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RIGOROUS SYNTHESIS

EdTech for Learners with Disabilities in Primary School Settings in LMICS: A Systematic Literature Review

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Notes

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Abbreviations and acronyms

AAC	Augmentative and Alternative Communication
ADD	Attention deficit disorder
ADHD	Attention deficit hyperactivity disorder
ASD	Autism Spectrum Disorder
AT	Assistive technology
CAI	Computer Aided Instruction
CBM	Christian Blind Mission
CVI	Cerebral Vision Impairment
DFID	Department for International Development
ECC	Expanded core curriculum
ERIC	Educational Resources Information Center
FCDO	Foreign, Commonwealth and Development Office (previously the Department for International Development)
GATE	Global Cooperation on Assistive Technology
ICF	International Classification of Functioning, Disability and Health Framework (also known as ICFDH)
ICT	Information and Communications Technology
INGO	International Non-governmental Organisation
LMIC	Low- and middle-income country
NGO	Non-governmental Organisation
RCT	Randomised Control Trial
SPuD	Searchable Publications Database
TSL	Thai Sign Language
UDL	Universal Design for Learning
UNCRPD	United Nations Convention on the Rights of Persons with Disabilities and Optional Protocol
SDG	Sustainable Development Goal
VR	Virtual Reality

Executive summary

Introduction

Educational technology, arguably, plays an important role in helping to ensure children / young people with disabilities have fair and optimised access to the school curriculum and ensuring they have opportunities to develop their independence, agency, and social inclusion. These principles are underpinned by a 'rights' agenda as outlined in the United Nations Convention on the Rights of Persons with Disabilities and Optional Protocol (↑UNCRPD, 2006), which demands fair and equal access to education for all. EdTech can play a powerful role in supporting children's learning, not only in ways of providing access but also in enabling children to use appropriate technology independently. This also enables them to enjoy the benefits of a full school curriculum and be able to participate in activities in different educational arrangements. Given these strong assertions, it is vital to carry out a closer examination of international published evidence to understand whether EdTech is making a positive difference to the educational experiences and outcomes of children / young people with disabilities in low- and middle-income countries (LMICs).

This systematic literature review was guided by the overarching aim of establishing the categories of EdTech that may be appropriate to support the learning of children with disabilities aged 6–12 years in LMICs. A critical review of the published literature was deemed essential. The field of disability and EdTech (mirroring larger trends in disability and educational research) has remained dominated by international assertions of support through the sustainable development agenda goals, anecdotal commentaries and strong personal assertions but these are substantiated by little evidence. Through a review of published papers, we endeavoured to establish how successful EdTech has been in terms of viability, improving educational access, learner engagement, and learning outcomes in LMICs. The review provides a synthesis of what we know from the evidence and highlights gaps in the existing knowledge base.

Conceptual framework

A model of access helps to frame this review by drawing on two complementary forms: 'access to learning' and 'learning to access' (see, for example, ↑McLinden, et al., 2016). 'Access to learning' emphasises a pedagogy and learning environment that allows learners with disabilities to access a shared curriculum with their non-disabled peers. 'Learning to access' recognises that there is a need to teach an additional or specialist curriculum (see, for example, ↑McLinden, et al., 2016) to promote learner independence and self-agency. This model provides a helpful lens to understand how learners transition from a situation where they receive targeted technological support to engage in the national curriculum, to one where, over time, they acquire the technological skills to be able to function and learn independently. Therefore, the type of scaffolding or inclusive practices required will be adapted accordingly as learners develop a range of other independent skills such as increased ability to use technology effectively. The teacher's role, within this model, is to help learners to take more control of their learning and have the required skills to access the national curriculum independently. This progression, and the implied balance and tensions between educational interventions, category, and severity of impairment are explored within this review.

Research approach adopted

A team of three academics, two of whom have significant experience in the field of disability and education in LMICs, developed a clear exclusion / inclusion framework and search strategy which involved the use of 58 keywords and phrases. Relevant studies were identified through automated searches using the electronic Searchable Publications Database (SPuD). This is a database developed internally by EdTech Hub that aggregates literature and publications focused on the use of technology to support teaching and learning in LMICs, all of which were in English. The search, conducted from July–December 2020, yielded over 20,163 sources out of which 187 studies were deemed relevant for full-text screening and a final total of 51 published articles and 9 reports (such as donor position papers and working papers) were included in the review. Studies were evaluated based on relevance and adequacy. 'Relevance' involved checking that all the studies addressed the use of educational technology to support the learning of primary school aged children with disabilities and 'adequacy' addressed the extent to which the research process was reasonably reported in the paper, hence providing some indication of its rigour and quality.

Key findings

Findings from the review identified novel ways in which EdTech is having a positive impact on the lives of learners with disabilities in different countries across LMICs, mainly in Asia and to some extent in South America. The studies explored novel opportunities for schools to pilot software programs or even provide learners with applications (apps) that can be used on mobile phones or tablets. There have been significant new developments in the number of Assistive Technology which are having a small but significant impact on how, where, and when learners with disabilities access and engage with the national curriculum. This has been noticeably the case for deaf and hard-of-hearing learners in Pakistan, who have been making increasing use of SMS and social media to access information for lessons and be able to communicate with their peers. The review also found other novel examples where apps are being used by learners to access the curriculum to, for example, teach sign language to deaf children in Thailand using videos showing finger spelling, pictures, and text captions. Furthermore, in India, zoom magnification and photographic apps are also being used on mobile phones and tablets to enable learners with low vision to access the same learning content at the same time as their peers. In Bangladesh, learners have been testing a new app known as mBraille to help them to learn to write Braille. Although the app shows positive signs of impact, it still requires further development, and better alignment with the curriculum before it can be considered appropriate in a learning context. These exciting advancements should lead to apps gradually replacing more traditional forms of AT (such as handheld magnifiers), but there still needs to be more evidence that they are pedagogically and environmentally appropriate for the target group of learners and can be afforded by the supplier (for example, a national ministry of education).

There is some emerging evidence that engaging with technology is having a positive effect on learners' levels of confidence and well-being across different groups, such as young people with autism, those who are identified as blind or deaf / hard of hearing, and learners with physical disabilities. While the rigour of these studies does not allow for nuanced understandings, there is broad agreement that learners are embracing technology and experiencing new ways of engaging with learning, and most importantly, forming friendships and creating new bonds at school.

Given the wide scope of this review, however, it is astonishing that there is so little evidence on *evaluations* of educational interventions which met the inclusion criteria. Some key findings from the evidence base and are summarised as follows.

Educational settings of research

While evidence highlights a broad range of EdTech being used in different educational arrangements, such as mainstream schools, special schools, and resource centres, this implies that there still is a real lack of evidence on how EdTech can be most effectively introduced in these settings, especially within mainstream settings. Despite the significant push towards inclusive education over many decades, the majority of the studies remain located in special school settings. A possible reason for this could be the rapid development and wide range of low-, medium-, and high-tech devices specifically for children with visual impairment and deafness or for the hard of hearing who have traditionally been in special schools.

Infrastructural limitations

While there has been an exponential increase in the breadth and choice of EdTech for persons with disabilities, many of the studies we found are still at an early stage with little projection of how they can be scaled up in regions where there is reduced access to power, a lack of technological expertise even within the same country, or dedicated funding streams.

Technocentrism

Evidence suggests there is more of a focus on developing technology per se, rather than aligning it to curriculum goals. As a result, there has been insufficient emphasis on finding out how technology can help teachers to support learners' access in a more inclusive manner. This is reflected in around half of the reviewed studies, which appear in either engineering, computer science, or health journals. Furthermore, there is a strong tendency to use EdTech to support entry factors, with little literature exploring the impact of these on children's learning outcomes, classroom engagement, and social inclusion.

Scope of studies

Most of the studies were of a short duration and had a small sample size. There is a disproportionate concentration on specific impairment types over others. For example, more than half of the studies in the review focused on deaf / hard-of-hearing and blind / low-vision learners. A possible reason for the lower number of studies involving learners with other disabilities, particularly with learning difficulties and autism, is the lack of consensus, of not only on *how* but also *what* AT can be used in teaching interventions. For example, there is lack of agreement on whether all forms of augmentative and alternative communication (AAC) fall into AT, particularly as some are electronic-based (communication devices) whereas others are more low-tech, paper-based forms (drawn symbols or pictures on laminated cards). There is also the added issue of AAC content not meeting the different languages and cultures of learners with disabilities. Evidence from the review suggests there is a lack of knowledge or agreement on the definitions of AT (see, for example, ↑UNCRPD, 2006, Article 2) globally, apart from devices commonly used for sensory and physical impairments.

Lack of gender awareness

Reporting on gender differences was rare. Less than 20% of the studies provided a breakdown of male and female participants with a tendency to aggregate both male and female into the total number of participants. When studies did provide disaggregated gender data, there were, on average, twice as many male participants. Two studies in China on learners with autistic spectrum disorders (ASD) only included boys in the study. This was the case for both learners with disabilities and their teachers who were surveyed. While it is not clear if these were single sex settings, nonetheless it raises important issues for ensuring that female learners and teachers are specifically included in the EdTech discourse — more so, given that there is a disproportionate use of access and usage of EdTech among women in many LMICs. It is important that gender equality be an integral part of the implementation of EdTech to ensure that technological advances benefit both male and female learners and teachers.

Teachers' use of EdTech

Findings of this review highlight a reluctance among teachers to actively adopt EdTech solutions / interventions in their everyday teaching. We noted significant gaps in the amount of knowledge teachers have on even the most basic technology used in the classroom. This could be due to the lack of know-how in relation to the use of technology to respond to the specific learning and social needs of different learners. Indeed, there is also evidence of the significant lack of training available to teachers to incorporate technology in their pedagogical repertoire in professional development programmes. Some studies called for an explicit need for teacher development to move beyond theory and focus on providing teachers with opportunities to practise new technological skills and gain confidence in using them with diverse learner groups.

Role of parents / carers

There was a real lacuna on capturing the perceptions and involvement of parents / carers of children with disabilities in the use of EdTech interventions. However, those very few studies that had included their views of technology and explicit 'buy-in' showed reduced rates of abandonment of devices by the children. Parental / carer involvement and monitoring of devices, such as mobile phones and tablets, also showed improvements in children's levels of communication, mobility, and overall confidence levels.

Adopting a holistic approach to using technology

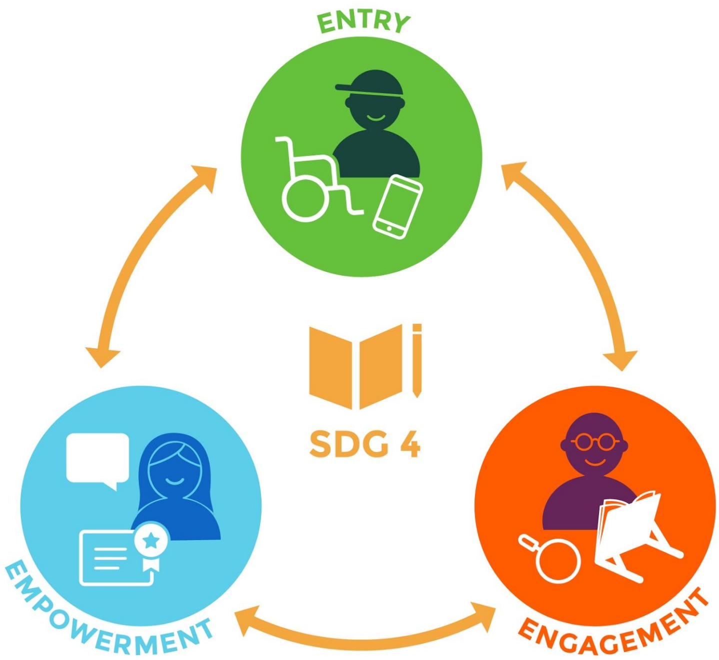
A key message emerging from the review is the gathering momentum that assistive technology apps for mobile phones and tablets are having on the education of learners with disabilities. Furthermore, when they are more sustainable, they are expected to have additional benefits within and outside the schools, leading to greater communication, independent living, and self-advocacy at home and in the community. Unfortunately, this added value for investment in AT apps can be lost when we look at pervasive technologies through a lens of just health, employment, or education.

Overall, our review clearly highlights that there is little understanding of how, when, and what type of technology should be introduced into the learning process in order to respond to the specific needs of children with disabilities. Moving forward, an urgent need exists for more interdisciplinary research that encourages AT designers to work closely with learners and other key beneficiaries, including teachers and parents / carers. We need to reduce barriers to children's learning by identifying new approaches to how learners with disabilities can access information to develop their knowledge, confidence, and diverse skills. 'Access' in the context of EdTech is a complex and multi-level process that requires innovative pedagogical teaching approaches.

Recommendations for research

This section sets out two sets of recommendations for further research into EdTech and disability. The first set of recommendations address ways of increasing our evidence base of robust studies on how EdTech can be used to support the education of diverse groups of learners in LMICs. The second set of recommendations are addressed to policy makers and donors who are responsible for implementing EdTech programmes within LMICs.

Better alignment of EdTech research to global commitments



New research into EdTech needs to be more aligned with global commitments set out in the UN Sustainable Development Goal (SDG) to "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" and the UN Convention on the Rights of Persons with Disabilities. Research focusing only on issues of access is limiting and does not take into account the need for inclusive and equitable quality learning experiences for learners with disabilities. The inclusion of learners with disabilities in educational systems is a significant challenge facing policy makers in many LMICs. EdTech can benefit learners through a multi-pronged focus of 'entry,' 'engagement', and 'empowerment'. Additionally, EdTech interventions need to develop a strong sense of self-worth and well-being, so that the learner continues to use the technology on a regular basis, takes ownership of it, and is able to self-advocate (in the present and in the future).

Identify research questions which address the diversity of learners

The field of EdTech and disability research needs to pose more pertinent questions. Research is needed to understand *how* and *which* technology is the most useful when it comes to facilitating the learning process. Robust research is needed to evaluate the conceptualisation, design, testing, and impact of appropriate technology within different environmental conditions (such as gender, age, location — urban, peri-urban and rural, public / private schools, curriculum area) to meet the needs of the full range and diversity of learners with disabilities in LMICs.

Robust research designs

Research designs, including randomised control trials (RCTs) and strong participatory user-based methods, with sufficient sample sizes and conducted over longer time frames, are needed to put forward more robust results to inform effective policy making and programme developments.

Need for more sophisticated research designs which acknowledge intersecting variables

There is a significant disparity in the evidence base across different impairment groups, which needs to be recognised and addressed. Additionally, more thought needs to be given to intersecting variables, such as gender, location (rural / urban), and the socio-economic status of learners, which can have a pronounced impact when designing new EdTech interventions in LMICs.

Greater involvement with user groups

Learners with disabilities and their teachers should be consulted in the design and implementation of EdTech studies (for example, in relation to purpose of study, type of technology, integration into learning situation, and relevance to the curriculum) and EdTech initiatives. This includes discussions about the viability of the proposed EdTech in the learning settings (for example, to what extent apps or software can be installed onto devices where there is a lack of power supply), which can form the basis of moving from small-scale, design-centred studies to larger-scale, multi-country studies that measure the impact of technology on learning outcomes.

Developing research capacity in LMICs

To generate new EdTech research which responds to needs and is sensitive to context, funders will need to allocate sufficient funding and time for the development of research capacity within research institutions, particularly those in low-income countries where evidence has been limited. While we are unable to reflect critically on the nature of North–South partnerships in this review, given the lack of information, there is a need for research capacity-building in many LIMICs. Researchers should be encouraged to publish in recognised international peer-reviewed journals through open-access routes.

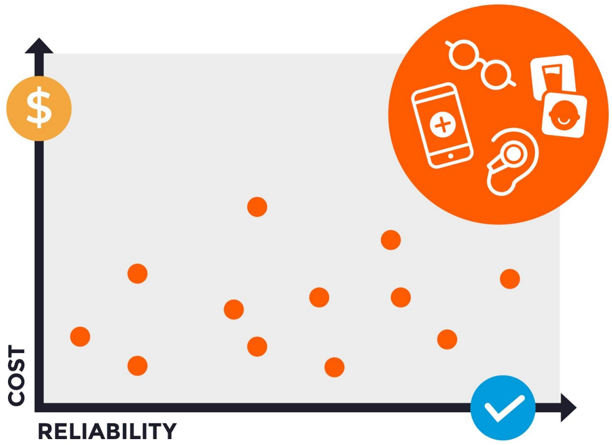
Recommendations for policy

Greater investment in mobile and portable devices

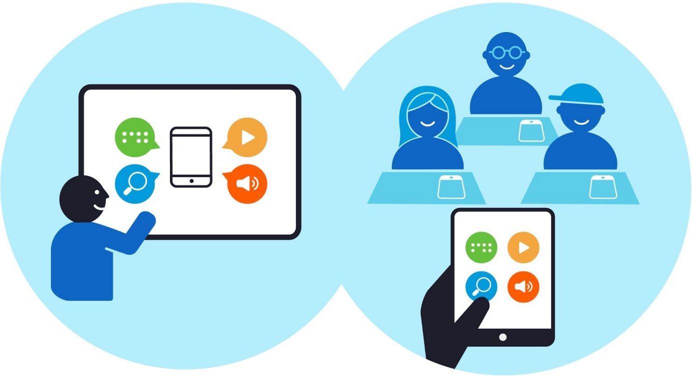
With a growing shift from using PCs to mobile and portable devices, investing in apps for phones has additional benefits for learners with disabilities when the investment is sustainable. The same technology can be used to support daily living activities at home and increase opportunities for independent living. Governments should invest in more technology that encourages greater opportunities for ubiquitous learning opportunities within different learning and social arrangements (schools, residential settings and / or home). There is a need for a more expanded, holistic vision which allows for both mobile and more fixed technologies to be used interchangeably within both education and home settings. This creates greater flexibility where the technology moves with the learner, rather than the learner always being restricted to where the technology is located.

