EdTech Hub

Clear evidence, better decisions, more learning.

WORKING PAPER

Problem Analysis and Focus of EdTech Hub's Work

Technology in Education in Low- and Middle-Income Countries

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Notes

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Abbreviations and acronyms

DBR	Design-based research
EdTech	Educational technology
EGRA	Early Grade Reading Assessment
EMIS	Education Management Information Systems
FCDO	Foreign, Commonwealth and Development Office of the UK government
HIC	High-income country
ICTs	Information and Communications Technologies
LAYS	Learning adjusted years of schooling
LIC	Low-income country
LMICs	Low- and middle-income countries
OECD	Organisation for Economic Co-operation and Development
OER	Open Educational Resources
OLPC	One Laptop Per Child
PISA	Programme for International Student Assessment
SDG	Sustainable Development Goal
SEND	Special educational needs and disabilities
SPuD	Searchable Publications Database
SQC	Smaller, quicker, cheaper
TA	Technical assistance
TPD	Teacher professional development
UIS	UNESCO Institute for Statistics

The potential of educational technology to contribute towards addressing the learning crisis and achieving SDG4 remains to be realised.

Abstract

Educational technology (EdTech) is often promoted as a key 'solution' to the challenge of achieving Sustainable Development Goal 4 (SDG4) by 2030, promising enhanced learning in low- and middle-income countries (LMICs). However, this raises an additional question: what are the specific 'problems' that EdTech is trying to solve? To date, investments in information and communications technologies have seldom achieved sustained positive impacts on learning outcomes at scale, and particularly for marginalised learners in LMICs. Use of EdTech can potentially help bring us closer to achieving SDG4, but in isolation it is very unlikely to be the 'silver bullet' that some have suggested it is. To achieve sustained improvements at scale and reach marginalised learners in specific contexts, we must seek to understand the various reasons why many previous EdTech programmes have not fulfilled their potential and what EdTech designs and systems are needed for more effective outcomes.

In this position paper, we situate the work of EdTech Hub in relation to the SDG4 goal of inclusive and equitable quality education for all. After reviewing and critiquing research methods and use in this area, we highlight the emergent challenges that shape EdTech Hub's strategic research plan, whose overall objective is to: *undertake and collate rigorous research to improve the evidence base for innovating, scaling, and sustaining the use of EdTech to improve learning, teaching, and education systems in LMICs, with a particular emphasis on the most marginalised.* Within a multi-stakeholder approach, the Hub has three thematic focal areas: learners, teachers, and educational systems, each in support of SDG4. We further set out planned approaches to building evidence and engagement in the EdTech and broader education space.

1. Introduction

The main global target of EdTech Hub is aligned with SDG4: 'Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all'.

In this position paper, we set out a research framework that underpins the work of EdTech Hub, and outline its underlying rationale in terms of central issues and problems concerning our substantive focus areas within the field. The audiences are both internal and external, including researchers, educators, sponsors, policymakers, and other change agents concerned with the use of EdTech in development contexts. An accompanying, shorter briefing paper summarises the main points.

1.1. The global challenge of equitable quality education for all

In 2015, the UN proposed a set of 17 Sustainable Development Goals (SDGs), including SDG4 with a particular focus on learning outcomes for children.[1] While access to education has increased dramatically in LMICs over the last two decades, it is far from ubiquitous. In 2017, 262 million young people across the world (aged 6 to 17 years) were out of school (↑UNESCO, 2019). The Covid-19 pandemic has greatly increased the number. This reached a peak of 1.5 billion learners out of school in June–July 2020, of which 463 million were estimated not to have any access to education provision at all (↑UNICEF, 2020a). The UN estimates that 23.8 million of those learners are likely to never return to school (↑UN, 2020).

As we enter the final decade of the 2030 SDG agenda, the evidence suggests that the rate of progress is insufficient to achieve the inclusive, equitable, and quality education for all that is enshrined in SDG4[2] (↑UNESCO, 2019) and its specific targets (Annex 1). Poverty is the most prominent factor; for example, only 4% of the poorest 20% of learners complete upper secondary school in the lowest income countries, compared with 36% of the richest in those same

[1] https://sustainabledevelopment.un.org/sdg4
[2] See the UIS Technical Cooperation Group on the portal for exploring data related to Indicators for SDG 4.

countries (↑UIS, 2017).[3] When poverty interacts with other sources of disadvantage (such as gender, ethnicity, language, and disability), inequalities are amplified (↑UNESCO GEM, 2020; ↑UNICEF, 2018; ↑Wagner, 2018a). A further prominent cause of marginalisation is conflict and crisis leading to displacement, which in turn disrupts learning. Approximately four million 5- to 17-year-old refugees were out of school in 2017 (↑UNHCR, 2018), with numbers currently growing due to the Covid-19 pandemic. Previous crises, including conflict and refugee situations as well as disasters associated with natural hazards, have often led to school closures and increased the likelihood of children staying out of school (↑Save Our Future, 2020).

For these reasons and others, children's learning as evidenced by literacy and numeracy rates in many LMICs has remained stagnant or fallen below expected levels (↑World Bank, 2018). According to estimates by the UNESCO Institute for Statistics (UIS) (↑UIS, 2017), more than 380 million children worldwide (56% on average and 85% in sub-Saharan Africa) will finish primary school without being able to read or do basic mathematics. Achieving substantial improvements and reducing learning inequalities are specific indicators for SDG4 Targets 4.1, 4.6, and 4.7 (see Annex 1).

Teachers are central in the education system in every country and are critical to improving outcomes for marginalised learners. For instance, the ↑Education Commission (2019) report on transforming the education workforce states that "teacher quality is the most important determinant of learning outcomes at the school level, but in many countries teachers are in short supply, isolated, and not supported to provide effective teaching and learning" (p.6). In LMICs, teachers are often under-qualified and lack access to in-service teacher professional development (TPD) opportunities. Some research has shown that teacher education interventions are associated with positive effects on primary school learning outcomes in LMICs (↑Angrist, et al., 2020a; ↑Evans and Popova, 2015; ↑McEwan, 2015). However, there is considerable variation in the efficacy of programmes (↑World Bank, 2018), which are not always linked to practical classroom applications nor sustained over time (↑Orr, et al., 2013).

Behind these challenges are education systems failing to support learning and quality teaching, with significant gaps in coherence and accountability (↑Pritchett, 2015). Often, education systems have little systematic information on who is learning and who is not (↑World Bank, 2017). Lack of data and data

[3] The Hub's focus is on primary and secondary school-level learning (both formal and informal) and teacher education (both initial and continuing / in-service). Early childhood is inevitably part of our work because of the continuum into primary, but it is not an explicit focus. Higher education is not an explicit focus and is only part of our work when it enables us to build evidence specific to earlier levels of education. The exception to this is that any form of higher education that is specific to teacher education is an explicit focus.

use leads to decreased accountability for poor performance and makes it more challenging to both achieve and monitor progress towards universal educational goals (↑UNESCO Institute for Statistics, 2020). Without metrics of how well students are learning, teachers, in turn, are unable to target support at those falling behind (↑World Bank, 2017). It is estimated that 68.8 million more teachers need to be recruited globally and effectively deployed in order to enable every child to access primary and secondary education (↑UNESCO, 2016). In parallel, already insufficient education funding has been dropped by as much as 10% due to budget reprioritisation toward other sectors (↑Al-Samarrai, 2020; ↑Wagner & Warren, 2020) and an overall annual education financing gap of between USD 178 and 193 billion for the 2020–2030 period is expected (↑Save Our Future, 2020). Concurrently, there has been an exponential shift to remote learning and reliance on parents and caregivers to supplement lessons, owing to the pandemic (↑Brossard, et al., 2020). Not only are these imposing challenges in and of themselves, all of them are interlinked at various levels within the system. A radically new approach is thus needed in order to address the education crisis.

1.2. The role of EdTech in addressing the learning crisis

EdTech has an important potential role to play in accelerating progress towards SDG4. We define 'EdTech' as technologies — including hardware, software, and digital content — that are either designed or appropriated for educational purposes. We deliberately use a broad definition of EdTech. This includes any use of information and communications technologies (ICT) at any point within the education system — in ministries, schools, communities, and homes, including between individuals and for self-study. Most of EdTech Hub's work relates to digital technologies but not exclusively so. We also seek to emphasise our commitment to including the most marginalised learners, for example, those in remote rural areas who typically only have access to low-tech devices like non-digital radio and television. All kinds of technologies are disproportionately used by the most privileged learners *within* each LMIC (↑Castillo, et al., 2015; ↑Liyanagunawardena, et al., 2013; ↑Selwyn, 2016b).[4] This has been especially notable in recent responses to the Covid-19 pandemic; poorer students have been less likely to access remote learning, hardware and parental support (↑Vegas, 2020; ↑World Bank, 2016). In both low-income countries (LICs) and high-income countries (HICs), for instance, many private schools quickly offered access to lessons in online virtual-learning environments while many state-funded schools relied on less sophisticated

[4] Increasingly stratified education systems mean that learners in elite private / international schools are differentially able to take advantage of resources, including access to technology. A 'digital divide' is also apparent within marginalised communities in many HICs.

technology — or offered no provision at all (for example, ↑Jansen (2020) describes the Google Classroom, WhatsApp, and Radio-Television groups emerging in the 220 South African schools studied). The pandemic responses indicate that socio-economic inequities both in schooling and in homes continue — and can be exacerbated — in terms of access and engagement with remote teaching materials (↑Asadullah, 2020; ↑Le Nestour, et al., 2020). They have highlighted the importance of including low-tech modalities in emergency responses in low-resource contexts. Where appropriate, we also consider 'digital' beyond 'technology' and include issues regarding the use of data or digital licensing; the use of printed materials and learning packs as part of Covid-19 responses highlights the importance of considering design across a range of media (↑Dreesen, et al., 2020).

There is growing evidence that effective use of EdTech — in conjunction with other strategies — has potential to lead to improved learning outcomes in LMICs. In their meta-analysis of 77 randomised controlled trials undertaken in primary education in LICs, ↑McEwan (2015) found that interventions using computers or other forms of technology yielded the highest average effect size (0.15 standard deviations) when compared to other interventions[5]. Still, much has to be done in order to determine which EdTech designs can be most effectively (and cost-effectively) deployed to promote learning among those who are marginalised (↑Unwin, 2020; ↑Wagner, 2001).

1.3. Setting out a research agenda

EdTech Hub has multiyear support from the Foreign, Commonwealth and Development Office (FCDO), the World Bank and the Bill and Melinda Gates Foundation. Its overall strategic research objective is to *undertake and collate rigorous research to improve the evidence base for innovating, scaling, and sustaining the use of EdTech to improve learning, teaching, and education systems in LMICs, with a particular emphasis on the most marginalised learner.* In more detail, the Hub aims to:

- Build robust evidence for how to accelerate, spread, and scale EdTech interventions that maximise the benefits in delivering improved learning outcomes of school-age children in LMICs, with a particular emphasis on the most marginalised.
- Identify and highlight the role of the contextual factors influencing the impact and sustainability of EdTech initiatives at systems level.

[5] While this is a modest effect size, we expect this to grow as EdTech initiatives improve over time. Moreover, median effect size of educational interventions on learning in LMICs is likewise low at 0.1 (↑Evans & Yuan, 2020).

