, spoken languages and geographical locations. In one example, the *Talking Book Programme* in Africa, was designed as an intuitive handheld audio player to deliver agricultural and health extension lessons following human-centered design principles (Castillo & Vosloo, 2017a). An extensive prototyping process conducted through

multiple field visits and user input informed an iterative design. The device has reached over 400,000 rural Africans and has led to positive health outcomes for low-skilled and low-literacy communities (Castillo & Vosloo, 2017a). In another example, *Mobile Vaani,* a voice-based mobile platform deployed in India, was developed specifically for low-literacy populations without regular access to print media and internet connectivity to provide access to important health information and local resources (Castillo & Vosloo, 2017b). Utilizing an interactive voice response system and deployed through participant's feature phones, audio content was distributed widely to rural areas.

Context matters, but it is not always clear which contextual features matter more than others for personalized learning. Pilot testing can assist, and is often employed. But how much and how broadly should pilot testing be carried out? This brings us to the to the issue of *scale* (and scaling up), a central feature of EdTech since its origins, and up till the present.

4.SCALING: TOWARDS AN INTEGRATED ADAPTATION DESIGN

The domain of EdTech has been often under policy pressure to focus more on the "low hanging fruit" – that is, where ICTs can be more easily implemented. Within a national policy framework, this perspective tends to advantage urban schools, boys, electric grid access, internet connectivity, majority (or international) language speakers, school infrastructure (both digital and physical) and so forth. In a very real sense, this is an important storyline of EdTech access in LICs since ICTs began to appear (with increased private sector investments) in schools in the late 1990s.

The notion in technology that what works for some can work for many – with a greater return on investment (ROI) through lower unit-costs – soon followed. The most popular instantiations of this concept are evidenced in private sector firms like Uber, Amazon, and many others. In the education arena, a similar trend has been importantly influenced by the work of Elmore (1996), who stated that educational reform *at scale* should be motivated by uniformity and simplicity. In intervention science, going to scale is also sometimes thought to embody the notion of a "silver bullet" – which refers to a special or unique way to overcome one or more substantive obstacles through rapid expansion. More recently, Elmore (2016) sought to modify his original thesis – arguing that scale for its own sake is less important than "demonstrating that powerful ideas can work in diverse environments." In other words, Elmore argued that after 25 years of scaling efforts in educational reform in the U.S., producing predictable and replicable effects across settings and contexts, was nearly impossible to achieve in practice. Rather, he found that effective reforms should emerge organically from diverse settings.

Given the considerable challenges associated with education in LICs, where there tend to be fewer resources to invest in FLN, technology is often seen as a very important type of intervention. This view is often presented in terms of "leap frogging" the constraints of older and more limited technologies (Robinson & Winthrop, 2016). The broad goal is to achieve lower unit-costs by reaching larger numbers of students (Piper et al., 2016; 2017; World Bank, 2016; Olsen, 2022). Either by leapfrogging or through reducing unit-costs, there is little question that scaling up remains a strongly held policy goal in most countries, wealthy or not. Indeed, as described above, the *Mobile Vaani* initiative has grown to reach over 2 million unique users in twenty-five districts throughout central India while reducing the project's cost-per-user to only USD $0.25 – and is often cited as a major success in scaling up (Castillo & Vosloo, 2017b).

Yet, going to scale is a term that can also create confusion, as there are multiple dimensions of what scale actually means. While often thought of as generic, there are very different ways to think about scaling in EdTech: vertical, horizontal and diagonal (see Figure 2), as described below.