Keep the cost of AT affordable

A significant barrier to accessing technology, as noted in this review, is the consistently high cost of AT, especially for learners with sensory impairments. Thus, there is an urgent need to seek formal agreements with specialist suppliers of AT to find solutions to keep the cost of AT to affordable levels. There is also a need to source AT more locally in order to reduce additional import taxes and develop reliable supply chains within countries.



High-quality competency skill training in EdTech for teachers



A consistent theme across the review was the lack of awareness, confidence, and adequate training among teachers. Teacher development programmes therefore need to incorporate high-quality competency skill training to improve their digital literacy (for example, looking at ways to use mobile technology more creatively within the core and expanded core curriculum) and also for teachers to acquire practical experience. This is particularly important in instances where there is a need to apply more complex AT to provide increased learning opportunities and effective learning experiences for children with disabilities in different settings.

Strong government incentives to subsidise costs of appropriate EdTech

There are greater benefits to be achieved by ensuring that the needs of persons with disabilities are being met by the new influx of mobile phones, tablets, and AT apps in LMICs. For example, the proliferation of mobile phones and apps is having a positive impact on how the curriculum is being re-conceptualised and delivered to deaf and hard-of-hearing learners, but there are considerable cost implications for schools and learners unless there are strong government incentives to subsidise costs.

Investment in EdTech infrastructure and technology for schools

Evidence from the review indicates a lack of infrastructure (such as reliable supply of electricity) and availability of AT in schools, which is evidence of underinvestment even when EdTech is highlighted as a priority. Governments need to commit to better resourcing of appropriate EdTech for children / young people with disabilities if we are to deliver on promises of inclusive and quality education.

Clear guidelines on who is responsible for sourcing technology

An emerging tension noted in a few of the studies was around who pays for some of these technologies, for instance mobility devices (such as wheelchairs, walkers, crutches, callipers), which will enable some children / young people to access school. There were clear differences in opinion about who is responsible for sourcing some of these devices, i.e., the school or the parents / carers, and indeed whose remit it falls under nationally, for example, the ministry of education or the ministry of health. Therefore, clear guidelines are needed at a national level, and this will also allow for transparent budget lines and appropriate allocation of funds.

Conduct a four-stage consultation to create a priority list of assistive technology and a support training package

Given the significant need but lack of spread of EdTech, in the longer term there is a need to build on the World Health Organisation's Global Cooperation on Assistive Technology (GATE) initiative. This initiative is currently focused on Universal Health Coverage but could be expanded to improve access to high-quality affordable and appropriate assistive technology in education.

We propose that this could be a four-stage process, which involves:

1. Carrying out a robust mapping of the efficacy of AT in maintaining or improving an individual's functioning, independence, and well-being.
2. A Delphi exercise that involves diverse stakeholders, such as international organisations, donor agencies, professional organisations, academia, and user groups to agree on a list of high-priority devices which cover the range of low- to high-tech.
3. Focused national surveys to capture the opinions of a larger population, especially those of learners with disabilities and their families.
4. A consensus meeting between diverse stakeholders, which will agree on a training package including four essential steps of service provision: assessment, fitting, training, and follow-up and repair.

This will ultimately require the generation of a list of reputable, affordable, and reliable national and international suppliers of AT, being particularly mindful of issues of sustainability and effective use of local resources.

1. Introduction

Over the last few months, the potential of technology in educational spaces has been amplified due to the precipitation of a global pandemic. As of 30 June, 2020, across more than 180 countries, 85% of the world's learners (approximately 1.6 billion children) had been out of school for close to 11 weeks (↑McClain-Nhlapo, 2020). These were the biggest closures experienced during peacetime and across all countries — both in high-, low- and middle-income countries. During this time, many countries relied on technology to engage learners; in many LMIC contexts, examples of distance-learning approaches supported with radio and broadcast media and online digital learning portals have been reported (↑McClain-Nhlapo, 2020).

However, the digital divide between learners related to access to equipment, electricity, the internet, and teacher ability has further exacerbated the already existing learning divide in every country, especially for learners with disabilities, who have the additional barrier of inaccessible learning content. A report published by the Inclusive Education Initiative (↑World Bank, 2020) notes that nearly 40% of disadvantaged learners in LMIC countries have been left entirely unsupported in their education, and among these, children with disabilities are disproportionately represented.

Globally, there are more than one billion people who need one or more assistive products or devices (↑WHO, 2019). With an ageing global population and a rise in non-communicable diseases, by 2050 more than two billion people will need at least one assistive product or device, with many older people requiring two or more products. Today, only one in ten people have access to assistive products (↑WHO, 2019), which leaves many individuals unable to enjoy the levels of inclusion and participation they are entitled to. If we look at specific devices, only 5–15% of the 75 million people who need a wheelchair have access to one (↑Gupta, et al., 2011); hearing aid production meets only 10% of global need and 3% of the need in low-income countries (↑WHO, 2017a). Moreover, 200 million people with low vision do not have access to spectacles or other low-vision devices (↑WHO, 2017b).

EdTech plays a significant role in enabling learners with disabilities to access learning at school. It can also support the development of different skill sets (such as communication, problem solving) while encouraging independence. It also has an important role in reducing educational and social exclusion for these learners and in reducing the widening digital divide across the globe. Scientists and teachers have an important role in meeting the challenge of being able to exploit the flexibility of EdTech to enable children with disabilities to learn in their communities.

This review, with its focus on critically examining the evidence base on the use of educational technology in supporting children with disabilities in LMICs, is pertinent and timely. By undertaking this deep dive, we aim to identify interventions and / or enabling factors that can support the learning of children with disabilities through technology, and also highlight gaps in our current understanding.

1.1. Focus

Keeping in mind the significant focus on the potential of EdTech in supporting the learning of children with disabilities, this review was guided by the overarching aim of establishing the categories of EdTech that may be appropriate to support the learning of children with disabilities aged 6–12 years in LMICs. We decided to focus on this age range partly because it includes the compulsory basic education years across the globe and is also a critical learning period for brain and physical development through school learning, where children not only learn in subject-matter domains (such as language, numeracy, the arts) but also develop their personalities. The early primary school years are additionally a critical time for remediation and early intervention for children with developmental delay and disabilities. The purpose of this review was to focus on published empirical evidence from LMICs in order to get a clear picture of the EdTech landscape in them. It was not an aim to make any comparisons with how EdTech is being used in high-income countries as this is largely already documented in peer-reviewed journals.

The main research questions which guided this review are as follows:

- What kinds of EdTech may be appropriate to support the learning of children with disabilities aged 6–12 years in low- and middle-income countries?
- What interventions have been trialled and how successful were they in terms of viability and improving educational access and learning outcomes?
- What are the limitations of this evidence?
- What is the potential for further development of this field, particularly in terms of scalability?

While there is no shying away from the use of EdTech, honest and open deliberation is needed to ensure EdTech interventions are inclusive, sustainable, and ethically and effectively implemented. In order to do so, we need to understand the existing evidence base, which is the primary focus of this review.

1.2. Overview

The report is divided into seven sections:

1. Introduction, including key definitions used in the report
2. Conceptual framing of the study
3. Methodology
4. Synthesis of the evidence
5. Main findings
6. Key themes emerging
7. Recommendations

At the outset, it is useful to briefly define the concepts of EdTech and disability, as used in this report. However, we also acknowledge that terminologies used differ within and across national contexts, and, as explained in the research design section of this report, we used both impairment-specific terms and overarching concepts such as special educational needs (which in many contexts is used synonymously for referring to children with disabilities: ↑Singal, et al. (2019) in our search for literature. The review is specifically focused on children with disabilities across the primary age group.

Throughout the report we use person-first language, such as 'persons with disabilities', and not 'disabled people'. In doing so we highlight a need to focus on the individual rather than the disability. Our choice to use person-first language also arises from the geographical spaces that this review covers.

1.3. Key terms used

Educational Technology (EdTech) EdTech generally includes a number of broad definitions across disciplines; however, for the purposes of this report we regard it as the use of technology for teaching and learning. We deliberately use a broad definition of EdTech, which includes any use of ICT at any point within the education system — for example, in schools, communities or homes. In this review, however, we have not included use at home as this was not within the terms of reference. This inclusive definition reflects our commitment to inclusion of the most marginalised. Where appropriate, we also consider 'digital' beyond 'technology' and issues regarding the use of data or digital licensing.

Assistive technology (AT) AT includes any item or piece of equipment that helps a person with a disability increase, maintain, or improve their functional capabilities as a learner[1]. AT can range from low-tech devices such as reading stands that help learners with low vision access print to high-tech devices such as voice-activated software programs or devices for learners with physical disabilities and communication or sensory impairments. An AT service is any direct assistance to the learner with a disability in the selection, acquisition, or use of the AT device. An AT service could comprise the purchase, leasing, or lending of a device to a school to enable a learner to access the curriculum or other materials. Principles of design for all and universal design for learning are helpful starting points when deciding on curriculum development and instructional practices for educational services. Ostensibly, the more specialised the AT device is, the greater the need for the provision of specialised training for the learners and teachers to use it effectively in the learning environment.

Disability For this report, we frame our conceptualisation of disability in accordance with the World Health Organization's (↑WHO, 2002) *International Classification of Functioning, Disability and Health Framework* (ICF), which considers disability and functioning as outcomes of interactions between health conditions (diseases, disorders, and injuries) and contextual factors (↑WHO, 2002). Among contextual factors are external environmental factors (for example, social attitudes, legal and social structures, natural and built environment, products and technology); and internal personal factors, which include gender, age, coping styles, social background, education, profession, past and current experience, motivation, and self-esteem, all of which can influence how much a person participates in society. This view of disability, which positions it as part of the human condition is central in the discussions of the World Disability Report (↑WHO, 2011).

1 https://www.disabilityrightswa.org/publications/assistive-technology-special-education-students/

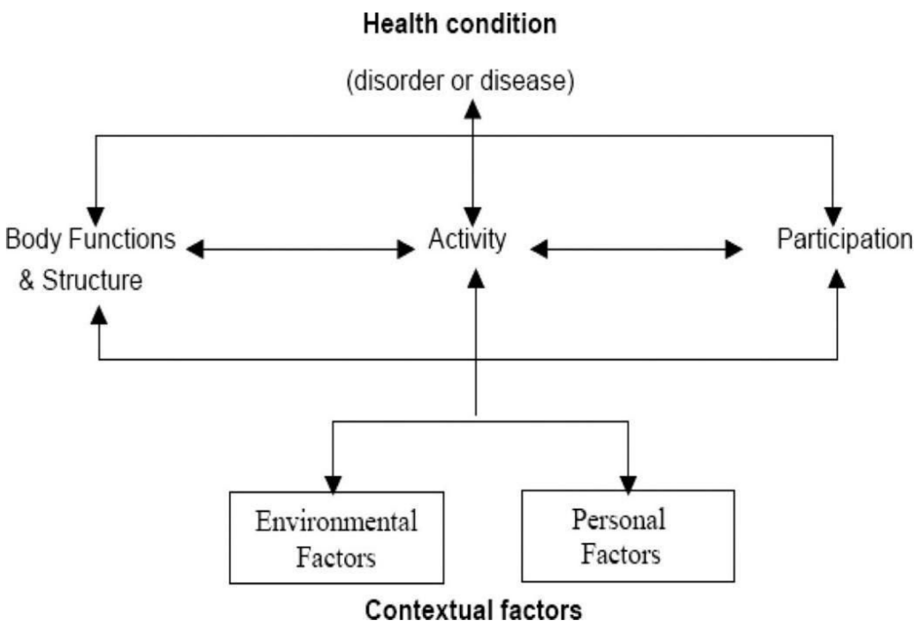
It is important to acknowledge here that in this report we have used person-first terminology (*person with disabilities* rather than *disabled person*) in line with the contexts we are reviewing. Additionally, in places we have used the terminology as noted more frequently in the literature rather than imposing our own preferences, such as *autism* rather than *neurodiversity*, which is now becoming a more common term in some high-income country settings, including England.

Impairment An impairment can be temporary or permanent; progressive, regressive, or static; intermittent or continuous, as elucidated in the WHO's International Classification of Functioning, Disability and Health Framework (ICFDH[2], also known as ICF). The presence of an impairment necessarily implies a cause; however, the cause may not be sufficient to explain the resulting impairment. Also, when there is an impairment, there is a dysfunction in body functions or structures, but this may be related to any of various diseases, disorders, or physiological states. For example, the loss of an arm is an impairment of body structure, but not a disorder or a disease (↑WHO, 2002).

To give an example of how the ICF framework works, let's take the case of a child catching an infectious disease such as meningitis (a *health condition*) which could lead to them acquiring a profound hearing impairment (*bodily functions*), which in turn could affect their hearing and communication (*activity limitations*). The consequences of contracting meningitis may have an impact on the child being able to go to school (*participation restrictions*) unless they receive assistive technology (such as a hearing aid) or possibly learn sign language (*environmental factors*), as well as receiving social and emotional support (*personal factors*). The ICF framework recognises three levels where disability is experienced: the body, the person, and the person in the context of their community. Figure 1 provides an illustration of what the components of the ICF framework mean in relation to the different factors of the case study (activity, participation, environmental and personal factors).

2 https://www.who.int/standards/classifications/international-classification-of-functioning-disability-and-health

Figure 1. *WHO ICF Framework of Disability (2002).*



2. Conceptual framing of this study

Technology can be empowering, but it can also be frustrating and stigmatising when it is complicated to use and when users perceive that their devices look different from what other people use (↑Martinez & Scherer, 2018). Introducing new technology that addresses specific access difficulties for learners with disabilities into a classroom can itself create difficulties for learners using the technology if there is insufficient awareness-raising about inclusion at classroom and school levels. Enabling and inclusive environments must begin with a fundamental belief in the equity and rights of all children and families, especially for those who are most vulnerable, including learners with disabilities. Thus, EdTech must address fundamental issues of equity and support effective inclusion for all.

Building on the WHO's ICF framework, which places the individual at the centre, we look at how learners should be given the 'voice' and 'space' to identify the most appropriate solutions to ensure greater participation within the community and school. Once a decision has been made about the benefits of providing technology to enable participation, it is essential to examine how the selected piece of technology or device will be introduced to the learner and other key stakeholders (namely, parents[3] and teachers). It is also important to establish whether it creates new opportunities for the learner to participate in school activities. Therefore, a good match of person and technology requires attention to:

A. Aspects of and resources in the environments in which the technology will be used.
B. The needs, expectations and preferences of the user.
C. The functions and features of the technology and service delivery process.

If the match is not a quality one from the view of the learner, and the learner's experience is unsatisfactory, then the device may go unused, or may not be used optimally. There is a strong need for an improved person–technology matching and outcomes assessment process to reduce levels of dissatisfaction and non-use or discarding of technology by individuals (↑Martinez & Scherer, 2018). Table 1 outlines some examples of 'good' and 'bad' matches in relation to the person, environment and technology.

[3] We acknowledge that children are raised and looked after by parents and other carers (such as other family members and guardians). For brevity, we use the term 'parent' to include other family and non-family members.

It is also important to consider the complexity of meeting an individual's requirements with regard to a 'good' match in relation to international conventions such as the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD), underpinned by the social model, which explicitly embeds the concept of 'reasonable accommodation' within the principle of non-discrimination. Furthermore, Article 2 of the UNCRPD unambiguously recognises that *reasonable accommodation* is vital in enabling persons with disabilities to enjoy and exercise their rights on an equal basis with others. However, it also explicitly states that "the appropriate modification and adjustments [do] not impose a disproportionate or undue burden," which is difficult to interpret as no specific guidance is provided. Nonetheless, reasonable accommodation should entail balancing the needs and interests of both the person with a disability and the duty-bearer (such as the department or ministry responsible for the education of learners). Additionally, the difficult issue of cost needs to be raised as much high- and medium-cost EdTech still remains prohibitively expensive and therefore beyond the already squeezed budgets (even more squeezed now as a result of Covid-19) of governments in LMICs.