- Adapt priorities so that interventions and funding shift toward an evidence-based learning equity agenda for the most marginalised by creating a balanced approach based on local needs as well as the UN Sustainable Development Goals.
- Evaluate, strengthen and build a global body of research about how technology is used in education, including, (a) raising awareness across the education sector of methodological issues, and (b) developing and sharing rigorous research methods and approaches to measuring impact and cost-effectiveness of EdTech.
- Build a shared blueprint for accelerating growth of small-scale innovation through iterative trialling and user-centred, contextualised adaptation of EdTech applications.
- Increase demand for and uptake of EdTech research evidence in programmes by making EdTech findings actionable, available, and accessible to a wide range of stakeholders in user-friendly formats.
- Foster a vibrant, global community of practice in EdTech across the education sector by engaging multi-disciplinary champions of change among researchers, educators, policymakers, and development partners.

Three pivotal themes will help to focus the Hub's work while paying attention to 'high-potential evidence gaps':[6]

- **Adapting to the needs of diverse learners:** In particular, using technology to adapt to the needs of learners marginalised by poverty, gender, language, disability, displacement, and being out of school.
- **Supporting teachers:** Using technology to enhance teacher effectiveness through TPD, retention, and attendance.
- **Strengthening education systems:** Using technology to strengthen education system governance, data management, and accountability.

The themes are interconnected, and research studies will flow amongst them so as to create five cross-cutting emphases, framed as the research questions in Table 1. All studies supported by the Hub are expected to engage with one or more of them.

[6] A high-potential evidence gap is defined here a specific area that the Hub considers to be a priority substantive focus because of the potential impact that could result from related new research. These gaps, which will likely change over time, have been identified by drawing upon the evidence to date.

Table 1. *Cross-cutting research emphases, objectives, and questions.*

Cross-cutting emphasis	Associated objective	Cross-cutting research question
1. Learning outcomes	To improve the evidence base regarding the effectiveness of EdTech in relation to specific learning outcomes.	How can specific learning outcomes on literacy, numeracy, and socio-emotional learning outcomes be strengthened through the use of technology?
2. Equity	To improve the evidence base regarding the effectiveness of EdTech in relation to equity.	How can equity for the most marginalised (girls, learners with disabilities, children affected by crises, and minority language learners) be improved through the use of technology?
3. Context	To improve the evidence base regarding the effectiveness of EdTech in relation to context.	How does context, including low-infrastructure contexts, shape appropriate uses of technology, especially in reference to education systems, cultural specificity, and political economy factors?
4. Cost-effectiveness	To improve the evidence base regarding the effectiveness of EdTech in relation to cost.	What are the most cost-effective uses of EdTech and how can these be measured and compared?
5. Scale and sustainability	To improve the evidence base regarding the effectiveness of EdTech in relation to scale and sustainability.	How can the use of technology in education be designed and implemented in a way that is scalable and sustainable?

One important goal of the Hub is to foster better evidence production. Thus, for practical reasons (including building on long-term relationships), at-scale research efforts will be carried out in a group of focal countries that have ongoing EdTech research capabilities. Through a process drawing upon country scans and scorecards, broad consultations with stakeholders, and relationship building through helpdesk requests and technical assistance, the Hub has identified six initial focal countries: Bangladesh, Ghana, Kenya, Pakistan, Sierra Leone, and Tanzania.

The paper is structured as follows. In Section 2, we present a critical discussion of some of the limitations of prior EdTech initiatives, and the need for a broader educational systems approach. We discuss some of the challenges that form the cross-cutting emphases of the Hub's work. In Sections 3 and 4, we introduce the frameworks that will be employed to help ensure more holistic and sustainable changes at scale, including the current and evolving

range of practical Hub strategies and activities that are used to operationalise our goals. Section 5 presents brief conclusions. This document will serve as a strategic framework for use within the Hub, and hopefully the wider community, and will be updated as research and evidence in EdTech expands in the coming years.

2. Barriers to the effective use of EdTech at scale in LMICs

Identifying the potential for technology to enhance education in LMICs is not novel in itself. However, hype and political and financial interests have often led development in this sector (↑Selwyn, 2016a; ↑UNESCO, 2019; ↑Wagner, 2018a; ↑Wagner, 2018b), with unrealistic goals of widespread economic and social change. Sustainable, positive change at scale has in reality proved elusive. For EdTech to be used effectively to support progress toward SDG4, focused attention and a much stronger evidence base are required.

The use of EdTech has the potential not only to accelerate progress and increase equity (↑Kozma, 2011; ↑World Bank, 2016), but also to cause unintentional harm and increase inequity (↑Rubagiza, et al., 2011; ↑Selwyn, 2016b; ↑Wagner, 2018b). This is a particular risk in the rush to deploy technology in times of urgency and crisis; this risk is clearly reflected in the reliance on technology in Covid-19 responses, despite unequal levels of ownership and access to technology within countries (↑Dreesen, et al., 2020).

In this section, we critically reflect on the field of EdTech in LMICs and identify persistent challenges which the Hub will need to address in its work if it is to contribute to sustainable improvements to education systems. The discussion is focused around two key (and linked) aspects of EdTech research and development: first, the body of research available on the topic, and its limitations; and second, design and implementation.

2.1. Methodological quality, theory, and scope of research and evaluation

There is broad agreement that more and better evidence is essential in order to understand how EdTech can be used effectively and, especially, to support the needs of marginalised learners. The rate of technological development, largely led by the market for consumer technology, outpaces research. The EdTech sector often relies on anecdote and aspiration rather than robust evidence (↑Jameson, 2019; ↑Selwyn, 2012), and even high-profile programmes might not be rigorously designed or evaluated (↑Wagner, 2018b). Further, progress is impeded by the many unfounded or untested claims and by uncritical assumptions about the potential 'transformation' that ICTs can bring to education.[7] This means that policymakers, educators, developers, and

[7] This is technological determinism, "the belief that technology shapes society in some way — which includes social practices such as learning" (↑Oliver, 2011, p.374), that assumes that technology itself has agency to drive change.

researchers do not necessarily learn lessons from negative or mixed findings of large-scale evaluations, including in LMICs. The One Laptop Per Child (OLPC) programme is an example notable for its sheer scale, having distributed 2.4 million laptops to under-served primary children in 42 countries around the globe without piloting or evidence of positive impact; evaluation of the scheme eventually showed it to be problematic and ineffective for children's learning (for example, see evidence from Peru and Uruguay: ↑Beuermann, et al., 2015; ↑Cristia, et al., 2012; ↑De Melo, Machado, and Miranda, 2014).

Methodological issues are frequently observed across the field of EdTech research. They have been exacerbated by the relatively low levels of funding available for researchers in LMICs. More than a dozen years ago, ↑Wagner (2005) recommended a baseline of funding support for monitoring and evaluation of EdTech interventions that has not yet materialised. Initiatives themselves may be under-resourced: even appropriate uses of technology are often not sufficiently funded, maintained, communicated, or supported (↑Unwin, 2020). Studies up to the present time have tended to be small-scale and short-term, defined by funders' priorities. Follow-up and longitudinal studies are rare and optimal durations of interventions are not systematically investigated. For instance, using personalised learning software for a shorter duration (less than half a school year) appears to offer around the same, if not slightly more, effectiveness as use over longer durations (↑Major, et al., forthcoming).

Until relatively recently, research on EdTech often focused on learner motivation and engagement rather than measuring learning outcomes (↑Haßler, Major, and Hennessy, 2016). Research was frequently conducted in experimental rather than naturalistic conditions. Lack of baseline measurement and control or comparison groups resulted in inability to attribute causality to change and identify added value; qualitative and mixed-methods research designs may not offer rich contextual detail or evidence to substantiate the claims (↑Hong, et al., 2018) and to help inform other researchers about wider applicability. These issues reflect a lack of quality assurance, as shown in a meta-review by ↑Lai and Bower (2020) — where only 6 of the 73 reviews (8%) had explicitly defined quality assessment criteria.

A robust theory of change is often missing in the design, implementation, and evaluation of EdTech initiatives. Theory needs to be supported by empirical findings, especially concerning effectiveness in diverse real-world settings (↑Joyce and Cartwright, 2020). Yet, evaluations have often not provided adequate explanations or convincing interpretations of findings. It is notable,

and dispiriting, that about 40% of EdTech research published in the three highest-ranked (according to citation impact factor) specialist journals[8] makes little or no reference to theory, while a further quarter makes only modest mention (↑Hew et al., 2019). There is also a need for more research on technology use at school level. The aforementioned meta-review by ↑Lai and Bower (2019) found that only 15% of the reviews across the field specifically focused on school-level education. Likewise, much of the work carried out by African scholars is focused on higher education, leaving use of technology in basic education underexplored (↑Rose, et al., 2019).

Regrettably, as with other educational research (↑Asare, et al., 2020), very little of the published research in EdTech has in fact been led by researchers based in LMICs. Biases within academic publishing and restrictions on open access to the literature can obstruct contributions from authors outside HICs (↑Medie and Kang, 2018) and stifle dissemination of research findings to local practitioners (↑Abraham, et al., 2008; ↑Czerniewicz, 2016). Furthermore, underfunding of higher education systems often prevents institutions from being able to fully support their academics' research activities, and while external sources can provide funding, academics in LMICs are excluded from setting the research agenda (↑Trotter, et al., 2014). Funding conditions often make it impossible for researchers in LMICs to lead partnered projects (↑Haßler, et al., 2020a).

Finally, EdTech needs to broaden the scope of its work towards SDG4, and to link with other SDGs, the commitment to 'leave no one behind', and in particular the issue of educational equity. There is limited published research specifically addressing issues within LMICs related to equity or the use of EdTech by marginalised groups within or outside of school systems (see, for example, gaps within the literature in relation to learners with disabilities: ↑Lynch, et al. 2020). This reflects a broader need for systematic monitoring and evaluation to be embedded as part of interventions in order to understand their impacts (↑Wagner, et al., 2005). In times of crisis particularly, the urgency to implement EdTech-based responses is likely to perpetuate further inequities unless support for marginalised learners is actively included in responses (↑Rubagiza, et al., 2011; ↑Wagner, 2018a). The Hub seeks to explicitly address equity by foregrounding it as one of its cross-cutting emphases.

[8] Computers and Education; British Journal of Educational Technology; Learning, Media and Technology.

2.2. Using research findings to inform EdTech design and implementation

The Hub gives central importance to the types of technology and their affordances[9] and suitability in specific contexts, and for particular purposes. We must pay greater attention to the needs of teachers and learners (especially the most marginalised, as highlighted above). Also, there is currently no recognised central location offering comprehensive, readily accessible evidence on the issues in the field of EdTech that concern policymakers, whose role the Hub expects to serve. The additional effort involved in accessing academic research along with policymakers' ability to use it effectively means that EdTech evidence has seldom been given sufficient priority when policy decisions are made, especially when they need to be made rapidly (↑Pellini, et al., 2021).