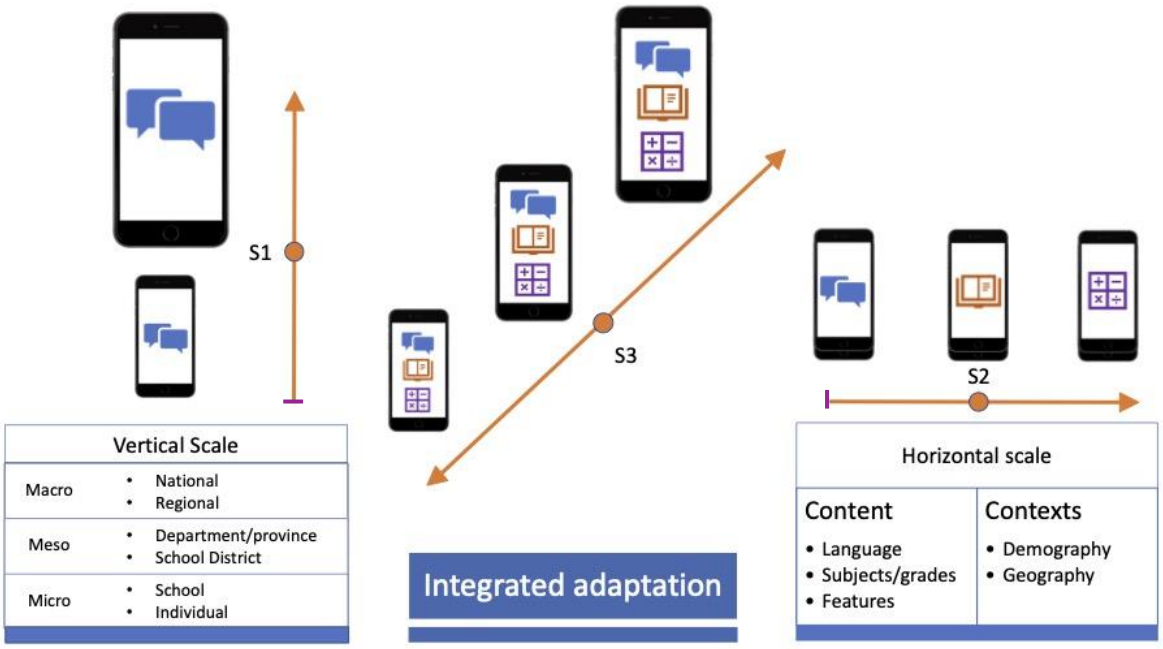

Figure 2. Scaling with EdTech: An Integrated Adaptation Design (IAD)

Note: See Box 1 for description of scenarios S1, S2, S3

Box 1: Three scenarios of scaling with EdTech

***Scenario 1*. In S1, usually at the beginning phase of work, a design is developed to focus on a single population demographic and context with limited content appropriate to the population. It can then be grown to a larger population with unidirectional vertical scaling, from bottom to top (see Box 2, on OLPC in Peru).**

***Scenario 2*. S2 expands reach of an EdTech intervention to a larger sample demographic and/or contents/languages, that can be grown in unidirectional horizontal expansion, from left to right). (See Box 3, IAI in Paraguay and other Latin American countries).**

***Scenario 3*. S3 expands the idea of greater ROI cost/learning reduction in entire geographic context and larger array of content/languages, comprising a bi-directional scaling, or IAD solution. (See Box 4, BFI project in India and South Africa).**

Vertical scaling. Vertical scaling is typically thought of as applying an approach (app, tool, pedagogy) in a way that is expanded within a single population, language, gender or other known demographic dimension. Its vertical nature would build from a pretested pilot project, and then scaled to other similar populations (more schools, for example) in the same context as the previous pilot. There exist a myriad examples, and it is probably emblematic that most pilot efforts would like to be scaled, as this is their fundamental *raison d'etre*. A recent example of vertical scaling may be seen in the work of Angrist et al., 2021 who used text messaging in Botswana to achieve low unit-costs for improving FLN outcomes. Earlier, the One Laptop Per Child (OLPC) initiative in Peru sought to build on piloted laptops designed in the United States initially, for a scaling up effort in Peru (see Box 2). Thus, in Figure 2, the left side of the graphic, in the OLPC example, indicates an increase in the units made available across a population. The simple fact that these units were not made available in Quechua language content meant that, at a minimum, they would be far less effective for non-Spanish speaking populations.