Table 1. *Matching person with technology model. Source: (↑Scherer, 2021; ↑Scherer & Federici, 2015)*

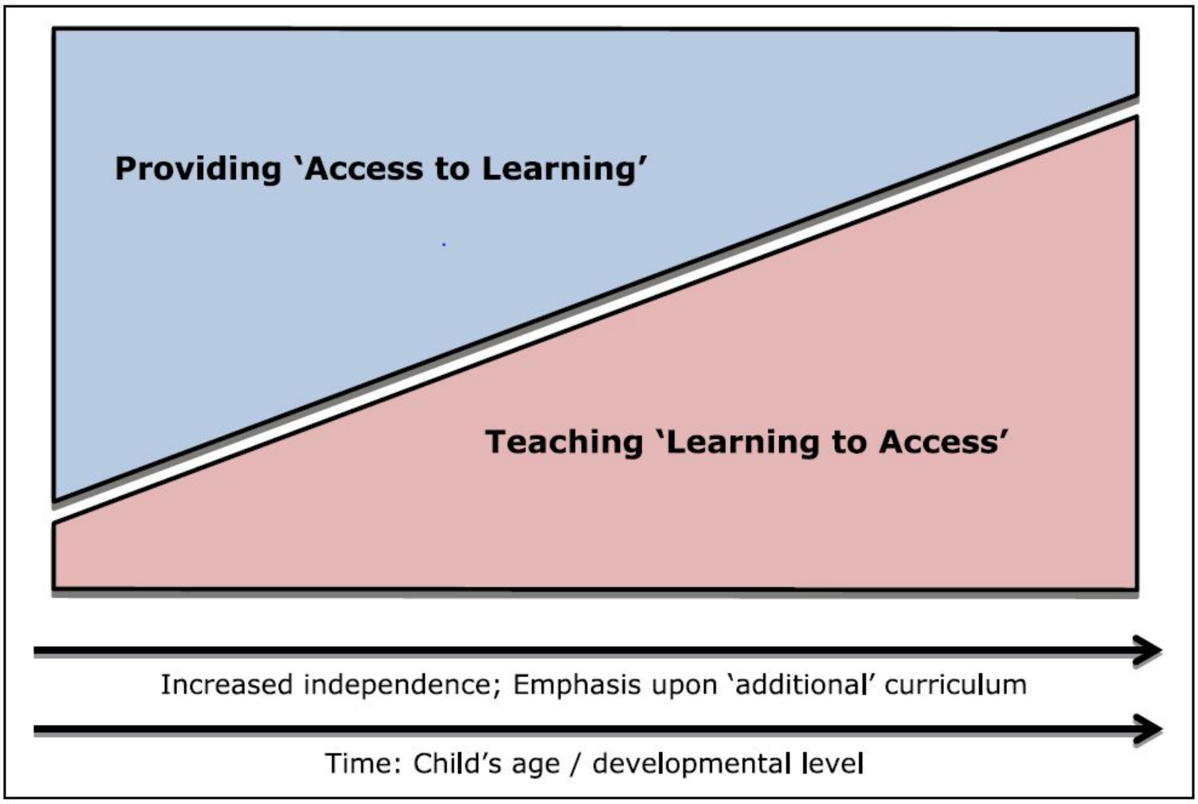
	Person	Environment	Technology
Good Match	▪ Comfort with using device ▪ Motivated to use device ▪ Technology use fits with lifestyle ▪ Has the skills to use the device ▪ Perceives discrepancy between desired and current situation ▪ Realistic expectations of use	▪ Support from key others ▪ Realistic expectations of key others ▪ Setting / environment supports and rewards use ▪ Availability of assistance for selection, maintenance, repairs	▪ No pain, fatigue, or stress with use ▪ Compatible with / enhances the use of other supports ▪ Is safe, reliable, easy to use and maintain ▪ Has the desired transportability ▪ No better options currently available
Poor Match	▪ A thorough assessment was not done	▪ Lack of support from key others	▪ Too much effort or discomfort with use

■ Person doesn't want device ■ Does not experience benefits from use ■ Embarrassed to use device ■ Use requires many changes in routine / lifestyle ■ Does not have skills for use ■ Changes in priorities or needs	■ Unrealistic expectations of others ■ Assistance not available ■ Setting / environment discourages or prevents use or makes it awkward ■ Lack of adequate training for use	■ Requires a lot of set-up ■ Device is inefficient ■ Perceived or determined to be incompatible with the use of other supports ■ Too expensive ■ Long delay for delivery ■ Is difficult to use ■ Repairs / service not timely or affordable ■ Other options are preferred

EdTech arguably plays an important role in helping to ensure children / young people have fair and optimised access to the school curriculum and ensuring they have opportunities to develop their independence, agency, and social inclusion. These principles are underpinned by a 'rights' agenda (UNCRPD), which demands fair and equal access to education for all, but they are also about an individual being supported to develop bodily integrity, self-determination, and independence. For this review, we propose a dual model of access to help to frame these principles by drawing on the terms 'access to learning' and 'learning to access' proposed by ↑McLinden, et al. (2016). This model provides a helpful lens to understand how learners transition from a situation where they receive targeted technological support to engage in the national curriculum, to one, where, over time, they acquire the technological skills to be able to function and learn independently. Therefore, the type of scaffolding or inclusive practices required will be adapted accordingly as learners develop a range of other independent skills, such as increased ability to use technology effectively. The teacher's role within this model is to help learners to take more control of their learning and acquire the necessary skills to access the national curriculum independently. This progression, and the implied balance and tensions between educational interventions and practices, are explored in later sections of this report.

Figure 2 (see below) provides a visual representation of the dual model, showing two equal-sized triangles. The first area is concerned with equal access to education and is balanced with a second area which is linked to maximising children's ability to develop as independent learners within the school environment but also as part of a broader agenda of preparation for adult life, independent living, and employment. The areas of intervention captured within the terms 'access to learning' / 'learning to access' are most commonly discussed in relation to the school curriculum, with a particular emphasis on and the distinction between a 'core' curriculum and an 'additional' or 'expanded core curriculum (ECC)'.[4] Although this model looks at a learner's trajectory from the early years through to primary, secondary, and tertiary education, for the purposes of this review, we apply it to primary-aged learners who have a broad range of disabilities (and impairments) and attend different education arrangements (such as mainstream schools, special schools, resource centres, rehabilitation centres).

Figure 2. *The role of teachers in balancing 'access to learning' and 'learning to access'. Source: (↑McLinden, et al., 2016).*



We can further conceptualise a 'good' match between technology and the learner when considering their individual needs within a learning context. For instance, learners with visual impairments such as blindness may first

[4] The term 'expanded core curriculum' (ECC) is used to describe areas including compensatory or access skills, career education, independent living skills, orientation and mobility (O&M), and use of AT.

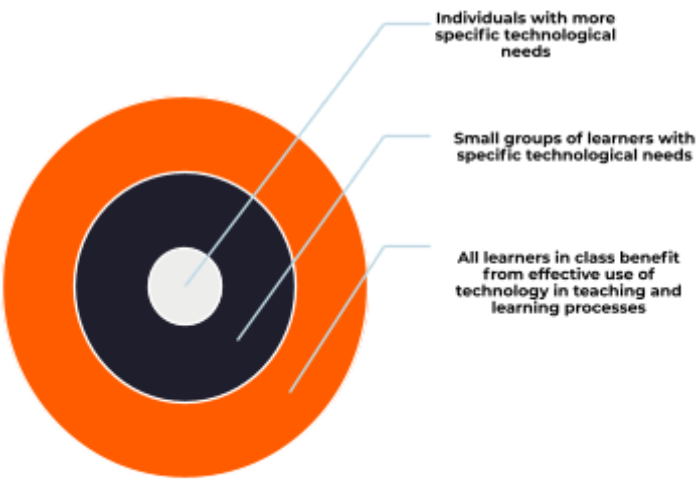
need access and training on how to use AT (such as a computer screen reader) to be able to access other forms of inclusive, enabling, or mainstream digital technology programs (such as apps and e-learning materials) which hold core and other curricula materials. Figure 3 shows a three-level nested model that can be operationalised by teachers and other support workers within a school setting to address the technological needs of learners with disabilities at individual, group, and whole-class levels. Again, a learner with a visual impairment will move between the three levels depending on what activity they are doing and the amount of technological assistance needed. This system fits within the principles of Universal Design for Learning[5] (UDL), which acknowledges that all learners understand, process, and express things differently.

UDL recognises that teaching and learning should use multiple methods to support all learners, including and not limited in its application to learners with disabilities. Therefore, teaching should provide multiple means of:

1. Engagement, by motivating learners to learn through a variety of methods.
2. Representation, by presenting content in a variety of ways.
3. Action and expression, by enabling learners to show what they have learnt in a variety of ways.

UDL can be challenging for teachers who have little knowledge or have not received adequate training on how to include technology for learners with disabilities in their teaching, and this will be explored in this report.

Figure 3. *Illustration of access to different levels of technology for all.*



[5] For more information please see: http://www.cast.org/impact/universal-design-for-learning-udl

Although there is a strong case for leveraging sustainable educational technologies that accelerate the uptake and application of UDL throughout education systems, factors such as the high costs of more specialised technology and more specific training still hinder the integration of EdTech into schools, across many contexts. This in turn can create barriers to access to the curriculum for individuals who require more specialised technological support for their learning, and can lead to unequal access to learning in the classroom or other learning setting.

3. Methodology

This systematic literature review aims to map out what is known about how technology is being used to support the learning of children with disabilities, to identify areas of uncertainty, and establish areas where little or no relevant research has been done. The review was undertaken between July and November 2020 after agreement on the protocol. The review team comprised three researchers, two with extensive experience of conducting research on issues of inclusive education with a particular focus on children with disabilities in LMICs. The third team member has been actively involved in undertaking systematic reviews within the broader field of education and technology. The methodology was guided by ↑Petticrew & Roberts (2006) as well as recommended Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (↑Moher, et al., 2009).

3.1. Review protocol

At the start of this review, a protocol was prepared based on terms of reference established by EdTech Hub and the Faculty of Education, University of Cambridge. This was in turn circulated internally among the research team for feedback and discussion. Upon agreement among the members, the review was undertaken between July and November 2020.

Given that this review aimed to systematically capture research undertaken in the intersecting areas of disability and educational technology, we were mindful of not making any assumptions about preferred research designs. Being conscious of the fact that the field of disability research tends to be dominated by qualitative studies (and in many instances comprising small samples) with few RCTs, large-scale, and / or longitudinal studies (↑Singal, et al., 2019), we decided to not to prioritise one design type over another.

We took our starting point as all articles in peer-reviewed (English language) journals. To widen the net for capturing potentially important ongoing work in LMICs the search was extended to include peer-reviewed conference proceedings as well as relevant International Non-governmental Organisation (INGO) and Non-governmental Organisation (NGO) reports and grey literature. The inclusion of INGO / NGO reports, though not necessarily peer-reviewed, was important given that this sector has historically played (and continues to play) a key role in the field of disability and education in LMICs (↑Singal, 2020).

The eligibility criteria for including studies in the review are described in an inclusion and exclusion framework presented in Table 2.

Table 2. *Inclusion and exclusion framework.*

Quality	Inclusion criteria	Exclusion criteria
Population	Learners attending mainstream and special schools at the primary level (6–12 years) Teachers Parents	Older than 12 years (secondary school age and older)
Geographical location	Low- and middle-income countries based on World Bank Group list	High-income countries
Type of Publications	**Primary Sources** Empirical peer-reviewed journal articles Empirical peer-reviewed conference papers **Secondary Sources** Grey literature: NGO Reports International monitoring and evaluation reports by INGOs Key reports published by international organisations, which are publicly available	Guidance reports that do not include research evidence but are commentaries of what should be done
Search Engines	EdTech Hub Searchable Publications Database (SPuD) comprising articles from 2007–2019 pooled from five major academic journal databases Educational Resources Information Center (ERIC) and Scopus for complementary searches of publications between 2019 and July 2020 publications only	Other search engines were not searched
Date	2007–2020	Older than 2007
Language	English	Any other language

3.2. Search strategy

This stage involved developing a search strategy by identifying keywords and undertaking an extensive search of the literature. The process of generating key search terms — namely, key words and phrases — was done in collaboration with two main researchers due to their extensive familiarity with the field of special educational needs and inclusive education. The keywords generated included: 26 disability terms covering categories of blindness, deafness, intellectual impairments, and physical impairments; 16 EdTech-related terms that described technological devices as well as inclusive-education approaches used to support the learning of children with disabilities; and 16 relevant keywords to capture the population of interest and the contextual parameters of the review. These are listed in Table 3.

Table 3. *List of key words and phrases.*

Disability Terms	Technology Terms	Population Terms
blind	assistive technology	student
low vision	enabling technology	pupil
partially sighted	inclusive technology	child
visually impaired	adaptive technology	children
deaf	assistive devices	learner
hard of hearing	assistive aids	early childhood
hearing impairment	'alternative and augmentative communication (ACC)'	primary school
deaf-blind	'universal design for learning (UDL)'	special school
multi-sensory impairment	'one laptop per child (OLPC)'	resource centres
intellectual impairment	mobile handheld devices	parents
intellectual disability	smartphones	principals
learning disability	tablets	teachers
slow learners	laptops	special needs teacher
mental retardation	tv	special teacher
autism spectrum disorder	radio	resource teacher
'attention deficit hyperactivity disorder (ADHD)'	ICT	'special education needs coordinator (SENCO)'
cerebral palsy		
dyslexia		
dyspraxia		
physical disability		
physical impairment		
physically challenged		
disability		
disabled		
impair		
impaired		

Relevant studies were identified through automated searches using the electronic 'Searchable Publications Database (SPuD)', which is a database developed internally by EdTech Hub that aggregates literature and publications focused on the use of technology to support teaching and learning in LMICs. SPuD is a highly sophisticated search engine with embedded features that support automatic searches by applying lengthy search strings comprising of a main 'keyword' along with multiple options such as 'geographic country / regions (gd)', 'technology education / other (TE / TO)', 'population education / other (PE / PO)', 'development terms (DT). SPuD searches the following databases:

- ProQuest
- Web of Science
- Scopus
- Directory of Open Access Journals (DOAJ)
- Education Resources Information Center (ERIC)

An example of a search string generated from a SPuD search is shared in Appendix A. The search results from SPuD were downloaded into the 'Zotero' referencing manager using Research Information Systems (RIS).. At the time of the review, SPuD contained work published from 2007–2019.[6] Given this limitation, complementary searches were done in ERIC and Scopus targeting the period 2019–2020. Simpler Boolean strings were used based on combinations of disability and technology terms, such as 'deaf' AND 'assistive technology' and 'deaf' AND 'enabling technology'.

As mentioned previously, we also looked at the grey literature by searching the websites of databases from organisations such as the Department for International Development (DFID), the Foreign, Commonwealth and Development Office (FCDO), USAID, Christian Blind Mission (CBM), Leonard Cheshire, SightSavers, Humanity & Inclusion, UNICEF, and the World Bank, thus yielding relevant published reports. We then went through these publications to look for any relevant research and / or report. The database searches were done between July and October 2020.

3.3. Study selection and data extraction

The process of title and abstract screening was conducted by one author. In full-text screening, parallel independent assessments of all of the

[6] The SPuD database has since been updated.

manuscripts were performed by two researchers to determine if they should be included in the review. This involved assessing adherence of each study to the eligibility criteria. Studies were evaluated based on relevance and adequacy. 'Relevance' involved checking that all the studies addressed the use of educational technology to support the learning of primary school-age children with disabilities, and 'adequacy' addressed the extent to which the research process was reasonably reported in the paper. Articles were excluded if there was insufficient description of the research methods in relation to sample size, age groups, and impairment group. Papers in the final list were all reviewed twice to ensure that they all met the agreed eligibility criteria. For papers about which there was a lack of agreement on whether to include or exclude them, joint discussions were held to achieve consensus.

Data were extracted from individual studies and recorded in a predefined data extraction form by two of the researchers in the team (see Appendix B). This form was used to record key background information about each study, including the location of the study, the sample size, and duration of intervention as well as key findings and any limitations. This form became the basis of more in-depth analysis.

No formal risk of bias or quality assessment was conducted given the heterogeneous nature of disability research particularly in LMIC contexts. The validity of eligible studies was considered at a holistic level based on 'adequacy' of the research to the scientific process across each type of research method. In doing so we ensured that we were inclusive of different research designs and approaches, especially when reviewing literature from different academic traditions and national contexts.

3.4. Data synthesis

A thematic matrix was developed using Nvivo 12.0 software and agreed upon by the team members. Main themes and subthemes were inductively generated during the coding of the studies and internal member checking was undertaken to establish an inter-rater validation exercise by selecting a random sample (20%) of studies, which were independently coded, and an agreement reached on thematic categories and the inclusion of evidence into those categories. Codes were continually refined to ensure that the interpretations were thorough and consistent across the articles. This process ensured that the specific delineation of the categories was consistent and congruent with full agreement on the themes identified. We conducted thematic analyses to identify the main outcomes and contributions of the articles that made the final list of selected articles for this review report. Finally, we created node clusters according to similar methods, approaches, and keyword-in-context into auto-generated subthemes.

The research questions are addressed using a combined quantitative and qualitative synthesis approach. To answer RQ1, a quantitative summary of the research landscape is provided by unpicking specific questions such as:

- What impairment types are the focus in research studies?
- Where has the research been undertaken?
- Who is funding the research?
- Where is the research being reported?
- What types of methodologies are being used?

This overview sets the foundation for the qualitative synthesis reported to address the research questions. The thematic analysis strategy used involved exploring the relationships and differences between the study findings and the extent to which they reflect common, higher order themes (↑Petticrew & Roberts, 2006).

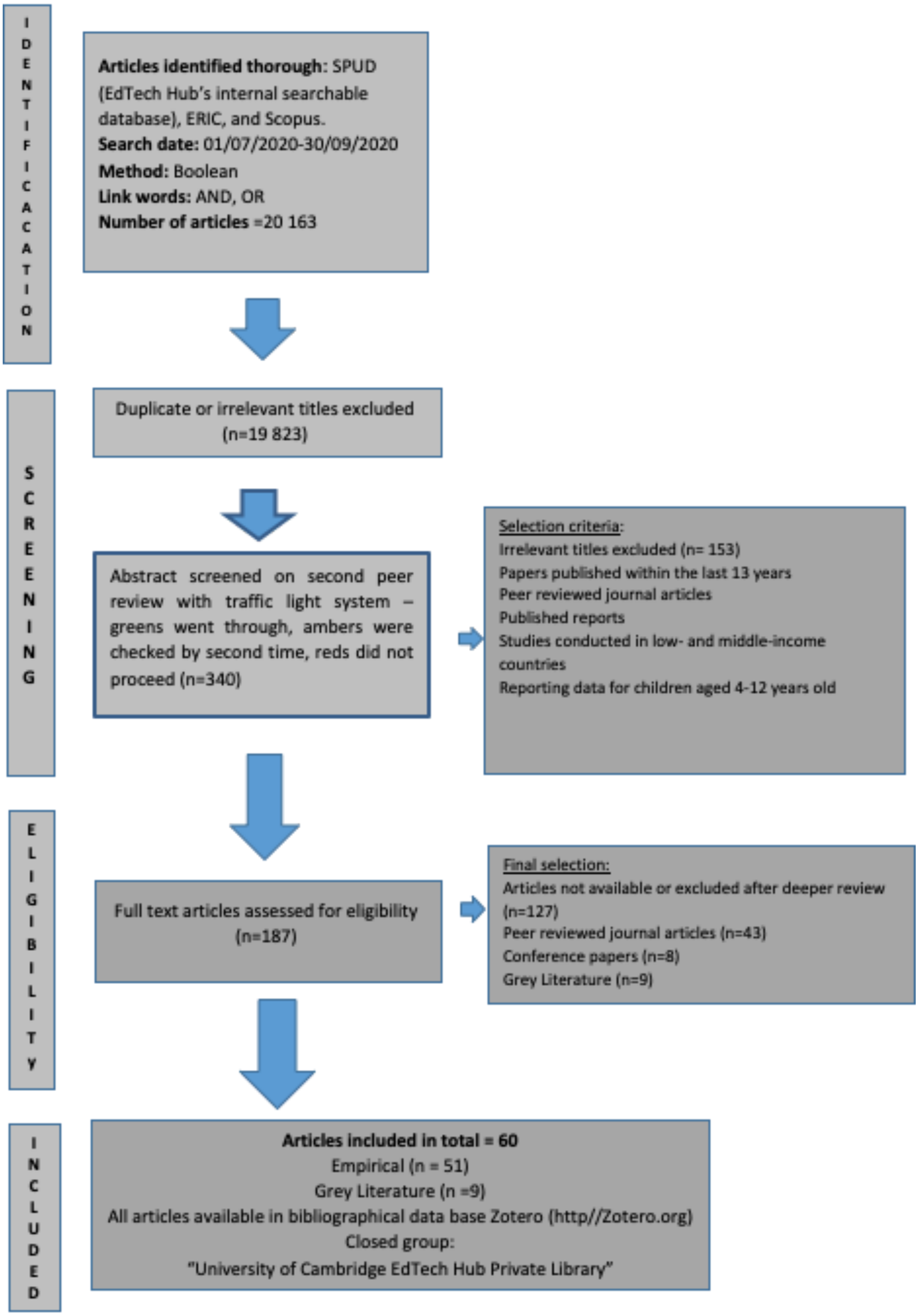
4. Results

The results of the literature screening are presented along with a description of the characteristics of the studies in the review sample. This is followed by findings from the literature synthesis.