2.2.1. Context, cultural responsivity, scale, and sustainability

There is a growing awareness of the need for researchers to strive to understand, capture and describe the contexts and conditions that constrain and support technology adoption (↑Gu, Crook, and Spector, 2019). While interventions that work reliably across wide-ranging circumstances and populations are the most promising (↑Joyce and Cartwright, 2019), we consider the popular terms 'best practice' and 'what works' to be misleading since they suggest that there are universally valid recipes for promoting learning. Instead, effective practices — including choices of technology type — are successful in specific contexts and circumstances, accounting for variation in educational purposes, characteristics, and needs of learners, teachers and other stakeholders (↑Wagner, 2018b).

Scalability and sustainability of the impact of EdTech interventions are two key dimensions of the Hub's work and its lasting relevance across multiple contexts. They depend on a strong awareness of the importance of appropriate local contextualisation; these cross-cutting themes are closely interrelated. While technology initiatives are critiqued for not always being effectively or faithfully implemented, and this is considered to impact significantly on their efficacy (↑Kerwin and Thornton, 2020; ↑Outhwaite, et al., 2020), rigid and unachievable notions of 'faithful reproduction' (fidelity) are in

[9] The notion of affordance is first attributed to James Gibson (↑Gibson, 1979), referring to the perceived, i.e., fluid rather than fixed, properties of a technology that can be exploited for a specific purpose in a specific context. Affordances are interactions between an actor and a technology or other artefact; they have been said to pertain to a range of 'action possibilities' that may apply—be enacted—across different technologies and contexts (↑Major, et al., 2018).

any case unhelpful (↑Haßler, et al,. 2018). Scaling an initiative needs to be based on effective design principles derived from collaborative design, development, trialling, and reflection with local stakeholders who have ownership for shaping and implementing initiatives to address local problems and introduce relevant change. This process needs to draw on a review of research evidence, while acknowledging the need to test the boundaries of the theories and practical lessons learned in the studies, but also "on local knowledge, feedback and energy to foster learning from both success and failure" (ODI: Doing Development Differently manifesto). It is followed by further contextualisation for different settings and groups of learners — including marginalised learners and communities — during the 'rollout' across a system. At that stage, the design process needs to include the core elements as a starting point, and adapt the remaining elements to the local context (↑Perlman Robinson and Winthrop, 2016). Yet technology initiatives are often top-down and far from properly contextualised, and the impact of cultural factors on take-up and outcomes is typically not investigated.

Technology is not ideologically neutral, and its design comes with assumptions about values and practices which may not be valid (↑Ananny and Winters, 2007). *Culturally responsive pedagogy* (↑Brown-Jeffy and Cooper, 2011) and appropriate (for example, culturally relevant, linguistically accessible or suitably pitched) content are needed to incorporate local narratives and perspectives into design and implementation processes (↑Girgis, 2015). This includes situating academic knowledge and skills within the lived experiences and frames of reference of learners to improve learning outcomes (↑Gay, 2002). While studies on culturally responsive pedagogy and teaching have traditionally focused on ethnic diversity, in the context of EdTech the notion includes varied levels of cultural capital — including technological skills, appropriation, and norms of purposeful use — that combine with several other dimensions including differential socialisation experiences and access to material resources that reduce the benefits of computer use (↑OECD, 2010). We know, for instance, that learners and teachers from rural areas and low-income groups have less experience of technology use outside school and need more support of particular kinds (↑UNESCO, 2014).

Perceptions of the usefulness of EdTech varies greatly by constituency and context, such as by stakeholders (such as teachers, students, policy makers, parents, and caregivers). Involvement of the range of in-country stakeholders, including appropriate feedback mechanisms, along with attention to cultural knowledge, home experiences, and local ownership, is often lacking in EdTech initiatives in LMICs (see ↑Girgis, 2015). Thus, stakeholder awareness-raising needs to reflexively engage with grassroots issues and deployment constraints rather than simply garnering support (ibid). The OER4Schools programme has

made some headway, working with local educators and NGOs to develop substantial open resources for peer-facilitated, school-based professional development of interactive teaching (↑ Haßler, et al., 2018), but larger-scale investigation of the impact and sustainability of culturally responsive approaches is now needed. Moreover, cultural sensitivity needs to be a criterion in quality assessment of research outputs, as in the ↑Building Evidence in Education (2015) guidance.

2.2.2. Implementation with teacher support

Over time, there has been an historical focus on distributing hardware devices (for example, desktops and laptops, but now also, increasingly, mobile devices and tablets) — that is, on access to ICTs. Often, this has happened without clear educational purpose or associated teacher development focused on improving pedagogical skills (rather than purely on technological skills; see, for example, ↑Davis, Preston and Sahin, 2009; ↑de Melo, et al., 2014). This has been repeated to an extent during the Covid-19 pandemic; while the crisis has prompted some improvements to access, such as distributing hardware or negotiating zero-rating deals for educational content (↑Mashininga, 2020), this is the exception (↑eLearning Africa, 2020) and support for teachers in how to use technology for remote learning continues to be neglected. During the pandemic, teachers in LMICs are asked or required to communicate with learners but are not usually provided with any training for remote teaching (↑Vegas, 2020). A body of evidence suggests that interventions which focus upon hardware alone are ineffective compared with those coupled with other measures to promote pedagogic change or teacher development (↑Angrist, et al., 2020a; ↑Evans and Popova, 2015; ↑McEwan, 2015; ↑World Bank, 2020). Lack of appropriate, sustained support for teachers *before* classroom implementation is a major obstacle to effective technology use in the classroom (↑de Melo, et al., 2014; ↑Hennessy, et al., 2010). This also means equipping teachers and teacher colleges with digital technology before rollout to schools (↑Unwin, et al., 2020a).

2.2.3. Cost-effectiveness

Pivotal factors in the take-up of EdTech initiatives include quality, longevity, and appropriateness of the technology. These necessitate a fully informed cost–benefit analysis (↑World Bank, 2020; ↑Zhao, Lai and Frank, 2006). Understanding the supportive and constraining conditions for change is essential. However, practitioners on the ground also need to know whether learning gains are worth the additional cost, time, and effort (↑Joyce and Cartwright, 2019). Cost-effectiveness measurement is central to a replicable, comparable and rigorous research model, yet it is rarely considered as part of

EdTech research. Prominent initiatives like One Laptop Per Child were introduced without realistic cost–benefit analysis of the 1:1 learners-to-devices ratio; yet new 1:1 laptop schemes continue to be rolled out (for example, the DigiSchool programme in all Kenyan primary schools). New cost-effectiveness studies are beginning to provide better guidance within LMICs, however. Notable recent research includes ↑Angrist, et al. (2020a) on the use of SMS and phone-based support to caregivers in Botswana during the Covid-19 pandemic, and ↑Watson, et al. (2020) on educational television in Tanzania.

Whether calculations of cost-effectiveness for educational interventions are comparable or accurate can be contentious, as full donor or institutional costs may not be included. In addition, there may be hidden or indirect costs of implementation, such as the costs of maintenance, training, and communications. The 'Smart Buys' in education report (↑World Bank, 2020) identifies a number of cost-effective ways to improve learning in LMICs, including guidance on cost-effective implementation using a new metric, 'learning adjusted years of schooling' (LAYS) (↑Angrist, et al., 2020b).[10] However, the cost per child of an EdTech initiative may vary by country and context, and thus it may or may not be cost-effective for marginalised learners, particularly those who face overlapping and intersecting inequalities. Careful adaptations (which may well have additional costs) need to be properly sequenced or combined with other interventions (↑Ndaruhutse, 2020). It is thus important to recognise that the cost of reaching the most marginalised learners is often higher than the average unit cost.

2.2.4. Systemic factors

Technology has the potential to improve educational outcomes, not only for students and teachers, but also by improving the overall educational system. Understanding where and how to use EdTech in order to maximise its impact requires a view of education systems that is more nuanced than simply a sum of inputs and outcomes. To fully understand the factors that either facilitate or obstruct the take-up and effective use of EdTech, researchers need to attend to multiple (macro-, meso-, and micro-) levels of the educational system (such as politics, policy, governance and accountabilities, community, school, teacher, family, child), as proponents of an ecological framework have argued (↑Bronfenbrenner, 1979; ↑Hammond, 2019). However, to date, EdTech interventions in LMICs (and in HICs too) have often been fragmented and uncoordinated across stakeholders, which limits understanding of effectiveness and potential for greater scale and sustainability.

[10] LAYS is calculated by multiplying a country's average number of years of schooling by its average test score performance relative to a high-performance benchmark (↑World Bank, 2020, p.32).

Systems thinking provides powerful approaches for defining problems and solving them. It brings uncertainty to the forefront and contributes to drawing a complex picture in terms of understanding whether interventions are likely to succeed, including technology supply and resources, policy and planning, teachers and their skills, and mechanisms for management and research (↑DFID, 2018; ↑Omidyar Network, 2019; ↑Trucano, 2016). It challenges well-established linear planning and measurement approaches which favour the certainty of results and neat narratives or theories of change. A 'systems approach' is a way of considering a problem by identifying the critical elements and their interactions (↑Chen, 1975). However, it is the interconnection of these elements that achieves something, and once the relationship between the structure and behaviour of a system is seen, one can begin to understand how the system works (↑Meadows, 2008). The purpose of systems inquiry / systems approaches is to be able to understand complex phenomena and organisations in a manner that does not just examine specific parts or elements, but also interrelationships, with a view towards understanding the whole picture (↑Arnold & Wade, 2015; ↑Chen, 1975).

Even with a deep understanding of systems, there are multiple challenges in developing effective, sustainable, scalable interventions that lead to system-wide change in LMICs. These include systemic factors such as underfunding of education (↑UNESCO, 2015), political agendas, infrastructural readiness and constraints, external social structures, and political will ↑(Kingdon, et al., 2014). For EdTech Hub to achieve its goals at scale, robust evidence needs to be paired with understanding of the elements and linkages within the EdTech systems that we try to influence. Therefore, the Hub's research will aim to take a systems approach to explore the evidence across themes of learners, teachers and systems themselves, where relevant. Section 3.3 offers more information about the approach.

3. Thematic focus of EdTech Hub

The principal goal of the Hub is to improve evidence-based decision-making in using EdTech effectively to contribute towards addressing the global learning crisis and achieving SDG4.

As noted above, EdTech Hub has three pivotal themes:

1. Adapting to the needs of diverse **learners**, especially needs of girls, learners with disabilities, and out-of-school children.
2. Supporting and empowering **teachers**: improving TPD, retention, and attendance.
3. Strengthening education **system** governance, data management, and accountability.

Each of these themes is interconnected, and research studies will interweave them. In addition, each theme has a number of sub-themes (what we termed earlier as 'high-potential evidence gaps') and related research questions. These gaps will necessarily evolve over time, as the research base grows. The identified gaps may also be of interest to other researchers in the field, some of whom may work directly in collaboration with the Hub.

3.1. Adapting to the needs of diverse learners[11]

It has long been assumed that EdTech can have important benefits for learning, both in and out of schools (↑Wagner, 2018b; ↑Winthrop and Smith, 2012; ↑World Bank, 2016). But under what conditions will technology improve learning and educational quality? Might EdTech use actually increase the 'digital divide' with negative consequences for equity? What is the relevance of technology tools for improving educational assessments and management? These and related questions were relevant before Covid-19, and interest has only increased since the outbreak of the virus. In many countries, a natural response to the pandemic has been to replace in-person instructional time with virtual instruction (↑UNICEF, 2020a). However, a lack of access to the ICTs needed to learn remotely carries with it the potential to intensify the opportunity gap for under-resourced communities around the

[11] This section is an abridged version of a more extensive internal position paper on the theme of EdTech for learners (↑Damani, et al., 2020).

world, even within wealthy countries (↑Anderson and Perrin, 2018). This has been particularly evident during the Covid-19 pandemic, when the learning losses from school closures have been disproportionately felt by students with low socio-economic status (see, for example, ↑Engzell, et al., 2020; ↑Holmes and Burgess, 2020).