Box 2. One Laptop per Child, Peru

Developed at MIT in 2005, One Laptop per Child's (OLPC) originally aimed to address low learning quality in the poorest regions of the world by providing access to technology. The initiative leverages relatively low-cost devices to provide one-to-one computing at school and home. The use of bright colors and rubberized casing of the laptop itself was intended to be attractive to young learners, and at the same time durable. Further, government partners chose from a suite of applications to be installed on their laptops.

The first implementation at scale was conducted in Peru across 500 rural Spanish-language instruction schools with the distribution of 40,000 laptops (Cristia et al., 2012). The Peruvian government selected multimedia content for math, Spanish language, and other cognitive skills, as well as 200 age-appropriate e-books. Minimal adaptation beyond Spanish-language translation was incorporated into the implementation design. While the Peruvian government was able to select from a database of applications to include on the laptops, little attention was paid to the context of the local environment (language(s), cultural artifacts, or otherwise) and content consisted of basic processing programs, games, and Spanish language e-books (Cristia et al., 2012). An evaluation of 319 schools (209 treatment; 110 control) after 15 months of implementation resulted in limited impact on academic achievement, but did find positive effects on competencies related to computer use.

Horizontal scaling. Horizontal scaling, by contrast, refers to both additional demographic contexts and/or subject matter contents. In the former, one example might be expanding the use of an English language learning app, initially adapted for primary school children who speak Hindi as a home language, to teaching older youth or adults in India. Or, in terms of contents, broadening from an English reading app to, say, contents on math skills development. Within horizontal scaling, there may also be important functional differences, including for example building out platform features for improved efficiency such as modifying the log-in process or enhancing the teacher dashboard portal. Below, Box 3 provides an example of horizontal scaling within the context of interactive audio instruction in Paraguay and Latin America.

Box 3. Interactive audio instruction, Paraguay/Latin America

Interactive audio instruction (IAI), is designed to deliver interactive learning to remote areas through audio broadcast with songs, dramatizations, and games. During a scheduled time, teachers use the pre-recorded audio to guide students through narrated pedagogical activities as a whole class. An early numeracy IAI project implemented across 265 schools in the Cordillera region of Paraguay reinforced key learning concepts in Guaraní, the indigenous language prominent across the region (Naslund-Hadley et al., 2014). Story lines and games for the Paraguay program also included references to local customs and artifacts that celebrated Guaraní heritage.

IAI has also been used for horizontal scaling of audio content for English language acquisition elsewhere in Latin America. In 2014, the Ministry of Education of the Dominican Republic launched a program across 185 schools around the country. In 2016, this program was adapted to the local Honduran context and implemented in 14 departments, covering 21,000 students (Education Development Center, 2022).

In sum, vertical scaling concerns the *reach* within a designated population, while horizontal scaling concerns moving more broadly with either or both *content* and *contexts*.

Scaling with "integrated adaptation design" (IAD). Both horizontal and vertical scaling tend to be unidirectional: vertical scaling can be scaled-up (larger population), while horizontal scaling can be expanded to other contents or contexts. However, the world of learning is more complicated. We argue that a real-world approach necessarily involves both dimensions, as shown in the *diagonal* line in the middle of Figure 2. In addition, we suggest that the integration or intersection of both parameters should be consciously designed into each effort at scale, rather than as an afterthought; further, this diagonal is bi-directional, in that designers may decide to move to the top (outward), or the bottom (inward), depending on demographics, contents and contexts. Outward movement along the diagonal implies expanding the focus of context for learning equity at scale, while inward movement implies a narrower focus on more limited contents or demographics. Many EdTech projects make such decisions, even if not explicitly stated as part of an IAD solution.

Box 4. Bridges to the Future Initiative, India and South Africa.

The Bridges to the Future Initiative (BFI) is a multinational effort initially designed as an out of school youth (OSY) program in the southern Indian state of Andhra Pradesh via technology in the mother-tongue language (Wagner et al., 2010). The study found that a subset of OSY participants engaging with the computer assisted instruction (CAI) content, intentionally adapted to local context and language, produced modest but significant gains in the reading subtest scores as compared to the non-CAI group, as well as substantial motivation to pursue local language literacy learning.