4.1. Study selection

The initial pre-screening yielded 20,163 sources. After de-duplication and title screening 340 studies were retained. We carried over 187 articles for full-text screening. Full-text assessment resulted in studies being selected with 95% agreement. Consensus discussions between two authors were held to resolve disagreements (n = 10 papers) after independent full-text assessment of the articles based on the eligibility criteria. After systematic screening, insights from 51 articles form the core of this report. However, being mindful of the expansive grey literature in the area of disability (particularly in LMICs), we selected 9 reports — details on how we identified these are discussed later.

Figure 4. *Process of review.*



4.2. Key characteristics of the studies

Of the 51 papers included in the review; there were 43 journal articles and 8 conference papers. The papers represent work being undertaken across 27 LMIC countries: Asia (n=27), Africa (n=16), South America (n=6), Europe (n=2). The country breakdowns are visualised in the map presented in Figure 5 and the names of the specific countries where the studies were undertaken are named in Figure 6.

Figure 5. *Distribution of research by country.*

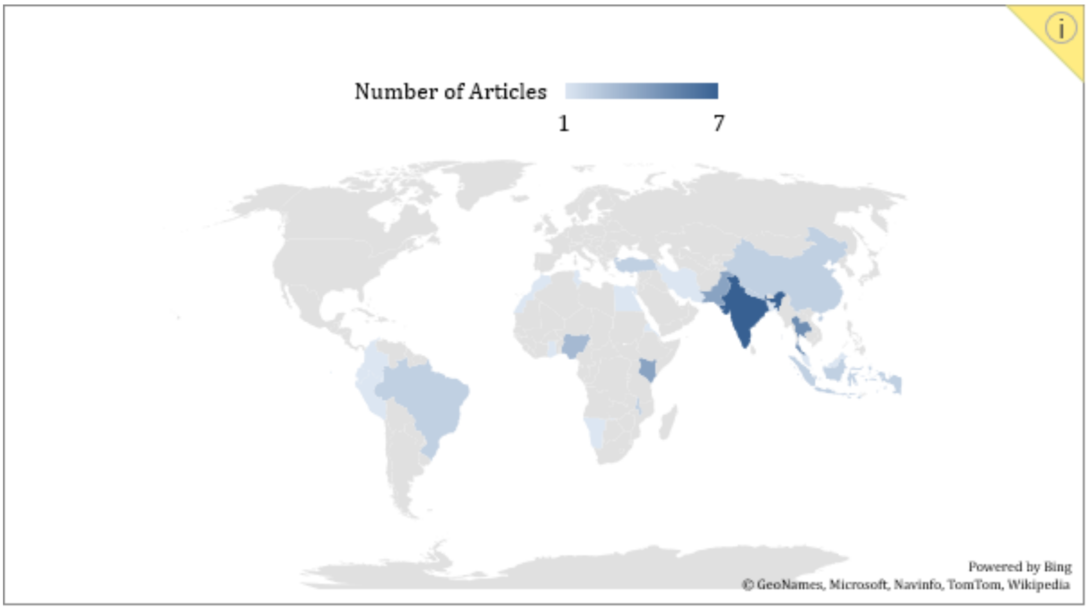
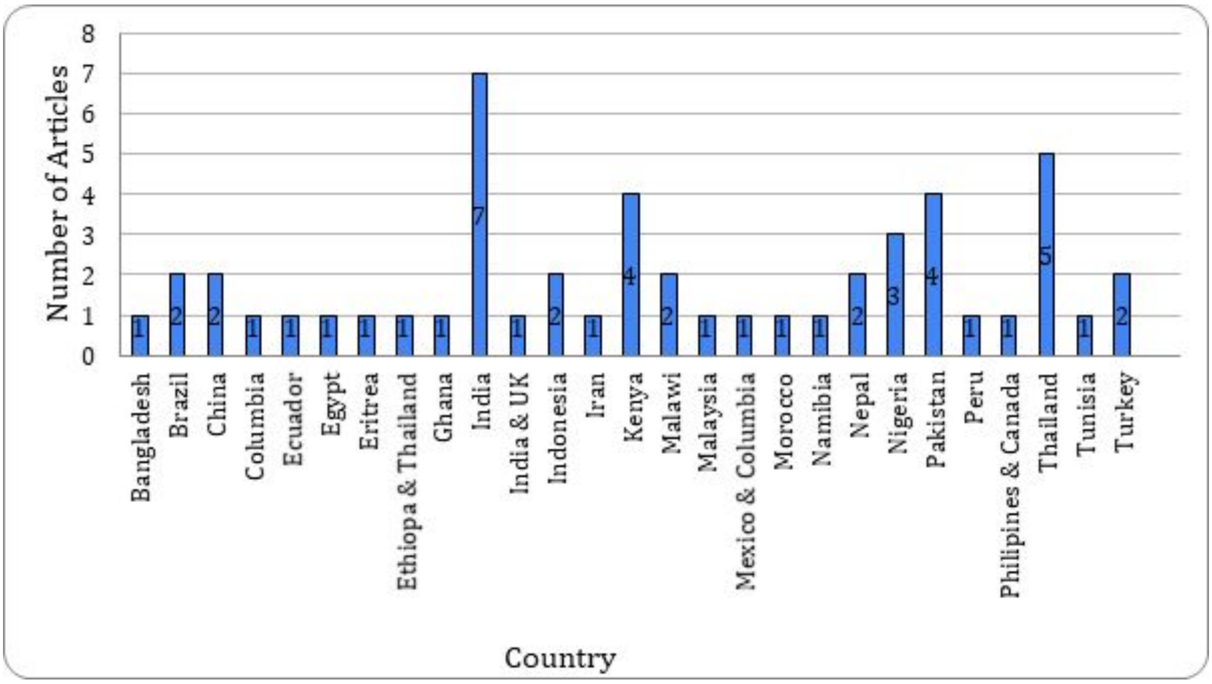
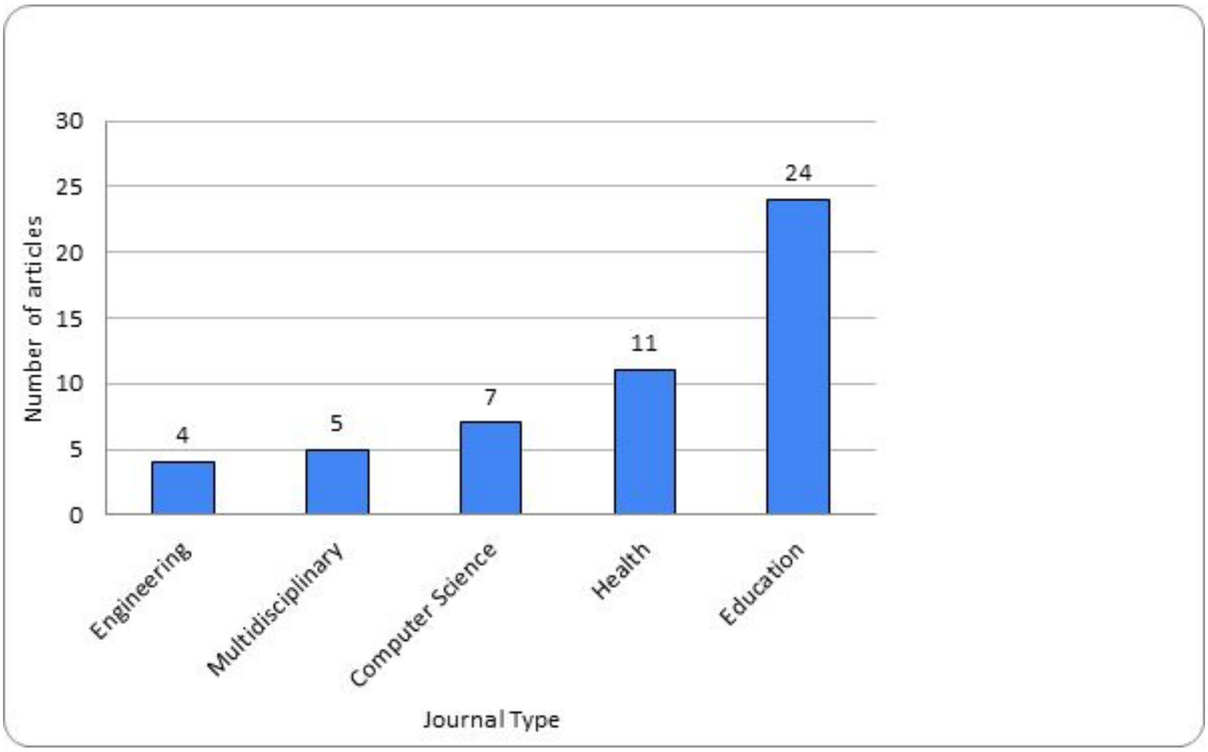


Figure 6. *Names of countries where studies were conducted.*



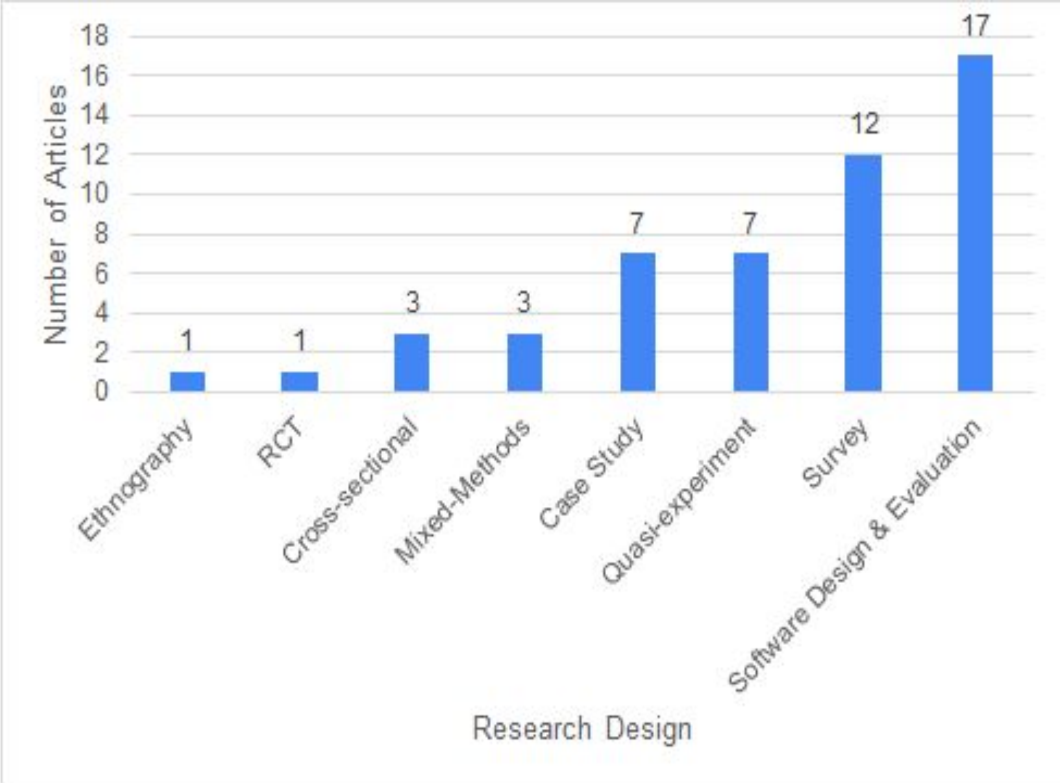
The journals in which these papers were published were diverse across education (n=24), health (n=11), computer science (n=7), engineering (n=4), and multidisciplinary journals (n=5), which suggests that a substantial amount of the research exploring technology solutions in education for children with disabilities is happening outside of the mainstream education field (see Figure 7).

Figure 7. *Type of journals where research has been published.*



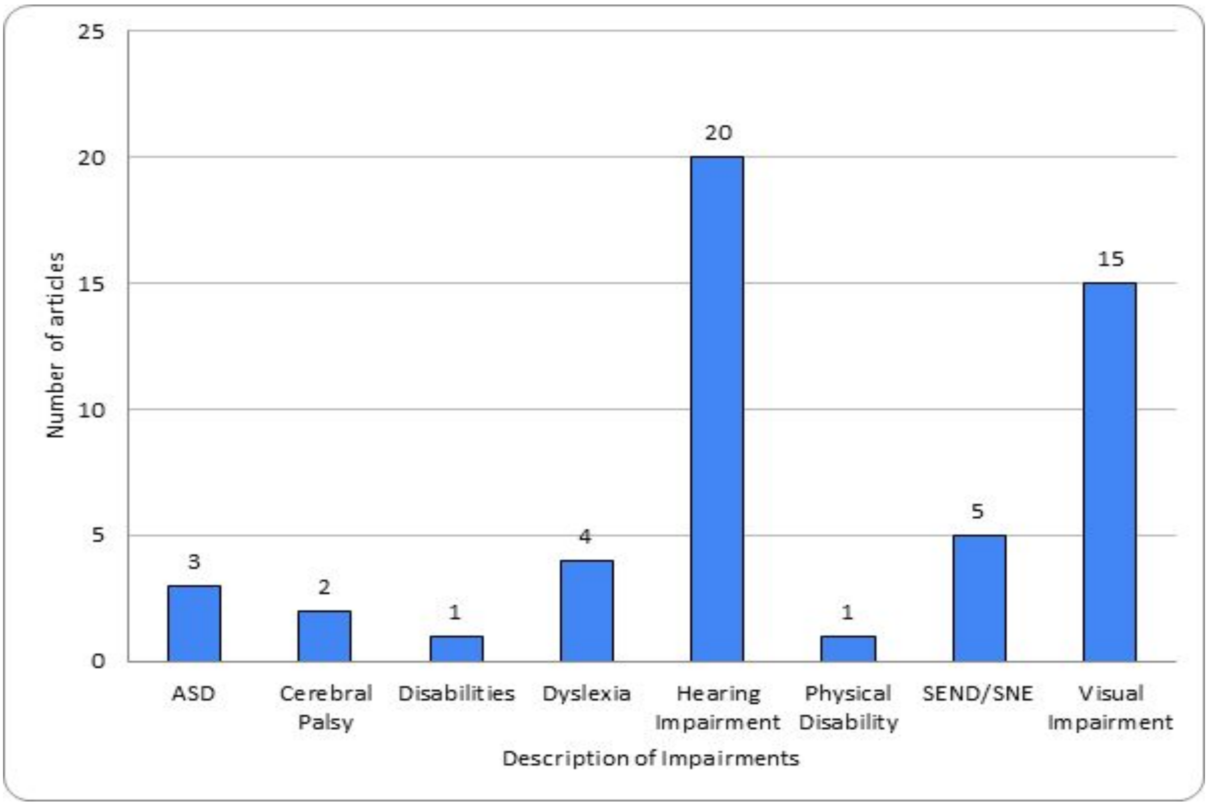
The studies reviewed adopted diverse research designs (see Figure 8), such as: software design and evaluations (n=17), surveys (n=12), case studies (n=7), quasi-experiments (n=7), RCTs (n=1), mixed methods (n=3), cross-sectional studies (n =3), and ethnographies (n=1). Significantly, the highest number of studies involved software design for deaf or hard-of-hearing learners (n=12) to teach sign language, basic mathematical concepts, and lip-reading. It is also important to highlight the high number of studies that used a combination of survey methods (such as questionnaires) to collect data about learners' and teachers' understandings and actual uses of technology. By contrast, only one study drew on an ethnographic design, which measured the outcomes of a speech therapy programme's goals against the expectations of teachers of deaf learners in India (↑Nanavati, et al., 2018).

Figure 8. *Types of research design.*



We identified 11 different types of impairments or conditions across the papers. These are described according to specific terms used in the papers found, namely, hearing impairment (n=20), visual impairment (n=15), special education needs or special needs education (SEND / SNE) (n=5), dyslexia (n=4), autism (n=3), cerebral palsy (n=2), general disability (n=1), and physical disability (n=1), (shown in Figure 9).

Figure 9. *Articles by types of impairment.*



The majority of studies did not give a breakdown of male and female participants in their studies, instead providing a total number. Eleven studies did not specify any sample size and only ten provided a breakdown of gender of which around twice as many were male to female (see, for example, (↑Nanavati, et al., 2018), 39 boys and 18 girls,(↑Joy, et al., 2019), 17 boys and 11 girls, (↑Ampratwum, et al., 2016), 23 boys and 12 girls). In the only study which surveyed teachers' knowledge and use of AT in Nigeria, out of a total of 433 teachers around 35% (n=153) were female.