The long-term implications for the use of new ICTs can be profound. The prospect exists for technology to offer innovative tools that help meet the goals of improving education, reducing poverty, achieving gender equity — and reimagining education under the pandemic. Still, those same developments could create new disparities between and within rich and poor countries and communities. Diversity is perhaps the most challenging aspect of ensuring that EdTech can support marginalised learners. Technology can and should be *adaptable to specific needs*, yet this goal is sometimes in tension with *scalability*. For example, learners who speak a specific indigenous language may need resources that cannot be used by larger (official) language groups, thus rendering the unit cost higher. In this case, scaling up is inherently limited, along with increased unit costs. This natural dilemma between adaptation and scalability must be attended to with care and consideration, particularly if the overarching goal is to reach the most marginalised, school-age learners. Some high-potential evidence gaps associated with the learners' theme are listed in Box 1 with sample research questions. Each of these represents a discrete field of study in itself (with separate Hub evidence reviews already produced in many cases); we elaborate below on how further EdTech evidence may be particularly helpful in each case.

Box 1. *High-potential evidence gaps associated with the learners' theme.*

1. **Use of technology to help improve access to education and increase learning for girls:** How can technology be used most effectively to maximise learning outcomes for girls?
2. **Use of technology to support personalised learning:** How can technology be used to maximise the effectiveness of personalised learning and teaching targeted at the learner's level to increase outcomes for learners?
3. **Use of positive messaging to increase participation in school:** What are the most effective (impact on learning and cost) ways that technology can be used to share information on the benefits of schooling with local communities — to increase participation in school and reduce the number of out-of-school children?
4. **Use of technology for learning in appropriate languages:** How does the choice of language impact children's learning and teachers' instruction in multilingual contexts?
5. **Use of technology to improve the assessment of learning:** How can EdTech be used better to capture data that can be used for accurate assessment of learning outcomes as well as adapting and improving learning outcomes?

6. **Use of technology to help improve access to education and increase learning for children with special educational needs and disabilities (SEND):** What kinds of EdTech may be appropriate to support learning of children and young people with disabilities in low-resource contexts?
7. **Use of technology to help improve access to education and increased learning for refugees and forcibly displaced children:** How can technology be used most effectively to improve access to and quality of education for children on the move?
8. **Use of technology to improve access for and participation of out-of-school learners:** How can technology be used to provide positive messaging about education to reduce the number of learners who are out-of-school, and support their return to formal schooling?

3.1.1. Girls and EdTech

Unequal access to quality education is associated with gender, with girls living in poverty being least likely to attend school (↑UNESCO, 2020a), for a variety of reasons (↑Evans, et al., 2020). As has been widely reported, girls are more likely to marry at a young age, get pregnant, and assume domestic duties, along with suffering impacts of emergency school closures (such as in the Covid-19 pandemic) ↑(Plan International, 2015). Improving participation rates and educational outcomes for girls can have many positive impacts for both individuals and society ↑(Sperling, and Winthrop, 2016), so this is an area which has particular potential to advance the SDGs.

EdTech Hub recently conducted a rapid evidence review on the role that EdTech might play in improving girls' access to education (↑Webb, et al., 2020). When girls have access to EdTech, it can be more empowering for them than for boys ↑(West, and Chew, 2014), with benefits including but extending beyond girls' education (↑Khan and Ghadially, 2010). However, girls often have much less access to technology than boys, as a result of cultural biases and gendered assumptions about girls' competence and enjoyment of technology, as well as the benefits and risks associated with them using it (↑Meno, 2012; ↑Pereznieto, et al., 2017; ↑Zelezny-Green, 2011). Girls' access to technology is often mediated by parents / carers and teachers. Unless carers and teachers are involved in programme development and receive ongoing technology and gender-responsive training, the digital gender divide will likely remain, or even widen if there is increased use of technology (↑Meno, 2012; ↑Vilakati, 2014). There is scope for overcoming persistent gender barriers and infrastructural challenges to facilitate girls empowerment through technology use if a broader range of technologies — particularly smartphones — are used in education (↑Webb, et al., 2020).

3.1.2. Technology-supported personalised learning

One of the key potential benefits of using EdTech to improve access and equity in education is the capacity for technology to adapt and 'personalise' learning. 'Technology-supported personalised learning' can be defined as "the ways in which technology enables or supports learning based on particular characteristics of relevance or importance to learners", and has been the focus of a recent Hub literature review (↑Major and Francis, 2020, p.8). Examples include allowing different kinds of content to reflect learners' own preferences and cultural contexts and enabling the pace, mode, and location of learning to be adjusted in a way that empowers learners (see, for example, ↑FitzGerald, et al., 2018). 'Personalised learning' does not necessarily mean 'individualised learning'; for example, it can include collaborative learning or be used to support pedagogical practices around giving feedback and scaffolding learning.

A growing body of evidence from LMICs indicates that using technology to support personalised learning can enable instruction targeted by learning level within a heterogeneous class, including adaptive remedial instruction, and reducing the negative effects of high teacher–learner ratios (↑Kishore and Shah, 2019). A meta-analysis by ↑Major, et al. (forthcoming) shows that, overall, technology-supported personalised learning (using mainly computer-assisted learning) has a moderately positive effect on learning outcomes in literacy and mathematics (0.18 SD). In addition to acknowledging issues relating to cost-effectiveness and value for money (↑Bettinger, et al., 2020), any introduction of personalised learning technology should not be interpreted as decreasing the importance of the teacher (↑Buchel, et al., 2020). One important area noticeably absent from the evidence to date relates to the ethics of technology-supported personalised learning. For example, and as discussed in Section 3.3 on systems, collecting personalised data may impinge upon learners' privacy, and various types of learning assessments can also create bias with minority language populations.

3.1.3. Positive messaging through EdTech

Positive messaging has been shown to be a cost-effective way to improve educational outcomes. Messaging can include sharing information with communities about the benefits of school, and ways to receive support for sending children to school, such as funding. This type of approach has been shown to increase participation in school and reduce numbers of out-of-school children; this may be particularly useful in encouraging a return to schooling following the Covid-19 pandemic. Positive messaging was identified as the only 'great buy' in the World Bank 'Smart Buys' report (↑World

Bank, 2020). In terms of LAYS, positive messaging emerged as being cost-effective, particularly due to the efficacy of providing information about school returns in Madagascar (↑Angrist, et al., 2020b). The 'Smart Buys' report highlights that in order for positive messaging to be effective, messages need to be carefully tailored to the context; messages need to provide quality, reliable local information, via an accessible medium and from a trusted source, for example.

There is clearly potential for technology to be used as a means to implement positive messaging strategies at scale; for example, the 'Smart Buys' report cites examples of using video and apps, in Chile and Peru (↑Neilson, et al., 2015; ↑Neilson, 2019). However, there are open questions around how different types of technology could be used most effectively, in ways which are contextually appropriate. Depending on the local context, mobile phone-based messaging may be a useful focus for further research.

To date, due to the Covid-19 pandemic and school closures, the Hub's work in this area has focused upon how to support and encourage parents and caregivers to engage in education remotely. The potential for mobile phones to be used to 'nudge' parents and caregivers in engaging with educational activities with children was highlighted in the recent rapid evidence review on the use of messaging apps to support education in LMICs (↑Jordan and Mitchell, 2020). How to engage caregivers and communities when introducing EdTech interventions has been a key question across recent sandboxes (↑Rahman, 2020). As schools reopen for the longer term, this focus can be expanded to encourage return to formal schooling (↑Chuang, et al., 2020).

3.1.4. Language and EdTech

To reach the poor in any country, one must not only locate and target this population, but also determine needs as well as ways to communicate (↑UNESCO, 2009). Typically, this would put an emphasis on rural children (especially girls) who most often speak languages other than the official national language. Ample research on women and ethnolinguistic minority populations suggests that these are among the most marginalised poor across the globe (↑Hornberger and Corson, 2008; ↑Wagner, et al., 2018a).

From an EdTech perspective, the scientific challenge is to determine what kinds of approaches would be most effective in reaching and supporting these children. If they can barely read, as Early Grade Reading Assessment (EGRA) evidence suggests (↑Gove and Cvelich, 2011), then one would have to create content that allows interaction and learning with limited reading skills, and also utilises local languages (and literacy) in order to assure understanding of content that is within the skill competencies of learners (see,

for example, ↑Alidou, et al., 2006; ↑Abadzi, et al., 2005; ↑Glewwe, et al., 2009; ↑Wagner, et al., 2010).[12] Furthermore, one would have to pay close attention to the cultural context in which learners are motivated (or not) to participate in organised educational programmes.

It is now widely understood that within-country heterogeneity poses one of the most important challenges to learning and the quality of education. Language diversity may be inherent by cultural traditions, or (increasingly) can be affected by internal and external immigration patterns (↑Dryden-Peterson, 2016). Research strongly shows that children's ability to access (orally or in writing) learning materials in their mother tongue has a major impact on learning outcomes. This is especially the case in marginalised populations, who are less likely to have mastered second or third languages supported by national education ministries. Thus, choosing the 'right' language(s) when delivering instruction in class or via distance learning is central to instructional effectiveness, whether formally in schools or in non-formal and informal settings. Research evidence shows that children whose families speak languages different from the official language of instruction at home most often perform at the bottom of the pyramid in terms of school achievement (↑Wagner, et al., 2018a).

Clearly, language issues will be a central focus of research in the search for EdTech solutions for the 40% of children who are taught in a language they do not (or poorly) understand (↑UNESCO, 2016). Finally, we need to keep in mind that issues of language and multilingualism are constantly in flux, particularly as national education curricula change, and consider these factors in EdTech interventions (↑Wu, et al., in press).