An in-school adaptation of the BFI multimedia program implemented across a broader set of basic education classrooms in the northern province of South Africa produced significant gains in key reading outcome measures in multiple languages (Castillo & Wagner, 2019). Further, the study found that the design of the content also facilitated the transfer of skills development from L1 to L2 (English) among the treatment group.

Our review suggests that most EdTech efforts that push to scale up (and achieve greater ROI) try to do so by either vertical or horizontal expansion, as illustrated in Figure 2, though *all* EdTech interventions should embody a purposeful and robust IAD version of scale along the diagonal.

In other words, “scaling up” or “scaling down” of an IAD solution can be considered bi-directional – in most cases, implementers seek to scale up, as described earlier. But there may be a strong case for “*scaling down*” (Myerson, 2016), where local adaptation (such as the use of the Guaraní language, in Box 3) is key for assuring equitable learning outcomes. An IAD solution that seeks to promote learning equity should pay particular attention to variations in language, socioeconomic status, and gender, as well as changes in globalization, migration, civil conflict and more.

5.POLICY IMPLICATIONS

Learning equity for those most marginalized. Much has been made of the potential of EdTech in the area of FLN, but few evidenced-based projects have been undertaken with poor and marginalized children – those most in need (Castillo & Wagner, 2018; Piper et al., 2014). As noted by IDRC (2022), it is vital to “make equity of impact an equal measure to magnitude of impact.” It seems clear that access (and interest) in the deployment of EdTech in primary and secondary schools has accelerated worldwide during the Covid pandemic, though the gap between the haves and have-nots within countries may have increased (Vegas, 2020). Research is now providing evidence as to the benefit of raising the floor and closing the learning gap is essential if learning equity is to be achieved (Crouch & Rolleston, 2017; Wagner, 2018; Wagner et al., 2022).

Language choice. Multilingualism in education is evolving rapidly as a function of increased globalization, internal and external migration, climate change and more (Wagner, 2018; Wu et al. 2021). Technology has opened up our ability to integrate targeted content in response to language marginalization. Language choice and other forms of cultural and context planning must be purposeful as part of future EdTech solution designs (Figure 1).

Scale and sustainability. Over the years, attempts at improving adaptive features of EdTech solutions have been informed through iteration to achieve a balance between aspects of breadth and depth in working with groups of marginalized students. In this review, we call this approach an integrated adaptation design (IAD) as a framework for linking EdTech scale with learning equity. One key assumption is that there needs to be a capable infrastructure and institutionalization of human resources, as well as hardware, software and connectivity. For example, the government of Uruguay established *Plan Ceibal* as a comprehensive and sustainable model for institutionalizing digital learning for basic education at scale (Plan Ceibal, 2020).

6.CONCLUSIONS

EdTech has continued to grow worldwide, most recently pushed forward by the COVID-19 pandemic. This has produced a need to better understand how EdTech can support learning equity, especially among marginalized populations. Up to the present, it has been difficult to balance the priorities of "scaling up" that has historically favored 'majority' populations, with the need for greater localization or "scaling down" (by language, age, and gender). The present analysis suggests an IAD framework for new solutions in EdTech to support learning equity in low-income countries.

In the end, every policy maker has to make choices. An effective policy maker will want to decide among options that are based on the most robust data available for learning outcomes, and what it will cost (in terms of time, cash, human resources, and opportunity costs). As such, education leaders have a serious need for timely, policy-relevant, and option-ready data on a frequent basis (Wagner, 2011). Yet, data on learning outcomes – especially in EdTech – need to take into account matters of equity, especially given EdTech's history of focusing predominantly on the more advantaged populations in LICs. Only through a reconsidered focus on *scaling-for-whom* will EdTech achieve its desired goal of helping the most marginalized in the world.

In the international development community, the focus of financial support over the past half-century and up to today has been to build ICT infrastructure, including electrical grid, devices and human capital resources (including teacher training). Investments that include learning outcomes are a more recent and less common phenomenon. As the implementation of the UN Sustainable Development Goals (especially SDG4) become national policy, we can expect to see learning equity as a more central component to the use of educational technology for the most marginalized populations.

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