Similarly, studies trialled a wide array of technological innovations for children with disabilities in school settings. Specific uses of technology included:

1. eye tracking (n=1)
2. speech therapy (n=1)
3. tangible user interface (n=1)
4. touch screen tablet (n=1)
5. website technology (n=1)
6. computer assistive technology (n=2)

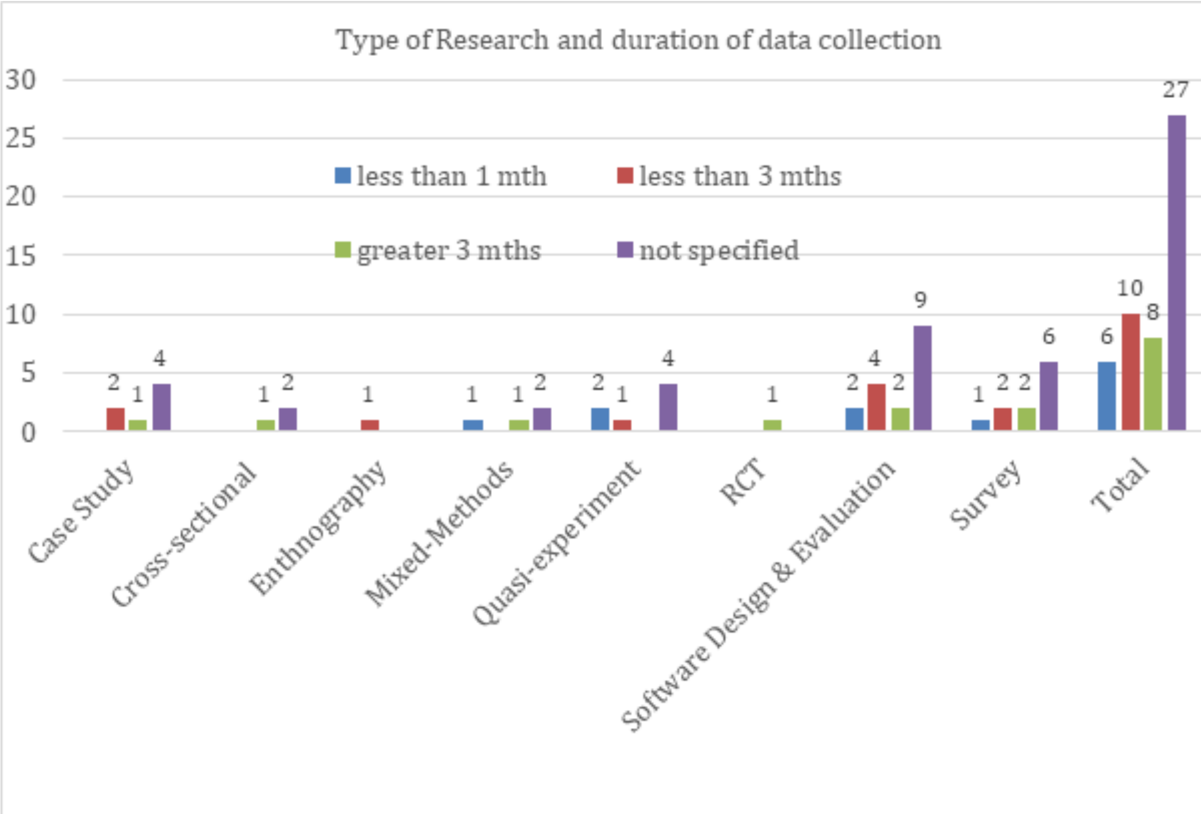
7. lip reading software (n=2)
8. optical devices for low vision (n=2)
9. sign language software (n=2)
10. braille technology (n=3)
11. virtual reality technology (n=3)
12. mobile phone applications (n=6)
13. 'Deaf' educational software (including teaching sign language) (n=9)
14. surveys about technology (n=15)

Individual research studies were conducted in different school settings; notably, a significant number of these took place in special education schools (n=34), with fewer taking place in mainstream schools (n=7), integrated schools (2), across multiple school settings (n=2), and non-school settings like rehabilitation centres, eye-care settings, or NGO sites (n=3). A few papers did not identify the educational setting (n=3).

Primary school age was the main focus of this review. However, some studies included wider age ranges extending beyond primary school level, particularly within special school settings that included both primary and secondary school learners. Other studies included older children because their developmental age corresponded with that of learners attending primary school; hence, these papers were retained in the review. The school-level categorisation of papers taking into account learners' ages included pre-primary only (n=1), primary (n=19), and a combination of primary and secondary participants (n=7), whereas a significant number of papers did not provide this level of descriptive information (n=24).

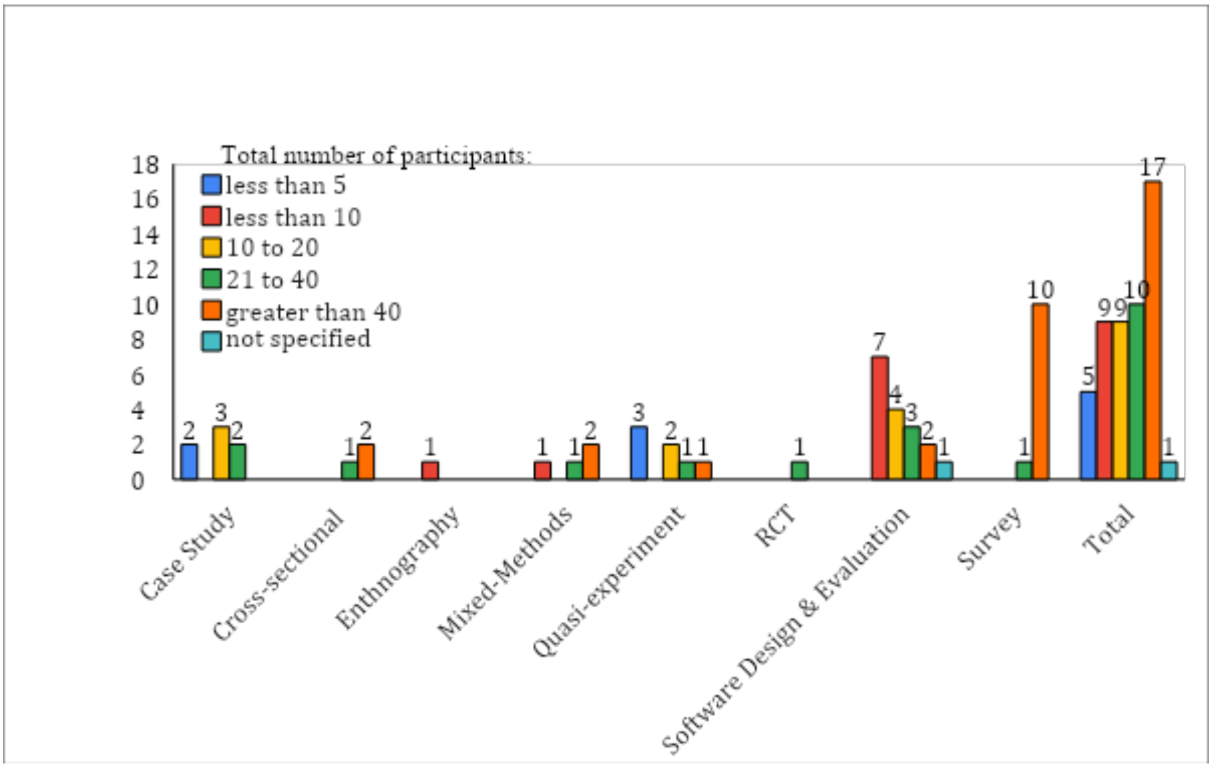
The length of time over which studies were conducted (that is, duration of data collection) ranged from less than one month (n=6), less than three months (n=10), and greater than three months (n=8). A bulk of studies did not provide this level of detail (n=27) but were included in the review as they indicated evidence of research exploring the use of technology with learners with disabilities in LMICs. The majority of these studies were typically user-evaluation studies which either entailed assessing the feasibility or usability of specific software or an app or device in the classroom. User-evaluation studies tend to involve very short trials to rigorously pilot a new piece of technology or carry out a rigorous educational intervention, hence generalisations from such short interventions need to be treated with caution. Studies that built in little lead-in time for learners to access and become conversant with the technology (learning to access) generally did not engage in relevance to the national curriculum or measure learning outcomes. Figure 10 compares the duration of data collection by type of research.

Figure 10. *Types of research and duration of data collection.*



A significant number of studies included small sample sizes. The breakdown of sample sizes included less than 5 (n=5), less than 10 (n=9), from 10 to 20 (n=9), between 21 and 40 (n=10), and greater than 40 (n=17). Six studies targeted teachers only and eight studies had a combined sample of learners, teachers, and / or administrators. Figure 11 compares the samples sizes used across different types of research methods.

Figure 11. *Types of research and sample sizes.*



The question of where the research is being initiated, by which institutions and by which donors was also explored to understand the wider landscape. It appears that the majority of the research was undertaken through universities and organisations (n=32). Five of the studies were undertaken by researchers whose institutional affiliation was external to the country where the research took place, and 14 studies are collaborations between institutions within and external to the country. A handful of studies reported receiving independent funding to conduct their research. Fourteen of 51 articles acknowledged either internal, institutional, governmental, or international donor funding. Three of the studies were funded by UK organisations (namely, the British Academy, VSO, Moorfields Eye Charity) and one by the Canadian Research Council to conduct a comparative study between Canada and the Philippines. Funding amounts were not reported in the articles but based on the small sample sizes and duration of many of these studies, funding levels seemed to be quite modest (see Appendix C for the list of funders reported).

The following sections present studies examining and exploring design and implementation of technology in relation to impairment or disability. We provide an overview of the studies under each type (in alphabetical order), followed by key takeaways at the end of Section 5 in Table 4.

5. Main findings from the review

Analysis of the reviewed studies highlighted a clear emergence of focus on specific impairment groups. In this section we begin by presenting these alphabetically, summarising the nature of the research and highlighting key learnings, where feasible. We then present cross-cutting themes emerging in the literature, focusing on the role of teachers and parents, as highlighted in the research studies. We conclude the section by providing an overview of insights drawn from the grey literature.

5.1. EdTech for children with autistic spectrum disorders

Only three studies for learners with autistic spectrum disorders (ASD), were identified. This small number of studies may reflect the current situation where diagnosis of autism is still relatively difficult in many LMICs (↑Durkin, et al., 2015). Furthermore, technology for this group often falls within the higher-tech range — for example, virtual reality (VR) programs — which requires specific teacher development and reliable technical support to ensure good quality access for the learner.

Two of the studies in China piloted a teacher instruction application, namely (Leap Motion-based) Computer Aided Instruction (CAI), with three learners aged 6–7 years with ASD (↑Hu & Han, 2019), another that worked with four children aged 9–11 years (↑Hu, et al., 2020), and a final one that examined the use of an AAC app on an iPad with 20 children with ASD in India.

Findings from the studies conducted in China indicated that the gesture-based instruction (Leap Motion-aided VR technology) has shown benefits for the learners, prompting on-task behaviours as well as improving gesture-based learning of matching-to-sample tasks. However, the results do not indicate any differences in their acquisition and maintenance of match-to-sample skills across the participants. One challenge in this study was that the hand-gesture recognition was not sensitive to young children's smaller hands. The small number of participants in two separate segregated settings makes it difficult to generalise the data to other settings, including those in rural areas of the country. Although previous research has reported gesture-based applications via Leap Motion as promising and as a possible strategy for improving the fine-motor skills of learners with ASD, this research provided no real empirical evidence of effectiveness of matching-to-sample skills training via Leap Motion-aided VR technology.

↑Hu & Han, (2019) carried out a small case study to test an AAC app compatible with an iPad to improve communication of 20 children with high functioning autism in India. The special educators reported that the children experienced increased engagement when using the app. However, no learning outcomes were measured. Based on anecdotal information, the trainers witnessed an improvement in the children's interest in using the touch-screen technology. The authors see the potential of using the app as an educational tool where many concepts could be added in the picture mode. They felt that the parents were convinced that using AAC devices makes a change in communication for children with autism, but parents were not included in the study.

5.2. EdTech for deaf / hard-of-hearing learners

The highest number of studies identified were for deafness (n =13) and hearing impairments (n=8). Eleven studies took place in Asia (for example, in Indonesia and Thailand) and two in Africa (in Kenya and Namibia). As is the case with visual impairment (discussed later), all these studies took place in special schools. Small sample numbers of learners were recruited in most of the studies, apart from a study in Kenya. With the exception of a study by ↑Muñoz, et al. (2018), which included deaf / hard-of-hearing learners in the development and testing of software, all studies were published in engineering, science, and technology journals with an emphasis on testing a software program for acceptability and usability, with little reference to pedagogy or the national curriculum. The following four subsections present those studies that met our inclusion criteria:

1. Technology to provide deaf / hard-of-hearing learners with access to learning.
2. Teaching of lip-reading using software.
3. Software to teach sign language.
4. Software to teach maths.

5.2.1. Use of technology to provide access to learning to deaf / hard-of-hearing learners

The following four studies give an idea of how technology is being used to provide access to learning in special schools in Pakistan (n=2), Peru (n=1), and Turkey (n=1). The studies mainly report on learners' preferences in relation to assistive technology and social media, with some indication of improved learning 'process', 'opportunities', and 'achievements' but nothing specific to the learning outcomes linked to the school curriculum or to the expanded core curriculum[7] (such as learning sign language). For instance, ↑Zahra, et al. (2018) carried out a survey to find out what mode of communication and software 362 children with hearing impairment aged 10–20 years were using while attending special education centres and schools in Pakistan. Around 50% of the children said they use Skype, Facebook, SMS, and email to communicate at school. In Peru, ↑Ramos-Ramirez & Mauricio (2019) tested a video game to help with writing Spanish with nine deaf children between the ages of 8 and 12 years. Apparently, those who used video games showed an improvement in the learning process, which is reflected in a 22% increase of the average grade.

In a larger survey of 100 Grade 4learners from seven schools for deaf / hard-of-hearing learners as well 60 volunteer parents of children with a hearing impairment, ↑Farooq, et al. (2015) found a significant positive correlation between the perceptions of parents about AT and the learning achievements of their children when using AT. Hearing aids are the most preferred and affordable devices for children with a hearing impairment in the Pakistani context. This study also conceded that there is a clear difference in the learning achievements of learners with a hearing impairment who use 'high-tech' AT (smart phones) in comparison to low-tech AT (sign language cards), but very little is said about what the different learning achievements are as a result of the differentiated learning experiences.

In Turkey, ↑Goker, et al. (2016) carried out a study with five children who had received cochlear implants in a private rehabilitation centre to evaluate educational software. The software was focused on teaching children ways of expressing their emotions to contribute to their academic success at earlier ages in their primary educational process. It was reported to be quite effective in terms of high usability, raising levels of ability to express

[7] Expanded core curriculum includes areas which would not typically be taught in schools as part of a core curriculum, such as mobility skills, low-vision and information access, social skills (for example, having friendship groups and self-advocacy skills), early communication and language development, and AAC systems.

emotions from 57% to 97.5% post intervention. The study does not provide a breakdown of the post-intervention range of emotions, and neither does it provide details about the hearing levels of the individual children before and after receiving cochlear implants.

5.2.2. Teaching lip-reading to deaf / hard-of-hearing learners using computer-assisted instruction

Two small research projects focused on developing deaf children's lip-reading skills in Thailand and Indonesia. ↑Nittaya, et al. (2018) developed an online lip-reading training course and game to help ten deaf / hard-of-hearing learners to learn to lip-read other children aged 10 years so that they could join a lip-reading class in Thailand. An average of 52% improvement was shown on the post-test with learners being able to recognise mouth movement and a 60% average improvement from the post-test experiment that learners could recognise mouth movement. In the Indonesian study, ↑Muljono, et al. (2019) developed a lip-reading educational media app to help deaf and hard-of-hearing learners to learn Bahasa (the official language of Indonesia). It was tested with five learners and five teachers. The conceptual model uses pictures, lip-reading video, text, and sign language to help the users understand the content. The results show that the prototype matches the so-called usability goals and positive user experience. Based on these results the application designers proposed a mobile application to help learners to use it more easily in their free time.

5.2.3. Software programs to teach sign language to deaf / hard-of-hearing learners

The following section analyses seven studies which piloted software programs to teach sign language or integrate sign language into present learning materials. All the studies were in South East Asia and only one study in Malaysia centred on teaching sign language to preschool children. Sample sizes ranged from only a few learners (n=3) in Malaysia to a much larger group study (n=141) in Thailand.

↑Ahmadi, et al. (2015) piloted a software program to help to support the hygiene health (such as washing hands, bathing, oral and ear hygiene) of deaf and hard-of-hearing learners in seven primary schools in Tehran, Iran. The multimedia software programs included educational videos with sign language, guiding images, and subtitles with simple short sentences, as well as deaf-specific designed animations. Results indicated greater learner understanding of personal hygiene and proposed ways the software program could be generalised across different learning areas.

↑Cano, et al. (2018) carried out a very small study in a special school for the deaf and a mainstream school in Colombia and Mexico to design a serious game for deaf and hard-of-hearing children aged 12–15 years who are experiencing literacy problems. Eight children from 7–11 years of age were also evaluated in the Institute for Deaf and Blind Children in Cali, Colombia. The model shows some promise but again the sample size was very small and it is difficult to determine whether both the model and teaching approach could be used in other contexts — although there would be some potential in other Spanish-speaking countries. Areas including affective, cognitive, and physical domains were identified. The physical aspect greatly influenced the way the children managed to communicate, since, depending on whether or not they have devices or hearing aids, their communication may be either verbal or through sign language.