3.1.5. Assessments of learning

The use of learning assessments has clearly become a driver for those who monitor and invest in education, including in EdTech. For example, national learning assessment has more than doubled over the past two decades (↑Benavot and Tanner, 2007),[13] and the participation of LICs in international assessments has also risen dramatically (↑Lockheed, 2010). This rise in the use of assessments, and educational systems that depend on them, creates both opportunities and challenges for the use of EdTech in LICs (↑Kamens and McNeely, 2009; ↑Meyer and Benavot, 2013). The opportunities exist to make

[12] Naturally, very user-friendly interfaces (see, for example, ↑Kam, 2013; ↑Medhi, et al., 2007) can be very helpful. But those who would simply promote mainly device-centric solutions, such as in the OLPC programme (see critique in ↑Cristia, et al., 2012), will likely come up short.
[13] This domain has become its own small industry, as exemplified by the Educational Testing Service (ETS), OECD / PISA assessments, the International Association for the Evaluation of Educational Achievement (IEA), and others.

better, evidence-based judgments within and across countries (↑Chromy, 2002; ↑Greaney and Kellaghan, 2008). The challenges can also be substantial since all assessments include real costs in time and resources, while the tools deployed and the interpretations of results can be controversial.[14]

In the domain of EdTech, major evidence gaps exist around the best ways to assess interventions on learning outcomes in and out of school. There are two broad assessment regimes that have typically been deployed, both in education generally speaking and in EdTech specifically. First, and traditionally most common, are the use by international and national agencies to measure the impact of technology on either school grades or performance on achievement tests (↑OECD, 2015; ↑Piper, et al., 2017). At the other end of the spectrum are small, sample-based assessments that have been termed "smaller, quicker, cheaper" (SQC; ↑Wagner, 2011) — such as the EGRA and citizen-led assessments (↑ACER Centre for Global Education Monitoring, 2015)[15] — which are increasingly being employed. Such assessments can take advantage of their modest size by more deeply exploring the multiple (and often context-dependent) factors that affect learning outcomes, such as language of instruction, language of assessment, and opportunity to learn (↑Castillo and Wagner, 2019; ↑Wagner, et al., 2010). This latter approach is particularly helpful in sandboxes and quasi-experimental studies, where the sample populations can be focused on those learners who are most marginalised — those who are *learning at the bottom of the pyramid*.[16] Whether one uses large-scale or SQC assessments, ICTs (especially mobile devices) can assume data gathering in real time, and shorten time for analysis (↑Piper, et al., 2018a).

3.1.6. Learners with disabilities and EdTech

Children and young people with SEND are among the most marginalised and excluded groups of children, particularly in LMICs, and are less likely to attend school (↑UNICEF and WHO, 2015). Use of EdTech has the potential to unlock both access and quality education for children with disabilities (↑Kuper, et al., 2018). The Hub is currently conducting a systematic review of the evidence on how educational and assistive technologies are being used to support the education of children with disabilities in different school settings in LMICs

[14] Broadly speaking, the costs include: (1) opportunity costs (what could be accomplished if a particular assessment was not done); (2) human resources (including training of highly skilled staff); and (3) actual budget costs ("total cost of assessments"); see ↑Wagner (2018a).
[15] In this technical review of these assessments, the authors found them to be generally reliable and valid for their purpose of providing a snapshot of reading and maths levels based on individualised assessments, mainly in local languages.
[16] The 'learning at the bottom of the pyramid' approach would also make room for considerations such as the language of assessment, even if not yet formally adopted by national assessments. (↑Wagner, et al., 2018).

(↑Lynch, et al., 2020). The literature surveyed concerns at least 25 types of disability, including categories of visual, hearing, and intellectual impairments. Additional complexities arise from the diversity of learner settings where technology is being trialled, which may range from mainstream schools and special education schools to resource centres. The process of synthesising data across different classifications of learner samples is challenging as age tends not to be a suitable proxy. There are also issues surrounding the quality of the evaluations included in the review, including small sample sizes, short duration of studies and lack of rigorous empirical data.

The limited provision of assistive technologies for learners with moderate to severe SEND needs to be further understood within the context of LMICs (↑Rohwerder, 2018). LMIC education systems are often forced to make difficult decisions between the priorities of SEND learners and others who are marginalised based on their context. The Hub's review highlights some of the technological innovations being trialled in LMICs that are providing a helpful testbed for potential replication and scale-up. It also identifies how the potential affordances of EdTech leveraged for all learners can address how children with disabilities can be included and educated with their non-disabled peers. It indicates that the degree of emphasis on disability issues within policy responses to the Covid-19 crisis has been mixed at country level. The findings have messages for policymakers and educators including the need to maximise match of technology with person, identify culturally appropriate resources, and integrate the voices of learners with disabilities and caregiver / family support into the learning process. E-learning modules could build the skills of teachers and other key specialists working in inclusive and special education, helping to reduce the levels of marginalisation and exclusion from learning.

3.1.7. EdTech in refugee education

A consequence of mega-trends such as globalisation, climate change, civil strife, and pandemics such as Covid-19 is human migration — leading to a greatly expanded number of refugees in many parts of the world, and millions of children out of school and / or in remote learning settings. In the period from 1990 to 2010, the number of international migrants increased by nearly 60 million people worldwide, with over 200 million people living outside their country of origin by 2010.[17] The rate of internal migration, or movement of people within countries, is about the same as the external international migration rate, with both showing significant increases in LMICs over recent

[17] Department of Economic and Social Affairs, United Nations, official statistics.

decades (↑International Organisation for Migration, 2010; ↑Skeldon, 2012; ↑UNDP, 2009). The broad trends of migration are massive and growing.

Technology can be used to help improve access to education and increased learning for the growing numbers of refugees, migrants, and forcibly displaced children on the move. EdTech, particularly in forms mediated by mobile devices, is well-positioned to be used to help in this fast-changing domain (↑Koomar, et al., 2020; ↑Wagner, 2017; ↑Yarrow and Capek, 2019). Refugees often face compound crises in their lives and education (education in emergencies is a related field; see ↑Ashlee, et al. 2020b). They can use technology to access information about continued educational opportunities when displacement, disruption or crisis has closed a preferred education pathway.

As part of the Covid-19 response, the Hub recently undertook a rapid evidence review focused on existing research literature in relation to EdTech and refugee contexts (↑Ashlee, et al., 2020a), identifying four major imperatives:

1. Continuity of access to education;
2. Diverse and adaptive ways of teaching;
3. Supporting educators of refugee children;
4. Psychosocial support.

The above themes highlight that there is a potential for EdTech to be used to support education among refugees and displaced persons — including learners and teachers — in a wide range of ways. Given the diversity of populations, languages, and contexts, more research is needed to expand the limited evidence base and understand how it can be used most effectively (↑Joynes and James, 2018).

3.1.8. Out-of-school children and EdTech

The Covid-19 pandemic has also greatly amplified the number of out-of-school children. As such, out-of-school learners are an increasingly important marginalised group that has been the subject of much of our work in the past year in the context of Covid-19[18]. However, significant numbers of learners are out of school regardless of the pandemic, for a number of reasons. The long-term 'hard to reach' children, who cannot access schooling (with or without the pandemic), remain a critical focus of the Hub, as they are among the most marginalised groups of learners. In response to the Covid-19 crisis, the Hub has conducted a series of rapid evidence reviews focusing on the use

[18] https://edtechhub.org/edtech-and-covid-10-things-to-know/

of radio (↑Damani and Mitchell, 2020), television (↑Watson and McIntyre, 2020), messaging apps and social media in education (↑Jordan and Mitchell, 2020), refugee education (↑Ashlee, et al., 2020a), education in emergencies (↑Ashlee, et al., 2020b), and accelerated learning (↑Damani, 2020).

The reviews have raised a number of further issues that new EdTech initiatives will need to tackle. The flexibility of low-tech EdTech modalities builds in much-needed resilience for education systems in LMICs, which can address disruptions to schooling during the Covid-19 pandemic, as well as more general educational provision for marginalised populations. This is particularly the case with out-of-school children who face marginalisation because of regular disruptions to their schooling, for familial, environmental, or cultural reasons. However, large variations in household access to radio and TV between countries, and between rural and urban areas, indicate that equity issues continue to surface (↑Dreesen, et al., 2020).

Even so, there is hope that education systems worldwide will be able to build back better on the basis of experiences during the pandemic (↑Save Our Future, 2020; ↑Giannini, 2020; ↑Vu and Savonitto, 2020). While broadcast media have been one key means of reaching out-of-school children in emergency remote education responses prompted by Covid-19, there is more to be done to explore the potential for using other types of technology too, such as mobile devices. It is crucial that lessons learned during the current pandemic are now directed towards addressing the ongoing challenge of how to reach the long-term out-of-school learners. Furthermore, the reopening of schools and learners' return to stable in-person education will be a critical period in the pandemic — as it is likely that many marginalised learners will not return.

3.2. Supporting teachers[19]

The goal of the Hub's second theme is to conduct research into use of technology to improve teacher development, and vice versa. Within the teachers' theme, we focus quite broadly on how technology use might potentially support — and be supported by — initial teacher education and in-service professional development. Increasing use of technology in education systems brings additional needs for teacher development. By considering professional learning both through and for EdTech use, this theme contributes to the Hub's ultimate aim of improving teaching quality and outcomes for learners.

[19] This section is an abridged version of a more extensive internal position paper on the theme of using EdTech to support teacher education and professional development (↑Hennessy, et al., 2020).

There is a body of existing research that has identified core facets of TPD associated with a range of positive outcomes of teacher development programmes in a variety of settings — from high-income to low-income (↑Darling-Hammond, et al., 2017; ↑ Hennessy, et al., 2016; ↑McAleavy, et al., 2018). Research into these contemporary models converges on the consensus view that the most successful approaches are designed to support local evolution, and with specific links to participants' own objectives and professional practices with technology (e.g., ↑Power, et al., 2019), again highlighting the need for local contextualisation (2.2.1). A few studies indicate that a needs-driven approach can be successful in designing effective technology-mediated TPD and in improving teachers' capacity to teach interactively with classroom technology in low-income countries such as Zambia (↑Hennessy, et al., 2016). The Hub will investigate the degree to which the contemporary models apply more widely in technology-related TPD initiatives in LMICs. We are currently undertaking a systematic review of the existing literature in relation to TPD and EdTech in LMICs. The review and this section of the paper are organised around the three main modes in which EdTech is known to be used in relation to teacher learning: EdTech as a means of delivering initial teacher education or professional development (3.2.1), professional learning about EdTech applications that support teachers' planning and assessment (3.2.2), and professional learning about learners' use of EdTech applications (3.2.3). The final section addresses sustainability and scalability (3.2.4). The discussion below touches on some of the main sub-themes and evidence gaps emerging from the review that will shape our research in this area; an overview appears in Box 2. These cut across the three main modes of use.

Box 2. *High-potential evidence gaps associated with the teachers' theme.*

1. **Technology modalities and blended approaches to teacher development:** How can modalities of technology use be optimally combined to form the basis for effective, sustainable teacher development at scale?
2. **Teacher agency and needs — accounting for contextual variation in tech-supported TPD:** How can teachers be encouraged to be creative in the classroom while also following effective pedagogical approaches?
3. **Using technology to support teachers to implement personalised learning:** Where personalised learning software is available, what role do teachers play and how can TPD support them?
4. **Using technology in teaching that adapts to marginalised learners' needs:** How can technology be used to help teachers adapt their teaching practices to address the needs of key groups of marginalised learners?

5. **Using technology to develop and support facilitators and coaches:** How can technology facilitate a more experienced peer or expert in providing support for teacher development?
6. **Using technology to support non-formal educators:** How can technology support non-formal educators through the use of structured lesson plans or text message-based nudges to help build capacity at home and in school?
7. **Supporting teachers' technology adoption:** How can processes and learning habits be embedded for teachers needing to frequently adopt — and adapt to — new technologies?