↑Joy, et al. (2019) recruited 28 learners to rigorously test an app (using open-source library TensorFlow from Google) to teach sign language (language not specified) using Android phones in a school for the deaf in Kerala, India. Positively, this app (SiLearn) can be used by children, parents, and teachers alike for learning sign language. One of its advantages is that learners can use the same picture books for learning vocabulary in sign language as those used by spoken language learners. Learners need to have access to mobile phones and picture books.

In a participatory case study, ↑Muñoz, et al. (2018) used observations to identify the strengths and difficulties of deaf learners while designing a guide on how to develop accessible and appropriate apps for deaf learners in Colombia aged between 7 and 14 years. There was positive feedback from learners but the sample group was very small (n=5). This study offers some good ideas in terms of the consultative process undertaken between designers and learners, a process which is generally lacking in many studies.

In one of the few studies carried out at preschool level, ↑Masitry, et al. (2013) developed a software program to teach Malaysian Sign Language alphabet and numbers to preschool children. Results indicated that learners showed improved learning performance using the program, e-MSL, compared to traditional learning methods. There is promise in terms of scaling up but the sample size of only three learners questions the viability of the program. There is also a possibility of enlarging the database of words to take account of dialects or slang, as well as options to incorporate instructions into other languages such as Malay, Chinese, and Tamil.

In a revealing ethnographic study of a school for the deaf in India, ↑Nanavati, et al. (2018) found a misalignment between teachers' expectations of deaf / hard-of-hearing learners' speech and language therapy goals and what software games were offering. Specifically, teachers described their approach to speech therapy as involving a binary distinction between learners who "can't speak" and those who "can try [to speak]" and they placed greater expectations on better matching of what the technology can do with the specific pedagogical difficulties the children were experiencing at school.

In terms of helping learners to acquire vocabulary in sign language, ↑Wicha, et al. (2012) developed a Total Communication with Animation Dictionary (TCAD) to enable deaf / hard-of-hearing learners in primary schools to acquire English vocabulary and improve their retention skills using sign language, finger spelling, lip-reading, picture captioning, reading, writing, and vocabulary in Thailand. The sample comprised 141 learners from one school for the Deaf in Chiang Mai. In a different study, ↑Iam-Khong & Suksakulchai (2011) developed an online Sharing Dictionary to teach Thai Sign Language (TSL) to improve the understanding and long-term retention of TSL for hard-of-hearing learners in Grade 5 from three schools for the hard of hearing. Results indicated that learning outcomes for the hard of hearing improved after using this system to learn TSL vocabulary. In a similar study on increasing the literacy skills of the deaf / hard of hearing, ↑Karal (2015) found that learners were building more grammatically correct Turkish sentences. Credit was given to the introduction of a new learning environment that provided the impetus for teachers to seek changes in how they teach the curriculum and apply new teaching methods to deaf / hard-of-hearing learners.

Finally, ↑Bouzid, et al. (2016) examined how nine deaf learners, aged 9–16 years used educational games for learning such as visual-gestural modality learning through a 3D signing avatar which used SignWriting notation and new vocabulary (MemoSign) in Tunisia. The project fostered and promoted vocabulary acquisition for deaf / hard-of-hearing learners in both signed and spoken languages. Around 89% of participants found the games useful and effective in supporting their vocabulary building; it offers an innovative approach to learning SignWriting notations and thus can constitute a useful tool for teaching the vocabularies of signed and spoken languages.

5.2.4. Maths software programs for deaf and hard-of-hearing learners

We identified four studies that tested mobile apps to teach maths using sign language to learners in Pakistan, Thailand, Namibia, and Kenya. It is positive to see studies that are investigating better ways of linking technology, such as apps, to the core curriculum for deaf / hard-of-hearing learners. For instance, ↑Parvez, et al. (2019) studied how a mobile app is using Pakistan Sign Language (PSL) to teach maths to 192 deaf participants aged 5–10 years at two special schools in Islamabad, Pakistan. Results showed better performance of participants who used the mobile apps when learning basic mathematical concepts but lower performance levels when teaching higher level concepts, such as geometry and algebra. In Bangkok, Thailand, ↑Techaraungrong, et al. (2017) designed and tested a multimedia resource to develop arithmetic (counting, subtraction, and addition) skills with 11 deaf / hard-of-hearing learners in Grade 1 compared with teaching counting, addition, and subtraction using a conventional teaching approach in Grade 1 (aged 7 years) in two boarding schools for deaf learners. Again, the results revealed that using multimedia improved learning more in addition and subtraction.

In Namibia, ↑Abiatal & Howard (2019) developed RekenTest (RT) educational software to help teach learners to practise, analyse, and test their arithmetic skills offering a range of problems from easy to difficult as well as progress reports after each session in a special school. There is no data about the pre- and post-tests given to the learners, but all the teachers involved were positive about teaching and learning with the AT and reported that it improved teaching and made it fun.

Finally, in Kenya, ↑Kiboss (2012) tested a special e-learning program consisting of eight geometry and pattern-making activities, which were extracted from lessons and the primary school syllabus recommended by the Kenya Institute of Education (KIE) for teaching during the school term. A total number of 66 deaf / hard-of-hearing learners were located in special education schools with available electricity. The learning activities were accessible through a simplified graphical user interface (GUI), using the mouse as a pointing device. Learners attained better results than when using the conventional mode of instruction but there was also an opportunity to enable deaf / hard-of-hearing learners to learn at their own pace. The study recommends that similar programs should be made part of classroom instruction to help teachers speed up and improve the delivery of concepts and lesson content to learners with special educational needs.

5.3. EdTech for learners with dyslexia

A total of four studies that explored technological solutions to assist learners with dyslexia were identified. This may be an under-reported and under-diagnosed disability in LMICs, with no evidence of studies being undertaken on this topic in sub-Saharan Africa. Although, interestingly, the only study included in the reviews that was conducted in North Africa

(Morocco) focused on dyslexia. The other three studies focusing on learners with dyslexia were located in India, Malaysia, and Pakistan.

In Morocco, ↑Benmarrakchi et al. (2017) evaluated the usability of an interactive educational mobile learning game to study and improve fundamental skills such as reading, writing, comprehension, Arabic orthography, short-term memory, and concentration of eight learners aged 8–10 years with dyslexia using tablets in a primary school. The study provides most details about the potential benefits offered by the use of ICT for dyslexic learners by focusing on the actual design of an adaptive mobile learning game, which, it claims, directly matches the learning styles of dyslexic learners through the use of advanced digital technology. However, there is little evidence to support these claims in the article. In a separate study in Malaysia, ↑Mohamad, et al. (2017) explored the use of tactile letters for teaching the alphabet in the form of an app (LetterReflex Mobile Application Educational Software) on an iPad with four children with dyslexia. The children practised naming and pronunciation of single letters individually within a game format on the iPad. The app was reported to have helped children to overcome common letter reversals in a game format that is inviting, engaging, interactive, and user-friendly. Again, more evidence through assessment could help to justify this claim.
In India,↑Pandey & Srivastava (2011) explored the use of Tangible Interactive Blocks (Tiblo Tiblo) with a group of children (number not provided) aged 8–10 years, which enables them to record their own voices while problem solving. The e-blocks can record and playback up to 10 seconds of pre-recorded sound and can be physically connected to other similar blocks in any orientation, with modifiable colours, sounds, and visuals. The interactive nature of the blocks was useful for both maths and English. Learners appreciated hearing their voices retelling their stories or problem-solving strategies and had a strong sense of ownership of the blocks through using them in different ways. No learning outcomes were measured or reported in the article.

In Pakistan, ↑Tariq & Latif (2016) tested a mobile app to identify learning, design, and conceptual and technological issues with 20 dyslexic learners under five years, which seems to be a very young age to be screening for dyslexia. They reported that around 30% of the participants (aged 3 –4 years) were having problems with reading, while more than half were diagnosed as also experiencing phonemic difficulties. The researchers reported that it is unclear whether assessments at that age are effective given the fact that exposure to the application was only for two weeks.

5.4. EdTech for learners with physical disabilities

We found few studies that looked at EdTech for learners with physical disabilities. Technology that matches this heterogeneous group of learners is very broad and tends to focus on physical mobility devices, which are an essential part of access to learning. A parental survey in Kenya conducted by ↑Kamau (2017) enquired about the provision of mobility devices and educational resources for children with physical disabilities in a specialist primary school. The sample size constituted 30 children with physical disabilities (the majority of whom had cerebral palsy), 30 parents and 4 teachers — a total sample size of 64. Around 54% reported that they provide mobility / assistive devices such as callipers, walkers, wheelchairs, and crutches, which enable their children to participate in various play activities at home, and 21% provide devices for use at school. About 33% of the parents believed that teachers should take responsibility for providing child mobility or assistive technology. Parents tended to provide mobility or assistive devices for home use.

In a published conference paper, ↑Alvarado-Cando, et al. (2019) summarise a study involving five children with cerebral palsy aged 5–7 years and testing an eye-gaze system (called Irisbond) in Ecuador. The system enabled the learners to control the computer through the movement of their eyes. The study demonstrated that four out of the five learners received a higher grade using the eye-gaze system than using traditional evaluation methods.

In a different study, ↑Martins, et al. (2019) explored two types of software programs:one that tests coincident timing in a learning environment through physical contact, and another called 'MoveHero' that provided virtual tasks for ten learners with cerebral palsy, aged 6–19, to improve motor performance, motivation and engagement. The results showed that there was an improvement in performance between the pre- and post-tests. The discussion on the expansion of this software is unclear.

5.5. Technology for learners with visual impairments

Unsurprisingly, technology for visual impairment (blind and low vision combined) featured in the second highest number of papers (n=19) after deaf / hard of hearing / hearing impairment (n=21). Assistive technology for visual impairment is one of the most developed areas of EdTech and has made impact in different ways, particularly in relation to the proliferation of low-vision devices, the greater sophistication of screen-reading software such as Job Access with Speech (JAWS) for blind users (↑Ampratwum, et al., 2016), and access to mobility and tracking devices, as well as technology for the reproduction of Braille in electronic and speaking formats and talking books. These technologies are captured in studies that mainly took place in South and Southeast Asia and within special schools. The following section presents a synthesis and analysis of the surveys (n=3), RCTs (n=1), interventions (n=3), and pilots of how mainstream and assistive technology are understood and being used in the classroom. Significantly, nearly all the studies took place in a special school setting.

In a study investigating the impact of AT on reducing barriers to access to computers at a special school in Ghana, ↑Ampratwum, et al. (2016) found that 95% of blind learners (n=35) experienced difficulties mastering the shortcut keys they needed to learn to master the QWERTY keyboard. This study highlights the need for blind learners to have access to touch-type tutorials that will enhance their ability to use the keyboard and give them greater independence at school over time (thus moving from 'access to learning' to 'learning to access'; see Figure 2).

Five out of the 19 studies investigated the use of low-vision devices or LVDs (such as reading stands and handheld magnifying glasses) in special schools, and although they do not look at specific learning outcomes, they do indicate the urgent need for all children attending special schools to receive regular comprehensive eye assessments, which include not only a visual acuity test but also functional vision assessments to establish children's eye condition (such as ocular and / or cerebral visual impairment[8]), their use of residual vision, correct prescription of spectacles and / or low-vision devices (such as reading stands, handheld magnifiers, stand magnifiers, monocular telescopes), and screening for potential deterioration of vision as a result of eye condition.

The following three studies highlight the importance of full clinical eye examinations for children attending schools for the blind and correct match of AT for their functional vision. Not receiving a comprehensive eye examination can result in children not being prescribed the correct

[8] Ocular conditions affect parts of the eye itself and commonly include refractive errors such as astigmatism and severe myopia (or short-sightedness). The loss arising from a given ocular vision condition can include a number of areas of function such as visual acuity (the ability to resolve detail), accommodation (the ability to focus), field of vision (the area which can be seen), colour vision, and adaptability to light. Cerebral vision impairment (CVI) affects the child's processing of visual information. CVI is particularly prevalent in children who have more complex needs and may be diagnosed by itself, or "may coexist with ocular forms of visual impairment" (Roman-Lantzy, 2007, p. 3).

low-vision device, leading to missed learning opportunities and waste of scarce resources. ↑Joshi, et al. (2008) conducted a study in Nepal at two special schools for learners who are blind and one school for learners with special needs in Kathmandu Valley. They found that around a third (23%) of the 62 learners screened at the special schools actually had low vision rather than total blindness. All these children were provided with low-vision devices and they used them regularly to access print instead of Braille. The teachers could see the changes in their lifestyles through improved mobility and better performance of day-to-day tasks. In addition, they noticed the learners' "significantly elevated confidence" in their academic performance compared with before the devices being prescribed. There is no data on what aspects of academic performance teachers were referring to, but the study focused more on the appropriate match of technology to the reading medium (print or Braille).

In a larger study of 779 learners aged 6–24 years with low vision attending integrated schools in 38 districts in Nepal, ↑Gnyawali, et al. (2012) found that low-vision devices were either damaged or misplaced (64%), with 32% of learners feeling discomfort while using the device, 18% having been given inadequate instructions on how to use the device, and 14% having been provided inappropriate lighting and sitting arrangements. In a later study in Eritrea, at a school for the blind, ↑Gyawali & Moodley (2018) found that many of the learners had not received a full clinical eye examination and functional assessment of vision of both eyes. Results show that out of 86 learners screened, 28% (n=24) could have received curriculum materials in print in mainstream schools and nearly half (n=44) were unable to identify or read the print on the near vision chart. A total of 8 out of the 42 children had normal near vision. Importantly, the number of children with severe low vision significantly reduced after correction of vision for 24 children, with 23 children having improved vision with low-vision devices and 19 (27%) children being able to read letters on a textbook with prescribed low-vision devices. In a survey of 250 learners with visual impairment who use AT in India, Semjan et al. (2019) found that teachers lacked awareness of the benefits of AT in accessing learning materials. There were also concerns about the cost of ATs, which may have contributed to the low take-up of low-vision devices in ten schools for the blind in Delhi, India. The results revealed that most learners were using Braille slate and stylus (almost 100%) and sound-based handheld audio recorders (96%) even though those with some residual vision could have benefited from low-vision devices. Other devices were poorly used, ranging from nil (typoscope) to 55% (screen readers).

In an RCT conducted in India, ↑Gothwal, et al. (2018) measured the impact of tablet computers on the education of 40 learners (20 in the UK and 20 in India) aged 10–18 years with low vision, with a specific focus on independent access to educational materials in India and the UK. The participants quickly learnt to operate the iPad in a classroom compared with the use of closed-circuit television. They were able to use the iPad to read the board using the zoom feature to magnify the content so that they could follow the lessons at the same time as that of their peers. In addition, they found the iPad convenient, as the single device could be used for multiple tasks such as reading, accessing the internet, and watching videos. We have to be cautious about the findings from this study but they show the potential of how tablets like iPads can be used to perform multiple tasks for learners with visual impairments and how they are providing an excellent way for learners to access learning content at the same time as their peers.

Finally, a study by ↑Nahar, et al. (2015) explored the use of a low-cost application (mBRAILLE) on an Android mobile phone to teach the writing of Braille in Bangladesh, which could lead to a major shift in how Braille is taught to learners with visual impairments. This evaluation study affirms that traditional AT (Braille frames and stylus), which have been used in classrooms across Bangladesh over the past 50 years, still remains too expensive for many schools. This innovation sensibly responds to the increasing use of low-cost Android mobiles in Bangladesh by introducing a program that helps learners to master writing Braille. It also rightly points out that it does not replace ways of learning how to read Braille, which continue to remain the remit of the teacher. Satisfaction levels on usability were relatively high for the five learners who tested the application during the pilot study. However, a follow-up study is recommended by the authors to see if teachers can integrate the application into the broader curriculum.

As a conclusion to this section, Table 4 summarises some of the different types of technology that were highlighted. It highlights some important considerations should funders and policymakers wish to scale up successful pilot studies. There are clear lessons that have been learnt from these studies, which should be taken into consideration when designing further development and scaling up in LMICs.

Table 4. *Summary of main findings and implications based on review of the evidence.*

Disability / impairment	Implications for potential development or scaling up in LMICs	Caveats / important considerations for scaling up

Autistic Spectrum Disorders (ASD)	■ Potential for VR to support children's interaction with technology but there are considerable cost implications (↑Hu, et al., 2020). ■ AAC has the potential to increase learning opportunities for children with ASD by expanding on the traditional instructional strategies such as pictures, flash cards, and videos (↑Sankardas & Rajanahally, 2017). ■ Gesture-based learning has limited success as not sensitive to learners with small hands (↑Hu, et al., 2020).	■ It is important to consider the feasibility of piloting high-tech applications in low-income countries where power supplies and availability of computer hardware are very sparse or non-existent. ■ No studies located in sub-Saharan Africa — need for more evidence in this region. ■ Exclusion of parents during testing of AAC can reduce chances of successful uptake of apps and touch-screen technology. ■ No studies examined communication systems that use pictures, symbols, or objects of reference (such as a cup for a drink).
Deaf / Hard of hearing	■ Good use of SMS and social media to access information for lessons and communication with peers in class (↑Zahra, et al., 2018). ■ Important to involve parents when introducing a new device to learners to help ensure support and reduce the chance of abandoning the device(↑Farooq, et al., 2015). ■ Hearing aids considered as preferred and affordable — need to examine the most appropriate aid for learners (↑Farooq, et al., 2015). ■ EdTech can increase overall learning opportunities and independence of deaf / hard of hearing (↑Goker, et al., 2016). ■ Population of children receiving cochlear implants is very small in LMICs — need to be able to broaden educational software to deaf / hard-of-hearing learners who use other devices (hearing	■ Cochlear implantation has involved strong links between medicine and education, which has implications in a number of areas: the medicalisation of deafness, which has been raised by the Deaf Community and concerns about the operation itself, and implications for education professionals working more closely with medical personnel. ■ Teaching deaf / hard-of-hearing learners to lip-read is controversial and is not encouraged by the International Deaf community. It is important to look at the local, historical, and cultural context of the community when deciding to teach lip-reading in schools. Potential misalignment with the UNCRPD that recommends "accepting and facilitating the use of sign language" (Article 21).

	aids) and sign language (↑Goker, et al., 2016). ■ Use of multimodal approaches to teach sign language — video, text, pictures, and finger spelling. Use of sign language dictionaries to help learners acquire new vocabulary. Multimedia games are appealing for learning sign language (↑Ahmadi, et al., 2015, ↑Joy, et al., 2019, ↑Wicha, et al., 2012). ■ Apps that help children, teachers, and parents to learn sign language. Deaf learners can access the same reading books as non-deaf learners using mobile phones. Additional costs of providing learners with mobile phones (↑Joy, et al., 2019). ■ Building on proof of concept could lead to software being expanded to enable hearing and non-hearing learners to learn together. Also, potential to teach other sign languages (↑Masitry, et al., 2013). ■ Implications of piloting e-learning programs where there is little or no available electricity at schools (↑Kiboss, 2012).	■ The proliferation of mobile phones and apps are having a positive impact on how the curriculum is being re-conceptualised and delivered to deaf / hard-of-hearing learners, but there are considerable cost implications for schools and learners without strong government incentives to subsidise costs. ■ Need to consider how similar studies which require specialist knowledge of sign language can be carried out in mainstream environments where teachers' knowledge of the ECC is limited.
Dyslexia	■ Apps are helpful to support learners' spelling through the use of games, tactile letters, and iPad (↑Benmarrakchi, et al., 2017, ↑Mohamad & Abdullah, 2017, ↑Tariq & Latif, 2016). ■ In India, learners had a strong sense of ownership of the computerised block although they used it in different ways, some focusing on sounds of individual blocks, some on the overall shape and some on the images in conjunction with sound (↑Pandey & Srivastava, 2011).	■ Very limited evidence on how best to support dyslexia. Need for more studies that are longer in duration and to address the heterogeneous nature of the group of learners.
Visual impairment	■ Need for regular eye assessments (both clinical and functional vision assessment) for children at special	■ Potential lost years of learning resulting in drop-out due to learners not receiving regular

	schools and those presenting with vision or other related difficulties in the classroom (↑Joshi, et al., 2008, ↑Gyawali & Moodley, 2018). ■ In Nepal, learners had "significantly elevated confidence" in their academic performance compared with before the introduction of low-vision devices (↑Joshi, et al., 2008). ■ Need for clear instructions on how to use the low-vision devices and to ensure they can be used to access different forms of learning materials. Prescribe more than one device for quality access as well as regular replacements for lost or damaged devices (↑Gyawali & Moodley, 2018). ■ Little or no training on how to use devices or software can lead to under-utilising the potential of the device and possible abandonment (↑Senjam, et al., 2020). ■ Use of zoom / magnification on mobile phones, iPads, or tablets can enable learners to access learning content at the same time as others, although cost is high (↑Gothwal, et al., 2018).	high-quality eye assessments and / or appropriate remediation through use of spectacles (correction of refractive errors) and low-vision devices. ■ Disappointingly, no evidence of how talking books (for example, through the DAISY Consortium) are being used to access the curriculum. ■ Need for much more training for teachers on what low-vision devices are available for learners with visual impairment and how they can be used to support access to learning and the curriculum and other educational activities. ■ Important to consider all accessible features available on different operating systems (such as 'Windows Ease of Access', 'Windows Speech Recognition').
Physical disability	■ A broad range of mobility and assistive devices are used by learners with physical disabilities to travel to and move around school unaided (↑Kamau, 2017). ■ Lack of clarity in determining who is responsible for purchasing mobility and assistive devices for learners. Teachers consider it the responsibility of parents, whereas parents consider it the responsibility of the ministry of education as part of its commitment to free primary education (↑Kamau, 2017). ■ Small evidence of improved motor performance and eye movement for learners with cerebral palsy in	■ Physical disability covers a wide range of impairments, from the ability to move quite freely with minimal assistance, to reliance on a motorised wheelchair. Persons with conditions like a spinal cord injury, paralysis, muscular dystrophy, and cerebral palsy may have a physical disability combined with other problems as well (such as injury from the brain, learning disability, hearing or visual impairment). The studies tended to focus on one impairment or disability. ■ Mobility devices (such as wheelchairs, walkers, crutches,

	Kenya (↑Kamau, 2017) and Ecuador (↑Alvarado-Cando, et al., 2019).	callipers) is an underexplored area within the education and disability literature. It is vital that the educational inclusion of learners with disabilities includes careful planning on access to school and participation in learning and social activities.

5.6. Cross-cutting Theme 1: the role of teachers in EdTech

A few studies (n=6) investigated the knowledge and skills of teachers, while only a handful (n=3) specifically examined teachers' attitudes towards using technology in their teaching.

Findings from these studies highlight significant gaps in the amount of knowledge teachers have on even the most basic technology used in the classroom. This is particularly concerning since the evidence comes from studies which took place in special schools, where specific types of technology really can support better access to the expanded core curriculum using assistive technology. For instance, schools for learners with visual impairment would benefit from a range of technologies that reproduce Braille in both tactile and auditory formats (↑Ajuwon & Chitiyo, 2015). In addition, having a greater choice of vision-based technology would help learners with even very low levels of visual acuity to use their residual vision to access print and other visual media (such as diagrams and drawings). Specialist teachers may also have had greater exposure to assistive technology as part of their training to become more specialised in their teaching. It is unclear from the evidence whether specialist teacher development courses are introducing new technology, although awareness levels seem to be higher in schools for learners with visual impairment.

There was little in these studies about the use of local materials and resources to support teaching strategies in schools. ↑Mukherjee, et al. (2014) found that some of the senior teachers in India had a mind set of not welcoming new technology' and felt more comfortable using traditional methods even after acknowledging the limitations of these methods. Younger teachers, however, seemed to be more receptive to change and were more willing to be trained in how to use new technology in the classroom.

↑Schiemer, et al. (2013) in their study of teaching learners with visual impairment and deafness / hard of hearing in Thailand found that materials are available but remain unused as teachers do not know how to operate or integrate them in teaching, and this might cause a higher workload. In a Nigerian study, ↑Onivehu, et al. (2017) examined teachers' attitudes and competency in the use of assistive technology and found that teachers did not know enough about the benefits of technology and identified gaps in teachers' knowledge and competency in the use of assistive technology for students with 'speech disorders, visual impairments, hearing impairments, physical impairments, and emotional and behavioural disorders. Similarly, they emphasised the urgent need for the improvised production of assistive technologies by using the broad range of raw materials and human resources that are available in Nigeria. ↑Lynch, et al. (2011) in a study of itinerant teachers for visually impaired learners found that they did not necessarily have access to specialised teaching materials outside large population centres, and access to mechanical Braille writers (such as the Perkins Brailler) was rare.

Notably, this lack of teacher awareness, limited opportunities for training, and reluctance to embrace new technology can also have a detrimental effect on learners' access to the most appropriate technology. ↑Senjam, et al. (2020) found that the majority of students in schools for the blind in Delhi, irrespective of their visual loss, were using tactile and sound-based AT despite the fact that those with some residual vision could have benefited from using AT for low vision.

More positively, in Turkey ↑Karal (2015) found that teachers were planning lessons involving technology which, in turn, aided their teaching and learning materials and activities, while implementing them in the classrooms and using assessment materials resulted in better results for the students. Furthermore, the introduction of a new learning environment provided the impetus for teachers to seek changes in how they taught the curriculum and applied new teaching methods to deaf/hard of hearing learners.

Focusing more on teachers' experiences and use of technology in the classroom in Sao Paolo, Brazil, ↑Alves, et al. (2009) found that 95% of the 58 teachers who taught learners with visual impairment and 76% of teachers who did not teach these learners did not use information technology for teaching purposes. The study found that over half of teachers surveyed (61.4%) understood the use of assistive technology resources for blind and low-vision students and 98% agreed that specific programs for learners with visual impairment are necessary in schools. Unfortunately, the study talks in general terms about the need to integrate technology into teaching practices, but it does not make any recommendation on how assistive technology can best support learning outcomes for learners with visual impairment. ↑Ajuwon & Chitiyo (2015) in a survey of 165 educators (including 141 special teachers) working in public schools in Nigeria found a general lack of knowledge of how to use AT to support greater access to learning for learners who are deaf or hard of hearing or have ASD. The survey found that teachers were willing to integrate AT into their teaching programmes if they had specific training on how to use it and access to the technology within their classroom to meet their students' learning needs.

In Malawi, ↑Lynch, et al. (2014) found that there was also a lack of monitoring and evaluation of any prescribed low-vision devices in terms of acceptance or usability by the learners themselves, partly because many of the devices had been prescribed by clinical eye services without any consultation with the learners or the itinerant teachers (visiting teachers of the visually impaired), who in turn do not encourage the children to use them in class.

5.7. Cross-cutting Theme 2: the role of parents

Few studies (n=5) involved consultation and participation of parents or carers in the development and piloting of new software or assistive technology. Those studies that included parents' views and participation showed reduced rates of abandonment of devices as a result of essential home support and parental buy-in. ↑Farooq, et al. (2015) found that parents' perceptions about the use of assistive technologies by their children positively affected the performance of their children in Pakistan. They concluded that assistive technologies are "good tools" for learners with hearing impairment, as they increase the overall learning opportunities and independence of children. ↑Kamau (2017) focused on exploring parental roles in the provision of mobility and educational resources for learners with physical disabilities in Kenya and found some disagreement on who should be responsible for the provision of mobility devices to support school attendance and participation in school activities.

The fact that there are few studies involving parents is concerning and will need to be addressed in future research. The small amount of evidence points to improvements in several key learning areas (such as communication, mobility, confidence levels) for learners with disabilities when parents were involved in the support and monitoring of the devices or programs.

5.8. Insights from the grey literature[9]

We identified a broad range of technical documents, guides, thought pieces, and toolkits (n=26) while carrying out searches using key search terms. Only nine of the documents are uniquely dedicated to AT, universal design, and accessibility. Although these are not peer-reviewed papers, they provide a rich range of guidelines or toolkits, such as advocating principles of UDL for the wider community of persons with disabilities, Organisations of Persons with Disabilities (OPDs) and other civil society organisations (CSOs).

The INGO sector, which has been central to the advancement of disability issues has published some useful documents on technology, especially taking a more practical and pragmatic view. For instance, CBM has published three documents including a position paper on better provision of audiology services (↑Santana, et al., 2015), a disability accessibility toolkit (↑CBM, 2018a), and a policy document on accessibility, all of which list service providers (↑CBM, 2018b). It is also interesting to see how CBM takes a particular stance on promoting specific types of AT (such as hearing aids and good quality audiology services), discouraging the uptake of cochlear implants, which are expensive to run (many have a short battery life) and require highly trained technical follow-up (↑Santana, et al., 2015). Sightsavers has developed helpful guidelines for teachers supporting learners with visual impairment in sub-Saharan Africa (↑Sightsavers, 2018). The guidelines give helpful advice on ways to create tactile learning materials (such as Braille and raised diagrams) as well as ways to introduce low-vision devices to learners who need them.

It is important to flag the vital contribution that a few large donors are playing in providing position papers and policy documents on disability and technology. For instance, the FCDO carried out a very recent rapid review of AT for persons with disability in India (↑Singh, et al., 2020), which contains a very short section on AT for education. Much of this section has raised the major issue of lack of provision of AT and how users are resorting to making other alternative arrangements to accessing information (such as recording

[9] As in common discourse we use the term 'grey literature' to refer to those manifold document types produced on all levels of government, academia, business, and industry in print and electronic formats that are protected by intellectual property rights, of sufficient quality to be collected and preserved by libraries and institutional repositories but not controlled by commercial publishers, i.e., where publishing is not the primary activity of the producing body (https://phelibrary.koha-ptfs.co.uk/greylit/). In the field of disability and education there are a number of these documents, which are published by INGOs and other bodies.

lessons on their mobile phones). The DFID Education Policy 'Get Children Learning' (↑DFID, 2018) responds to the strong need to engage marginalised learners by highlighting the setting up of the EdTech Hub and by addressing "low learning outcomes for the most marginalised … through enabling well-implemented facilitated learning for those outside of mainstream education or supporting teaching which is adapted to the right level for each child" (p. 22). EdTech Hub is now in operation and sponsored this review, which provides evidence to frame its work going forward in the area of EdTech use for learners with disabilities.

This urgency also resonates in a USAID document which notes that the 'learning crisis' is especially severe for children and youth with disabilities and will remain so unless significant additional efforts are made by the global community. The donor has produced a range of publications on ICT for persons with disability in LMICs including a recent publication, "Information and Communication for Education' (ICT4E), How-to Note" (↑USAID, 2020), which provides additional design and implementation information not provided in previous USAID publications. USAID's working paper from the Global Reading Network for enhancing skills acquisition for learners with disabilities on using ICT to implement UDL iterates the important point that although technology can benefit all learners with disabilities it should not be prioritised because an individual has a disability label and cannot replace the role of the trained teacher and specialists. There is no doubt that these are useful reports and guidelines but it is important to reiterate that more efforts are needed in building a robust evidence base to support many of the proposed interventions and other recommendations.

6. Key implications emerging from this review

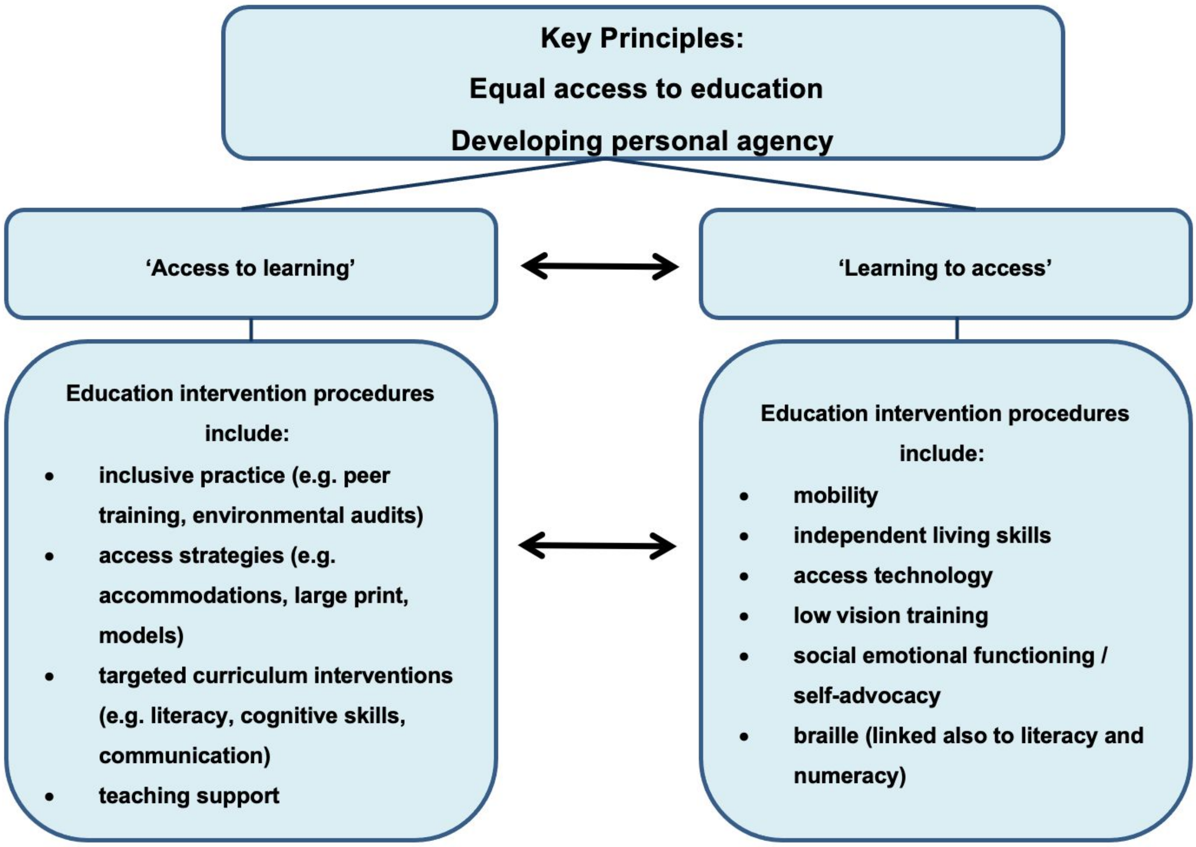
This section discusses the implications of the presented studies, drawing on the principles of 'learning to access' and 'access to learning' to argue the case for careful planning on how technology is introduced and integrated into different inclusive education contexts through a multi-pronged approach: entry, engagement, and empowerment. It also sets out the need for knowledgeable and trained teachers who will engage with the technology but consider ways of sourcing new technology in a sustainable and low-cost way and at scale.

6.1. Need for careful planning on how technology can be integrated into educational interventions

Given the significance of EdTech and education of children with disabilities, it is astonishing that there is so little evidence of studies and evaluations of educational interventions that met the inclusion criteria for this review. Beyond general access, AT offers the potential for supporting teaching in particular curriculum areas, which are more related to the expanded core curriculum (for example, teaching maths concepts, Braille, or the use of AAC). While evidence is limited, a key persuasive argument is that learners require focused teaching in relation to developing their 'specialist' EdTech skills in order to be able to self-advocate and become more independent at learning. This will vary for different children across different types and degrees of severity of impairment but will often include training in the use of particular access technology / software (such as a screen reader or a new sign language software program), which must be carefully planned in advance. Education interventions that use technology can play a significant role in the fulfilment of one or more aspects for many children with disabilities. Figure 12 helps to illustrate this point by showing the overlap between these broad areas, as illustrated by the horizontal arrows. Some of the skills can be embedded within a 'core' curriculum (for example, independence), and we note that general education curricula include skills that overlap with an ECC, such as working in groups (social skills). Also central to this distinction is a change in emphasis as learners may develop greater independence during their time at school and become advocates for their own learning and access needs. Therefore, the type of inclusive practice required will be adapted accordingly as the learner develops a range of independence skills, such as increasing confidence to adapt

EdTech to suit personal learning preferences and being able to generalise skills to new learning opportunities.