3.2.1. EdTech for teacher development

This area refers to the use of EdTech to improve teacher education and professional development processes. This is a wide-ranging category and accounted for over half of the studies in our ongoing review. The potential for open educational resources (OER) to be used to create customised, contextualised programmes has led to success in programmes in sub-Saharan Africa, such as OER4Schools (↑Hennessy, et al., 2016) and Teacher Education in Sub-Saharan Africa (TESSA)[20] (↑Wolfenden, et al., 2017). Video technology can be a useful tool for teachers to record and view lessons as part of reflective inquiry. Its use supports feedback and evaluation of practices amongst peers, a common and critically important feature of effective pre- and in-service programmes; nevertheless, evidence from LMICs is as yet inconclusive (↑Major and Watson, 2017). SMS and online forums are commonly used as a means of maintaining regular communication lines among teachers, for purposes such as sharing relevant educational materials and insights from classroom practice, as well as general social interactions. This type of communication is vital for creating remote communities of practice and active participation and engagement in initiatives. Technologies which feature less prominently include use of more costly hardware such as smartphones or tablets, but also low-tech broadcast media such as educational radio and television. However, further research is emerging following school closures due to Covid-19. For example, during the crisis, the Rising on Air programme (↑Lamba and Reimers, 2020) trialled interactive radio-based teacher development in 25 countries and promoted core pedagogical skills such as questioning and feedback in the process. The success of the programme is as yet unknown.

Studies on EdTech for teacher development tend to reflect the broader shift away from TPD models that aim to instil 'best practices' or fill 'gaps' in pedagogical knowledge, towards empowering teachers to be critical, reflective practitioners (see, for example, ↑Darling-Hammond, et al., 2017; ↑Schweisfurth,

[20] TESSA is a network of teachers and teacher educators across Sub-Saharan Africa, supported by a bank of curriculum-linked OER. See http://tessafrica.net for more information.

2015). Teachers are a diverse group, with varying levels of confidence and skill in terms of technology use and pedagogical and content knowledge. Some may require more support and resources than others and structured pedagogy is one approach. For example, the Primary Math and Reading (PRIMR) project in Kenya found that providing structured teacher guides with partially scripted lessons dramatically increased cost-effectiveness of professional development in relation to learner achievement gains (↑Piper, et al., 2018a). However, overly scripted guides were less effective than simplified ones, and teachers did not adhere to the scripts, often reducing group work and interactive aspects of the lesson (↑Piper, et al., 2018b). It is rare for technology-mediated TPD programme designers to assesses the learning needs of teachers, but there are some exceptions; one study in rural Kenya found that teaching practices could be developed through working with local TPD experts to create locally-relevant content, implemented in a blended learning approach based on reflective practice (↑Onguko, 2012). Educators in non-formal settings may benefit more from structured lesson plans or text message-based nudges to help build their content and pedagogical knowledge, however. A key question for the Hub's work is: what are the appropriate levels of support and structure needed for teachers in particular settings (and with particular characteristics) in LMICs? The wide range of practitioners, approaches, and types of technology leads us to explore how best to strike a balance between structured support and teacher agency, and cost-effectiveness and effectiveness in practice, and how to ensure that interventions are adaptable and appropriate for the context.

3.2.2. EdTech for teaching

This area refers to developing teachers' use of EdTech to support their planning, classroom-level assessment, and evaluation related to classroom teaching and learning. Using technology to develop lesson planning is a prime example. For example, mobile phones can support teaching through communication during lesson planning, by relating subject knowledge to authentic locations and activities during teaching and with image and data capture to support assessment and post-lesson reflection (↑Ekanayake and Wishart, 2014). Teachers frequently use internet sources and social media or online forums to develop lesson structure, content, and activities. Communities of practice (such as the Teachers' Research Exchange, for example) can form part of TPD initiatives. However, these communities have been examined primarily in relation to higher education practice and research, with a gap concerning teacher development initiatives at lower levels. There is again an unexplored tension between scaffolding to improve teaching quality and constraining adaptability when using scripted lessons.

3.2.3. Teacher support for EdTech use by learners

How can improved TPD support learners' use of EdTech (an app, for instance) in classrooms? This question is relatively under-researched and warrants further investigation. This may include, for example, exploring the extent to which TPD initiatives incorporate opportunities for experimentation and rehearsal with new technology (↑McAleavy, et al., 2018) so as to develop skills and confidence in using it with learners in classrooms (as in the OER4Schools workshops: ↑Hennessy, et al., 2016), and if this is not feasible, how it is mitigated (for example, through use of exemplar videos). Critical examination during TPD of issues and policies around child protection, data and privacy rights, and cultural sensitivity for using technology in the classroom is also required. Finally, it is striking that very little of the research on EdTech use in teacher development in LMICs supports adaptation to either learning levels (personalised learning) or marginalised learners' needs.

3.2.4. Sustainability and scalability of TPD programmes and outcomes

A particular challenge that is of clear relevance to one of the Hub's cross-cutting emphases is the sustainability and scalability of TPD programmes and meaningful measurement of their outcomes. The impacts often rely on teachers' self-reported perceptions of skill development and changes to practice, which may compromise the validity of the data. Examination results may be used to measure learner outcomes, although they only capture one type of benefit of programmes. Changes to teachers' practices and benefits to learning for learners may develop over the long term; however, projects are often short-term and capturing this type of impact is rarely designed into initiatives (↑Schwille and Dembelé, 2007). It is therefore vital to design for sustainability from the outset, particularly as the evidence base suggests that improved pedagogy arises from ongoing learning and development opportunities (see, for example, ↑Darling-Hammond, et al., 2017; ↑Schweisfurth, 2015).

A notable example of tech-supported TPD, which has shown considerable promise but may only lead to short-term benefits, is virtual coaching (↑Evans, 2020). Meta-analysis of 60 studies of coaching found that it led to similar significant positive effects on teaching practices and learner achievement as in-person coaching, and at lower cost (↑Kraft, et al., 2018). However, only a few studies reported outcomes following up one year or more after coaching had ended, and results were mixed. One follow-up study after three years showed that students of teachers with virtual coaching retained gains in their English listening comprehension, but the gains associated with in-person coaching

were about 2.5 times as high (↑Cilliers, et al., 2020). Moreover, home language literacy of the virtual coaching group was crowded out and actually declined. On-site coaching ultimately proved more cost-effective. Finally, research on using technology to develop and support coaches and facilitators of TPD is very sparse.

3.3. Strengthening education systems[21]

The use of technology may be conceived at the systems level as a potential tool for teaching and learning, as well as improving educational institutions, policies, and processes that support these activities. Systems approaches have been applied to the educational context for the purposes of education planning and management (↑Kraft & Latta, 1972), educational testing (↑Frederiksen & Collins, 1989), conflict management for students (↑Oyebade, 2001), and science and technology education (↑Chen & Stroup, 1993), and may be applied to numerous problems at varying levels of scale — from the individual user to ministries of education. Education systems can be defined as complex, soft, open, and adaptive (↑Abdul-Hamid, et al., 2017, p.1; ↑Banathy & Jenlink, 2003; ↑Karim, 2010). The ↑Omidyar Network (2019) identifies four critical factors within an educational ecosystem for successful EdTech interventions to thrive: EdTech supply and business models, enabling infrastructure, education policy and strategy, and human capacity. A systems approach is therefore essential for understanding what may be required in a particular context for EdTech initiatives to contribute to better learning and related outcomes (↑Kozma, 2005) given that these factors are all interconnected.

Approaching educational challenges at the systems level is especially critical in order to enhance the likelihood of EdTech interventions making lasting, effective, and positive change; as such, a systems approach is embedded in the very design of our programme. Changing or influencing a system involves attacking several problems concurrently and simultaneously through experimentation and testing and acceptance of uncertainty in terms of the outcomes (↑Stroh, 2015). This poses considerable challenges in early efforts to describe and apply linear planning and measurement approaches established over decades by development which favours certainty of results and neat narratives or theories of change (↑Green, 2016).

However, there has so far been only limited application of systems approaches to EdTech. Extrapolating from the systems thinking approach to education, we propose to apply a systems lens to understand the role of EdTech in improving outcomes in LMICs. However, some fundamental questions need to

[21] This section is drawn from discussion and work being developed as part of a forthcoming EdTech systems position paper (↑Nicolai, et al., forthcoming).

be addressed first: What problems within EdTech are best solved using a systems approach? How do we define the bounds of the EdTech system? Which systems theories should be applied to EdTech? And what systems research methods should we use for understanding EdTech systems?

In parallel to an examination and application of these frames, approaches such as political economy analysis will be used to understand the benefits and constraints from a systems perspective (↑Menocal, et al., 2018; ↑Pellini, et al., 2021). Analysis to date has the following systems-related high-potential evidence gaps emerging as set out in Box 3. Elaboration on focus for four of these gap areas is further detailed below by way of illustration, with several of these not detailed here due to a limited evidence base.

Box 3. *High-potential evidence gaps associated with the systems theme.*

1. **Use of technology for educational data:** In what ways can EdTech expand the availability, analysis, and use of accurate educational data, for both existing administrative datasets — such as Education Management Information Systems (EMIS) and learning assessments — and new datasets (including big data and real-time data)?
2. **Use of technology in support of mutual accountability between schools and parents:** In what ways can EdTech strengthen mutual accountability between schools and parents / carers, ensuring that existing data is being effectively analysed, publicised, and used, and enhancing communication to support learners?
3. **Use of technology for child protection, safeguarding and privacy in education:** What are the potential privacy and child protection risks of EdTech and what legal, technological, and social safeguards are necessary?
4. **Use of technology for learning futures, i.e. 21st-century skills and school–work transition:** Are current education policies and systems fit for purpose to support and guide schools in providing the skills and competencies today's learners need in the 21st century?
5. **Use of technology in policy planning and systems strengthening:** How can taking a systems approach to education inform understanding of where and how best to invest in EdTech for education system diagnosis and strengthening?
6. **Use of technology in teacher management and progression:** How can technology facilitate teacher incentives to improve their teaching?

3.3.1. Data availability, usability, and uptake

To make informed decisions stakeholders in an education system require timely and accurate information, and the means to interpret it. "Information and data play an essential role in the broad education system because of their ability to enable connectivity and linkages among subcomponents, to guide processes, and to ensure an adaptive environment by informing stakeholders

at all levels about the effectiveness of both the overarching system and their individual subcomponents" (↑Abdul-Hamid, et al., 2017, p.5). There is emerging evidence that the expansion of data systems may be one of the key contributions of EdTech in LMICs (↑Haßler, et al., 2020b). However, two key challenges exist: the first is the availability of data, its usability and uptake / demand (↑Crouch, 2019), and a second is minimising the potential harm that data can cause (which links closely with Section 3.3.3).

Across and within education systems, there is a significant lack of data that can be used to understand and address who is learning and who is not (↑World Bank, 2017). Lack of data and poor use of data can lead to decreased accountability for poor performance. For example, teacher absenteeism can go unnoticed or unaddressed in the absence of data. In Sindh, Pakistan 97% of the 2016 education budget was spent on salaries despite an estimated 40% of teachers being absent (↑Naviwala, 2016). Without metrics of how well students are learning, teachers, in turn, are unable to target support at those falling behind (↑World Bank, 2017). A lack of data also makes it more challenging to both achieve and monitor progress towards universal educational goals (↑UNESCO Institute for Statistics, 2020).

Often it is observed that there is insufficient staffing and funding of data collection and monitoring units within government ministries (↑Crouch, 2019). Lack of capacity for data analysis, inscrutable data presentation, deliberate neglect and the fact that information does not meet the needs of relevant stakeholders leads to underutilisation of data (↑World Bank, 2017). A lack of open technology standards to facilitate interoperability of datasets (↑Pathways for Prosperity Commission, 2019) leads to data underutilisation. Very often, the kind of data that is available does not inform the problem at hand (↑Haßler, et al., 2020b) and stakeholders do not demand access to information (↑Verhulst & Young, 2017).

Therefore, affordable software and hardware innovation in EMIS (↑Crouch, 2019) is needed. Innovation in turn requires private players to collaborate with public systems and incentive systems that encourage open data sharing, accessibility, and interoperability (↑Global Partnership for Education, 2018). Further, there is a need to establish global standards for the collection and use of data (↑Global Partnership for Sustainable Development Data, 2019; ↑UNICEF, 2020b) and to increase awareness amongst stakeholders for the demand for accountability via data (↑Afrobarometer, 2016; ↑Verhulst & Young, 2017).

In addition to the problem of data availability and usage, data management and user safety are also concurrent concerns. The use of technology in education has accelerated in the Covid-19 pandemic. This technology

explosion has been accompanied by large volumes of data being collected by various EdTech players, leading to the question of whether there are adequate measures for the protection of this data (↑Polonetsky & Jerome, 2014). While on the one hand, student data are crucial for improving teaching and learning, the potential for this data to be misused has also increased. Children are 'disproportionately affected' by the threats of the digital world such as sexual abuse, bullying and harassment (↑Unwin, et al., 2020b), and exposure to third party advertising (↑Barrett, 2020). Misuse of data may place children from marginalised groups at the risk of further marginalisation (↑Barrett, 2020). In nations with governments with poor human rights records, some technologies can lead to increased surveillance and a heightened risk of discrimination and persecution (↑Galligan, 2019). In recent times, where teacher accountability is often managed via technology, data could create a culture of over-surveillance and lead to a devaluation of teachers' sense of self-worth and professional pride (↑Naviwala, 2016).

3.3.2. Use of technology in support of mutual accountability between schools and parents / carers

EdTech can be used to provide greater accountability for monitoring improvements in education and strengthening school–parent connections and communication. For example, during Covid-19 a growing number of parents and carers used text messages, social media, and WhatsApp to access educational resources, leading them to become more involved in their children's education (↑Jordan and Mitchell, 2020). Using technology to gather educational data and strengthen communication is seen as a potential 'lever of change' as it can be used to support parents and carers in monitoring education quality, identifying problems, and demanding improvements. This is particularly important for marginalised communities where there is a power imbalance between education authorities, communities, and parents and carers, as data and regular communication could enable them to gain understanding and participate in improving education systems.

While an increasing number of parents and carers had to rely on technology to communicate with teachers during Covid-19, effective practices are still to be defined. There is emerging evidence illustrating the potential of low-cost technology to deliver existing data to parents and carers to improve outcomes for learners (↑Berlinski, et al., 2016). Positive results were also found when strategies using data for mutual accountability are aligned with formal mechanisms through the development of partnerships with local authorities and governments (↑Grandvoinnet, et al., 2015), and when local priorities are included into such strategies (↑Carr-Hill, 2013). While members of the People's Access for Learning Network have made further strides in this area, there is

limited rigorous evidence on how data could be used for mutual accountability, especially when it comes to using it to improve learning outcomes. Data for mutual accountability between parents / carers, schools, and communities tends to focus on monitoring infrastructure development, staff attendance, and budgeting (↑Global Education Monitoring Report, 2017). Using data and technology to monitor learning outcomes, review teachers' performance, and develop school improvement plans is more complex as it requires the involvement and coordination of multiple stakeholders as well as the implementation of pedagogical approaches to evaluate learning outcomes.

3.3.3. Use of technology for child protection, safeguarding, and privacy

As well as providing benefits, technology can cause children harm in a number of ways. As seen in the Covid-19 pandemic, children are 'disproportionately affected' by the threats of the digital world such as sexual abuse, bullying, and harassment (↑Unwin, et al., 2020b). From an education systems perspective, data collection needs to be matched by efforts to ensure data protection, cybersecurity, and privacy — all top technology policy priorities in LMICs (↑Phillips, et al., 2020; ↑Damani and Mitchell, 2020). There are also human rights concerns surrounding the misuse of increasingly powerful technologies in schools, especially by governments with poor human rights records (↑Galligan, 2019). Similarly, there are potential privacy implications of education being delivered through commercial companies with data-mining business models (↑Privacy International, 2020). Finally, there is a need to remain aware of the adverse effects of increasingly powerful data collection tools on educational governance and pedagogy (↑Selwyn, 2015).

In light of these challenges, there is a need for evidence on approaches to ensure that EdTech does no harm across the education system. At the international level, there is a need for evidence to improve international standards of privacy and child protection in EdTech and beyond (↑Raftree and Byrne, 2020). Nationally, there is a need to consider ways in which governments can incorporate and then enforce privacy and data protection in EdTech policies and laws. There is also a need for evidence on how EdTech impacts human rights (↑Groeneveld and Taddese, 2020). In the design space, there is a need to evaluate privacy-by-design and the technical implementation of privacy systems within technologies. Finally, at the school level, support and evidence are needed on how best to train the education workforce to ensure EdTech and children's data are used in ways that keep children safe.

3.3.4. Use of technology in teacher management and progression

In many LMICs, education systems are characterised by both lack of and very unequal distribution of teachers. In several regions, the proportion of qualified teachers has stagnated, while in sub-Saharan Africa, the percentage of qualified secondary school teachers has declined in recent years (↑Vegas, 2020). In the Gambia and Philippines, studies have documented how data systems have helped to distribute teachers more effectively to where they are most needed (↑Patrinos and Kagia, 2007). However, existing data systems often fail to provide the adequate disaggregation needed by decision makers to effectively incentivise teachers through targeted approaches. In Malawi, for example, the binary distinction of schools being either 'urban' or 'rural' has failed to take into account the additional hardships teachers working in remote rural schools face (↑Asim, et al., 2017).

Technology can be leveraged to better enable government officials to manage the assignment of new teachers and transfer of existing ones to where they are most needed based on real-time information. It can also help monitor where unauthorised transfers are occurring in the system. Using geospatial data, for instance, was found to be an effective way of more accurately distributing teachers in Indonesia (↑Nirwana, et al., 2019). In Malawi, geospatial data helped determine the characteristics of the school and its surrounding area to help the government consider how to target more accurately the amount of hardship allowance a teacher should receive (↑Asim, et al., 2017)

The physical inspection and supervision of schools is also a challenge in resource-poor education systems. This is especially the case with remote rural schools, which are often a considerable distance from where government officials are situated, and costly to get to. A consequence of this is that teacher absence is often more of a widespread problem in remote rural areas in many LMICs (↑Nirwana, et al., 2019). Technology has been utilised to address high rates of teacher absenteeism. In India and Indonesia, cameras were used to monitor teachers' attendance at the school at the start and end of each day. Coupled with this digital supervision was the linking of teachers' salaries being directly linked to school attendance. Not only did teacher attendance improve, but children's achievement levels also increased as a result (↑Duflo and Hanna, 2005,↑Duflo, et al., 2012).

Technology appears to offer considerable potential to advance equity in the allocation of teachers, support pay incentives, and help to address teacher absences. This suggests that the use of EdTech may offer further gains in the years ahead, and more effectively operationalise performance data obtained from EMIS, for example.

4. Operational framework for EdTech Hub

While EdTech can potentially be used to improve educational outcomes and address the global challenges discussed above, the complexity of the challenges calls for a range of approaches across educational systems and stages of research and implementation. We see research, innovation, and engagement activities as interdependent and reliant on a portfolio of mutually-reinforcing approaches that we believe will drive the production and uptake of evidence about how technology can support learning.

This section introduces the main approaches[22] that EdTech Hub will employ in combination to support and improve the whole ecosystem, from individual research studies to educational systems within LMICs and beyond. The range of approaches being used to generate evidence is shown here:

In Section 4.1, the seven approaches depicted are discussed and elaborated on. Section 4.2 then sets out some of the principles which underpin our ways

[22] The Hub strategy in response to the Covid-19 crisis has focused particularly on five elements, including: convening networks; curating resources; generating new evidence; providing direct country support; and creating guidance for policymakers (↑The EdTech Hub, 2020).

of working across all activities of the Hub — including commitment to open access and publishing and taking a multi-stakeholder approach, in particular responding to needs of policymakers.

4.1. Seven approaches for building evidence

4.1.1. Commissioned at-scale research studies

EdTech Hub will actively support rigorous EdTech research through external commissions involving teams of experienced researchers working in-country at scale. Such large-scale commissioned studies are expected to be undertaken on interventions operating at national scale or across several regions within a country. They may build on design-based research, sandboxes (4.1.4), or other small-scale studies in the same or similar contexts. Through large commissioned research studies, the most promising interventions will be trialled over time across an education system, and rigorously evaluated to provide robust evidence of impact.

4.1.2. Hub-led collaborative in-country research studies

The Hub's senior researchers are also expected to lead medium-sized studies in partnership with in-country researchers to investigate innovation in contexts that have a particular focus on marginalised learners. These build on what the Hub is learning from internal and external evidence reviews but will focus on local contextualisation and participation. The research designs will vary according to the priorities of each specific study and will generally employ mixed methods. Such designs may include quasi-experimental and design-based research (DBR) studies (↑Anderson and Shattuck, 2012) in the mix. DBR provides the opportunity to quickly identify and work alongside promising programmes, working rapidly and collaboratively with in-country researchers and other stakeholders in iterative cycles of design, evaluation, and re-design. DBR studies build theory and generate design principles as well as impacting on practice. They may be stand-alone or feed into large-scale and longitudinal studies. They may be conducted in several settings within a country.

4.1.3. Hub-led desk-based studies

EdTech Hub builds upon existing research through both rapid evidence reviews and large-scale systematic reviews of the field, including peer-reviewed and grey literature. These help us identify the high-potential evidence gaps that the primary research will address. A critical approach is taken to assess the evidence, understand both what has been effective in

particular contexts and why, and acknowledge unintended consequences and instances where interventions did not perform as expected. Particular attention is paid to quality assessment of research outputs, in line with the issues raised earlier, including conceptual framing (see 2.1), contextual detail, and cultural sensitivity (see 2.2.1) as criteria, as in the ↑Building Evidence in Education (2015) guidance and the Mixed Methods Appraisal Tool (↑Hong, et al., 2018) that form the foundation of the Hub's own framework. Synthesis of existing research evidence helps to address the fragmentation of individual research projects, forming both a strong foundation for the work of the Hub, and useful resources for others in the field.

4.1.4. Sandboxes

EdTech Hub's sandbox approach aims to identify — and ultimately accelerate the scaling of — the most promising interventions using technology, and to show others how to do the same. This approach involves a systemic, catalytic, and exponential strategy that uses innovative approaches to identify opportunities, generate evidence, and support implementation. Techniques such as open innovation calls, collective intelligence, and horizon scanning are used in this process. Sandboxes will combine lean startup methodology (↑Chang, 2019),[23] user-centred design, agile methodology (↑Kaiser, 2019), and behavioural innovation (↑Simpson, 2019) to support implementation in ways that are equitable and appropriate for the context, and that build on existing evidence from the sector, such as the Universal Design Principles for Learning. Investing in and working with EdTech in the real world is difficult, uncertain work. Part of the Hub's role involves matchmaking between EdTech interventions and users who have identified a specific challenge or opportunity. Sandboxes also involve rapid testing and iteration of EdTech initiatives led by stakeholders in local settings that allows for learning and adaptation in real time before and while developing promising ideas that might be taken to scale. Then, evidence gathered across sandboxes is captured and codified.

The Hub's first portfolio of sandboxes focused on addressing the education challenges created by Covid-19 school closures. Some examples are:

- Afghanistan: How might learners be supported by phone to bolster radio and TV education programming?
- Pakistan: What EdTech interventions are most suitable for providing distance learning for deaf children?

[23] 'Lean startup' refers to an approach to product development that utilises rapid, iterative cycles of development and testing, and which has been influential in software development in recent years but can also be applied to innovation in different contexts (see ↑Chang, 2019).

- Uganda: What is the most effective implementation model for using radio to improve learning outcomes?
- Lebanon: How might WhatsApp be used to deliver education content to children in refugee camps?
- Sierra Leone: How could technology be used to help disseminate TPD content to prepare for the return to school?

All stakeholders participating in sandboxes will join a 'Sandbox Collective' to promote better collaboration between these groups around common topics and challenges, and shared learning across the themes and regions. In future, the tools to run sandboxes will be made available for others, to test their interventions and ensure that they are building on the existing evidence on how best to address education challenges. This will include design principles for interventions alongside a Sandbox Toolkit.

4.1.5. Technical assistance

EdTech Hub supports governments in its focus countries with discrete technical assistance (TA) aimed at improving the design and implementation of EdTech interventions and generating programme-level insights. The Hub's TA activities have been explicitly Covid-19-focused, bringing evidence to decision-making processes, but they also generate new evidence and practical insights, build critical partnerships with decision makers in government and their partners, and deepen our contextual knowledge. They include:

- Contextual and feasibility analyses: for example, a virtual learning environment in Zanzibar.
- User research to inform design and implementation of a programme: for example, One Tablet Per School for TPD in Sierra Leone.
- Design of and guidance in rolling out implementation plans: for example, helping design Kenya's Covid-19 response plan for distance learning.
- Evaluation and monitoring support: for example, helping design a monitoring plan for Kenya's distance learning plan.

The Hub makes deliverables from these engagements available publicly so that other countries and decision makers can learn from them. Going forward, the Hub will explore additional TA work in alignment with high-priority evidence gaps to support our overall mission. By building partnerships based on trust with governments and development partners, the Hub's TA work sets

the stage for Hub researchers to engage effectively with country-level decision makers and partners. For example, TA to design or pilot a new programme could lead to a large-scale commissioned research study as the programme scales.

4.1.6. Helpdesk service

The Helpdesk is one way that EdTech Hub supports decision makers to use the latest globally informed, locally relevant knowledge and evidence in choices about whether and how to use EdTech. FCDO Education Advisers and World Bank staff working with ministries of education in 70 countries are eligible for short-term, discrete Helpdesk support. We work with requesters to understand their challenges and identify potential EdTech-enabled approaches that are evidence-based, contextually appropriate, realistic to implement, and cost-effective. We discourage use of approaches that risk exacerbating inequities or are unlikely to deliver improvements in learning.

4.1.7. Rapid commissions and calls

The Hub also has flexibility to offer rapid, small-scale commissions and calls for research proposals in response to emergent priority topic areas. The Hub call for proposals around the topic of EdTech and Covid-19 responses is an example of this type of approach. The calls require submission of robust, empirically-based projects, which are evaluated through a rigorous process involving Hub researchers and strategic advisors. The Covid-19 call has been restricted to research within the six focus countries but in the future, calls involving other countries may be run when resources allow and if particularly well aligned with high-potential evidence gaps.

4.2. External engagement, dissemination, and impact

The Hub's overall approach to engagement and dissemination — spanning all of the core activities outlined in Section 4.1 — is guided by core principles of community building, multi-stakeholder engagement, and open access to publications and resources. This approach is intended to help ensure that the Hub has as much impact as possible, including well beyond its focus countries.

4.2.1. Country engagement with multiple stakeholders

There is a striking gap between the available evidence and the degree to which this evidence is utilised in designing national policies and programmes. Where interventions have reached scale, a combination of factors is at play, for

example, incentives driven by political commitments and interests. Thus, the Hub takes a multi-stakeholder strategy, working with implementers and others inside and outside of government to solicit input, help secure buy-in and apply existing evidence to decision-making. This takes the shape of a collaborative approach meant to strengthen the long-term capacity of ministries of education, development partners, researchers, and educators across the system. It includes actively engaging in dialogue with a broad range of stakeholders, including government officials, other policymakers, NGOs, academic researchers and institutions, sponsors, EdTech providers, teachers, community members, caregivers, and school leaders.

The Hub aims to work with Local Education Groups of representatives from across the sector in each focus country. The Hub, its Specialist Network, and thematic expert groups bring global and regional perspectives to complement the expertise in each partner country, working together to apply evidence of the most promising interventions to new contexts and decisions through adaptive programme design and implementation. This process is, of course, not straightforward since stakeholders have diverse and sometimes conflicting agendas and varying levels of power within the system.

4.2.2. Building a global community of practice

Within the EdTech sector there are many diverse existing communities of practice, and fragmentation across sectors and locations of actors working on these issues — including governments of LMICs, private industry, academia, NGOs, and donors. This can be a barrier to collaboration. The Hub strives to play an active role in bringing together the key players in the global community around EdTech and its potential use in LMICs, increasing the impact of its work. Examples of partnerships so far include the Hub as a founding funder of the mEducation Alliance, participation in the Education Commission 'Save our Future' working group including authorship of a background paper on EdTech and Covid-19 response (↑Haßler, et al., 2020b), and establishing the 'Building EdTech Evidence and Research' (BETER) group. The Hub is a member of the UNESCO Covid-19 Global Education Coalition.

EdTech Hub has two overarching groups of advisors and experts: an Advisory Pool and a Specialist Network. The Advisory Pool harnesses expertise in the field from a large, multidisciplinary group of international, world-leading experts in the field, to advise the Hub and serve as change agents in the global EdTech community. This includes senior and strategic advisors, experts acting as peer reviewers, and interdisciplinary sub-groups focused on the thematic areas of the high-potential evidence gaps. The Specialist Network has an outward-facing role, working closely with the Hub team as consultants

to help give technical support to others through the Hub's Helpdesk and country engagement activities. This group allows the Hub to respond to demand for a broad range of advice by being able to call on specialists on an as-needed basis.

4.2.3. Curation of resources through public databases

Curated collections of relevant evidence, tools, and resources are shared through the Hub. The Hub website hosts the 'evidence library', a large, searchable database of EdTech research evidence and documents. It also provides access to an extensive database of EdTech tools — for learners, caregivers, teachers, and educational administrators — that can be filtered according to potential users' requirements, including educational level, connectivity requirements, and cost. In the near future, this database will also allow users to see which approaches have evidence of effectiveness or are likely to be effective based on design characteristics. We also make available specialised literature databases emerging from our systematic reviews; for example, the review of EdTech use related to teacher education and professional development in LMICs has yielded over 400 relevant sources in a searchable database with a fine-grained coding system that is already proving to be a useful tool for others in the sector. Scoping reviews of the EdTech research literature associated with the initial focal countries are currently underway, and a database of the literature identified will be published online in due course.

Currently in development is the Searchable Publications Database (SPuD), a comprehensive, searchable online database of existing research literature and publications which focus specifically on the use of technology to support teaching and learning in LMICs. The database presently contains 2.8 million records and is updated quarterly with new publications from five major sources (↑Haßler, et al., 2019). SPuD is currently being used by EdTech Hub researchers. It ranks results and offers searching by synonyms and Human Development Index values of countries.

4.2.4. Open publishing of a range of output types

Findings are presented as guidance in varied formats that are fit for purpose based on different audiences, the kinds of decisions those users need to make, and resources that facilitate access to evidence. EdTech Hub audiences include policymakers, researchers, funders, and anyone involved in the implementation of educational activities, such as practitioners, NGOs, and technologists. The following types of output have been published or are anticipated:

- Blog posts, short position pieces, and work-in-progress
- Helpdesk EdTech advice to FCDO and World Bank
- Policy briefings
- Technical reports from technical assistance engagements
- Sandbox reviews
- Rapid evidence and landscape reviews
- Country-level landscape reports
- Methodological papers
- Conference papers
- Rigorous syntheses, especially systematic literature reviews
- Journal publications of primary research and secondary data analysis

EdTech Hub is committed to working practices that utilise and promote openness and sharing of research findings and processes. Throughout the course of the programme, outputs are made available as 'global public goods' (↑Haßler, 2018). They are published under Creative Commons Licences as standard. We enable grant recipients to publish their outputs as open access too.

5. Conclusion and future directions

The strategic approach of EdTech Hub includes integrated activities designed to generate and ensure uptake of evidence, and attention to all levels of educational systems, needs of marginalised learners, cost-effectiveness, sustainability, scalability and contextual diversity.

In this position paper, we have situated EdTech Hub in relation to the global challenges that EdTech could be used to address and how we plan to help advance the field. While this framework has guided the Hub's strategic planning, the challenges identified — both in terms of the limitations of EdTech as a research field, and mapping the thematic areas related to learners, teachers, and systems which could benefit most from support through the use of EdTech — are also a roadmap for the wider field. The Hub's prime focus is on marginalised learners and the development of evidence that will expand the potential of a range of technologies to meet their diverse needs. The Covid-19 pandemic has amplified the immediate role of EdTech in supporting teaching and learning globally. Even so, inequities exist and will persist in the coming years — contributing to the widely cited need for education systems to 'build back better' (see, for example, ↑Save Our Future, 2020), in ways that are 'truly equitable'.[24]

These challenges are serious. The discussion above demonstrates the very valuable role that EdTech can play here. At the same time, it reinforces the need for researchers and implementers to critically scrutinise the promised benefits of EdTech initiatives, ensuring as far as possible that technology is fit for purpose and context, addresses stakeholders' needs, and adds value to SDG4. The aims of the Hub are ambitious, but in due course are expected to translate into a range of positive impacts and long-term uptake across education systems, in and beyond our focus countries. To identify a handful of sustainable interventions that are truly transformative — demonstrating significant learning gains and supporting educators' practices, yet cost-effective and culturally appropriate — and embedding them at scale, would be a significant success for the Hub. While implementation at scale is a major goal, reaching the most marginalised will also require serious

[24] International Parliamentary Network for Education presentation in 2020 webinar by Nidhi Singal: https://www.youtube.com/watch?v=_nNTftD1DWMandfeature=youtu.be.

context-specific strategies. By sharing our insights through open publishing, there is potential to reach a wide audience, from practitioners to policymakers, and to learn along the way from others in the sector. We invite input throughout, as working toward quality and equitable education for all (SDG4) is a truly global and collaborative endeavour.

6. References

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Annex 1. SDG4 targets aligned with the work of EdTech Hub

SDG4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

4.1	By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes
4.5	By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples, and children in vulnerable situations
4.6	By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy
4.7	By 2030, ensure all learners acquire knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development
4.C	By 2030, substantially increase the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially least developed countries and Small Island Developing States