Figure 12. *Relationship between 'learning to access' and 'access to learning' for learners with visual impairments. Adapted from ↑Douglas, et al. (2010)*



In the literature reviewed, the focus was primarily on the use of EdTech to support entry factors into learning, with little or no evidence exploring the impact of these interventions on children's engagement in school settings. In an era where mainstream discussions are focusing on children's continued lack of learning, EdTech offers an opportunity to assist all children, including (and rather importantly) better access to learning and also learning to access; however, current evidence falters in this regard. Studies which we reviewed did not engage with the impact on children's literacy, numeracy, or other functional skills, rather the absence of engaging with these important issues was indicative of the lacuna in the field.

6.2. Need to embed EdTech within larger efforts towards inclusive education

Another noteworthy finding from this review is that research on EdTech continues to be located predominantly within special educational settings, with little research being undertaken in mainstream schools. These studies do not necessarily adopt a strong social model and rights stance, and make little reference to social discourses on disability rights and 'Nothing about us, without us!' campaigns and / or the UNCRPD. While some researchers argue that they are consulting learners and teachers in the design process, there is a lack of evidence on this important consultative process with end users, namely, the learners.

One possible reason for a more 'medicalised' approach seen in many of the studies reviewed could be attributed to the large number of studies undertaken by researchers who have backgrounds in health, engineering, computer sciences, and software design and assistive technology — in particular in specialist fields such as haptic technology, human–computer interaction (HCI) and Artificial Intelligence using VR or other forms of technology. There has been an exponential increase in the breadth and choice of EdTech for persons with disabilities but many of the studies we found are still at infancy stages, with little projection of how they can be scaled up in regions where there is reduced access to power and lack of technological expertise, even within the same country or dedicated funding streams.

Here we should acknowledge that there is considerable variation in the number of studies for different types of impairment. For instance, sensory impairments combined represented over two-thirds of the total papers (n=40). A possible reason for this could be the rapid development and range of low-, medium- and high-tech devices for visual impairment and deafness or the hard of hearing that are available to learners in special schools. This would also explain why the studies are located in special school settings. However, in an area where the last two decades have seen a phenomenal push in inclusive education, the fact that most Ed Tech research remains located in special schools is glaring!

The UN's SDG 4 very pertinently notes the need for a focus on quality in inclusive education; this is missing within the larger stated objectives of current research in the field of EdTech and disability. This review only identified a few (n=7) studies that noted the rather spurious impact on learning outcomes. In many respects, learning outcomes were seen as secondary to the technological elements of the studies — accessibility, usability, and acceptability. This is also partly due to the type of studies that were undertaken (for example, the focus being on software design and / or evaluation) or indeed the information provided could have been determined by the type of journal the paper was submitted to (for example, engineering, computer science, educational).

It is gratifying to see some evidence of how learners' levels of confidence and well-being have improved as a result of having access to technology and having opportunities to use it to access learning in the classroom. Studies across all the impairment groups provide some details of how the technology had created new opportunities for learning for learners with: autism (see, for example, ↑Sankardas & Rajanahally, 2017); deafness (↑Zahra, et al., 2018, ↑Techaraungrong, et al., 2017, ↑Parvez, et al., 2019); dyslexia (↑Benmarrakchi, et al., 2017, ↑Mohamad & Abdullah, 2017); visual impairment (↑Joshi, et al., 2008, ↑Gothwal, et al., 2018); and physical disability (↑Alvarado-Cando, et al., 2019). It is difficult to verify these claims but the broad agreement across the studies indicates some similarities in how learners are embracing the technology and experiencing new ways of engaging with learning and, most importantly, forming and bonding friendships at school. In some studies (see, for example, ↑Al-Gawhary & Kambouri, 2012), a broad range of impairments were recruited in an intervention study therefore making it difficult to judge whether the intervention had benefited a specific impairment group or had broadly improved learning opportunities across the group.

The evidence indicates that learners are benefiting from the technology through the multi-pronged focus of "entry," "engagement" and "empowerment" (↑Singal & Florian, 2013). The inclusion of children with disabilities in educational systems is a significant challenge facing policymakers in many LMICs, thus a multi-pronged approach to Ed Tech intervention is also essential (see Table 5).

Current literature indicates that there are obvious signs of the first two approaches developing well (at least for some groups of learners) and forming important foundations for the learner. But it is also important to ensure that EdTech interventions develop a strong sense of self-worth and well-being so that the learner continues to use the technology on a regular basis, takes ownership of it and is able to self-advocate (in the present and in the future).

Table 5. *Entry, engagement, and empowerment.*

Entry	■ Physical access to school building and play facilities ■ Access to water, sanitation, and hygiene (WASH) facilities in school ■ Access to the curriculum on offer
Engagement	■ Participation in classroom teaching and learning processes ■ Participation in social activities
Empowerment	■ Schooling that fosters a positive sense of self and belonging ■ Schooling that enables children to connect with real life

6.3. Teacher knowledge and involvement in EdTech

This area of the review has been the most difficult to find reliable evidence in and so, apart from a few surveys, it is unclear what is happening in relation to teacher development and technology for learners with disabilities. In many respects, teachers and parents seem to have been left out of the process. This is very concerning given the heavy responsibility placed on them to ensure learners with disabilities use their matched device on a regular basis.

A consistent theme reflected in many studies included in the review is the continued reluctance of teachers to actively adopt EdTech solutions / interventions in their everyday teaching. Evidence alludes to this reluctance being based on lack of understanding of how to use technology in a way that is effective and meaningful in the classroom. Although we are all getting more accustomed to technology in our everyday lives, the reluctance of teachers to adopt it in their teaching processes could be the result of their lack of know-how on how to do this. Some studies (for example, ↑Mukherjee, et al., 2014) note that older teachers are more reluctant to adopt new technology.

Some researchers (for example, ↑Onivehu, et al., 2017, ↑Senjam, et al., 2020, ↑Schiemer, et al., 2013) have made a case for pre-service and in-service professional development to support teachers to integrate technology more successfully. However, such training cannot be designed as one-off sessions on just the use of EdTech; rather they need to be integrated within continual professional development programmes. There is a need to move beyond theory and focus on providing teachers with opportunities to practise new skills so that they gain confidence in using the technology in their teaching practice. Additionally, although follow-up support to help teachers integrate these skills into classroom practices benefits all children, being able to respond to the specific needs of children with disabilities is vital. These are the central principles of any good teacher development programme and they need to be adopted within the inclusion of EdTech in teacher development programmes.

↑Karal (2015) found that introducing new technology, such as new hardware, into the school environment in Turkey, provided the impetus for teachers to seek changes in how they taught the curriculum and applied new teaching methods. These changes reportedly had a positive impact on teacher–learner relationships with increased self-confidence for both parties. Furthermore, in their study in Kenya, ↑Yalo, et al. (2012) concluded that specialist teachers working in special schools for learners with visual impairment benefited from receiving training in how to carry out simple functional vision assessments in order to ascertain their learners' levels of working vision. This training could also help them to decide what type of AT would be most appropriate to help learners access materials at school. This is quite specific training, which can only be provided by teacher trainers who have a background in teaching learners with visual impairment (↑Lynch, et al., 2014).

A potential way forward to addressing the global training needs of teachers is to draw on ↑UNESCO's (2018) ICT Competency Framework for Teachers, which is closely aligned with the 2030 Agenda for Sustainable Development and attainment of ICT-related targets. It would be useful for teacher development services to look at ways of embedding EdTech for learners with disabilities into the three main competency areas — knowledge acquisition, knowledge deepening, and knowledge creation, to address the impact of recent technological advances on education and learning, such as the use of mobile phones and tablets to support and sustain inclusive knowledge societies.

It is important to reiterate that even teachers often have little access to PCs or AT in classroom settings; many are far more digitally literate in using an Android tablet or phone.[10] Teacher development programmes need to look at ways of aligning Android tablets, phones, and apps to the curriculum so that teachers can apply them to their teaching and be able to support individual learners' needs — the aim being to acknowledge the wider penetration of technology in human lives and to find pathways for

[10] A report on mobile phone penetration in some LMICs is available at: https://www.geopoll.com/blog/mobile-phone-penetration-africa/

translating the usage of these skills into school settings to support learners with diverse needs.

6.4. Need for more locally resourced solutions

While medium- to high-tech solutions (such as Android phones and tablets) are useful for some learners, low-tech options such as paper-based memory aids may be the most accessible and cost-effective for others. Use of technology is pervasive today and allows a vast array of compensatory strategies to be cultivated and developed for learners with disabilities (↑Martinez & Scherer, 2018). This flexibility offered by AT (mainstream and specialised technologies) can create personalised and motivating solutions that increase children's access to learning.

Various studies highlight the need for low-cost solutions, for investing in local resources, and for encouraging the government to take on a more active role in offering subsidies.. For example, in their study of testing new software to support Braille literacy of blind learners in India, ↑Kalra, et al. (2009) note that an application:

> "*must be affordable to people at the base of the economic pyramid who live on less than US $2 a day. We hope to make it affordable to every village or rural school even if it cannot be affordable to individuals. Our target price is US $20 per unit for systems requiring an external computer and US $40 per unit for systems with embedded text-to-speech hardware that can operate without a computer.*"
> (p. 603).

↑Nkiko, et al. (2018) noted that teachers were of the opinion that technology tools are expensive and spare parts are not locally sourced. In Thailand, ↑Schiemer, et al. (2013) found that financial constraints often restricted parents from providing ICTs, not only at school but also at home. Other parents did not even consider the use of ICTs as they seemed out of reach due to low income. If everyday communication with their child is sufficient without technology (for example, by using pen and paper, easy gestures, lip-reading), most parents do not see the need for AT. ↑Onivehu, et al. (2017) recommend that the Nigerian government should make AT accessible, available, and considerably subsidised so that administrators of special needs learners can purchase it easily. Affordability emerges as a key consideration in many contexts.

There needs to be a significant shift in our thinking from seeing mobile phones and devices as being uniquely for 'consumer tech' purposes to acknowledging their potential in serving the educational needs of all learners. Survey studies that have investigated how learners are using EdTech and social media in LMICs (↑Zahra, et al., 2018, ↑Farooq, et al., 2015) suggest that increasingly larger numbers of learners with disabilities are using mobile phones to help them learn and communicate at school, particularly in the case of deaf learners attending special schools in Pakistan.

There is limited but growing evidence from the review that apps are supporting the acquisition of basic maths skills for learners with disabilities on tablets in Malawi (↑Pitchford, et al., 2018), helping with Braille writing on a mobile phone in Bangladesh (↑Nahar, et al., 2015), or practising sign language to help with reading in India (↑Joy, et al., 2019). Overall, few studies have measured the extent of learning outcomes when using interactive apps, so it has yet to be determined if apps are effective at raising attainment for these learners.

6.5. Need for sustainable and scalable interventions

Although there is some emerging evidence of innovative development of software programs to facilitate the acquisition of critical skills for learners with different disabilities, they remain very much at the feasibility stage. This is true particularly in relation to new software programs and apps that have only been tested for a small number of weeks and in special school settings. It is heartening to learn about new initiatives to support learners' academic and social skills, but it would be premature to expect to see any real potential scaling up of piloted programs with small sample sizes in mainly large cities in LMICs.

In many instances, further proof of concept and more testing on larger sized groups is needed to increase the chances of software programs being scaled up. Furthermore, a significant number of pilots were instigated by public higher education institutions, which may have limited funding. A total of 13 studies received external funding from donors. Lack of access to substantial funding could result in some technologies not being developed further and scaled up. It is disappointing not to see studies funded by large software or IT solution companies or multinationals.

One of the key messages coming out of this review is that 'one size' does not and cannot fit all. The breadth of evidence, although quite thinly spread, shows the need for tailored or personalised solutions through the offering of technology. For example, learners with severe low vision are clearly benefiting from carefully prescribed low-vision devices followed up by regular eye check-ups. Deaf learners are able to better communicate and interact with their peers and teachers if they have regular access to their own sign language via interactive apps on mobile phones or other devices (such as iPads).

Although we were unable to identify any evidence of large-scale evaluations in the literature review, it is important to be aware of contextual needs, realities, and resources for shaping EdTech interventions. Researchers such as ↑Onivehu, et al. (2017) highlight the need for AT to be shaped by the use of raw materials and human resources that are available within a country, a point which needs to be kept in mind as we move forward.

In the evidence base there is also a significant gap in relation to the costing of technological support — both at the level of the system and at the level of the individual. No systematic cost–benefit analysis of EdTech programming was available. #Costing The Equity Report (↑Myers, et al., 2018) suggests that designing an accessible learning setting from the start costs less than making subsequent alterations to a non-accessible setting. It also notes that both recurring and non-recurring costs need to be factored into disability-inclusive education budgets but there is no indication of what these costs amount to in the evidence base reviewed for this report.

6.6. Final reflections

This review highlights the glaring gap in published evidence in relation to evaluations and impact studies. There is a significant dearth of RCTs and quasi-experimental designs. Thus, there is a need for EdTech providers to work more closely with practitioners to ensure that key indicators are identified and collected that can not only inform classroom practice but also provide much-needed evidence to inform policy decisions about what technology is working well, how, where, and why. While it is not simply a matter of advocating for more studies adopting a certain type of design, there is a need to support more research in the field of EdTech which is robust and offers insights that can be adopted and sustained at scale.

By design, conducting a literature review on countries under the overall umbrella of LMICs can obscure significant differences. In our review we noted that the countries covered in the evidence base fell into low-income (n=3), lower-middle-income (n=12) and upper-middle-income brackets (n=12), clearly highlighting that much of the evidence has come from middle-income countries and is focused on higher technology solutions. There is an urgent need to build a knowledge base of how EdTech is being used, particularly in low-income countries. It would be unhelpful to suggest the replication and scaling up of high-tech solutions in countries where the infrastructure does not allow for such solutions. What is considered 'high-tech' in one setting may already be much more widely used within another, so our understanding of what constitutes high-tech needs to reflect the shifting nature across settings and time. A potential way of tackling the growing digital divide is to look at what is happening in the area of health and AT and build on good practices there.

A useful example of drawing on contextually appropriate approaches can be found in the field of health and assistive technology. The WHO's GATE initiative is creating a series of e-learning modules that will build the skills and capacity of primary healthcare workforces to safely and effectively provide basic assistive products, including the Priority Assistive list focusing on the 5P interlinked areas set out by the WHO: people, policy, products, provision, and personnel.[11] A user-centred approach is critical to making sure that users' needs are addressed when developing policies and provision services. Services should not just be physically accessible but also culturally appropriate and tailored to users' needs. WHO not only promotes a user-centred approach but also works closely with users and user groups.

Reflections from the review also underscore the importance of sustainability. EdTech solutions which rely on individuals or producers who are not well-integrated into the supply chain will not be sustainable over time. Hence it is important for national governments to seek sustainable ways to ensure products continue to be supplied to schools should specific supply chains become disrupted. This also means seeking locally based solutions to manufacturing technology in case of problems with supply from overseas.

It is also important to consider the design and quality of the studies identified in the systematic review. Of the evidence gathered, high proportions were case studies or small-sample multiple baseline studies, and studies rarely incorporated control groups. In part, this reflects the nature of the 'disabled' population, which is not homogenous and is relatively small in some impairment groups. However, there is a challenge in designing interventions based upon imprecise and ungeneralisable evidence, which is particularly difficult given the heterogeneous nature of the population. For example, at what age should long canes be introduced for mobility, what are the teaching approaches that should be used, and for which children is this useful (and for which is it not)? What is perplexing is the larger number of studies for lower incidence impairments (such as

[11] This ecosystem approach looks at what needs to be done to support the implementation of AT by establishing a 'fertile ground' for the technology to take root and flourish and with the understanding that each 'P' needs to be in place for the implementation to be successful.

visual impairment and deafness) and the small amount of studies for higher incidence groups (such as autism and intellectual disabilities). Reflecting on a previous review of education for visual impairment, ↑Douglas, et al. (2010) speculated that the lack of evidence was linked to historic concerns with educational access, which means that comparator groups are often not used in research studies. We would agree with this speculation to an extent but other factors such as lack of funding and lack of research capacity in some LMIC contexts could also have an influence on low levels of evidence.

The access to learning / learning to access model, introduced at the beginning of this report, helps to highlight some of the difficulties that exist when emphasising equal access versus development of individual agency. It is vital that teachers, parents, and learners are able to make informed decisions about the type of technological interventions that are most appropriate for the individual. Decisions should be made in an inclusive way, drawing on helpful models such as the UDL and the WHO 5P initiative in order to avoid intractable dilemmas (such as inappropriate interventions), which can further marginalise a learner within the school setting and beyond. An important part of this decision-making process is linked to the age and development age of the child in question and accounts for the preferences of child and parents and the appropriate match with technology. To some extent, the evidence from this review offers some helpful examples about which technology and approach can be used at the relevant point in the child's learning cycle. Nevertheless, the review also reveals that evidence is often lacking substantive data and only based on very short studies, with little time for consultation with children, teachers, and parents.

7. Recommendations

7.1. Recommendations for research

This section sets out two sets of recommendations for further research into EdTech and disability. The first set of recommendations address ways of increasing our evidence base of robust studies on how EdTech can be used to support the education of diverse groups of learners in LMICs. The second set of recommendations (in Section 7.2) are addressed at policy makers and donors who are responsible for implementing EdTech programmes within LMICs.

7.1.1. Better alignment of EdTech research to global commitments

New research into EdTech needs to be more aligned with the global commitments set out in the UN SDG to "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" and the UNCRPD. Research focusing only on issues of access is limiting and does not take into account the need for inclusive and equitable quality learning experiences for learners with disabilities. The inclusion of children with disabilities in educational systems is a significant challenge facing policymakers in many LMICs. EdTech can benefit learners through a multi-pronged focus of 'entry,' 'engagement' and 'empowerment'. Additionally, EdTech interventions enable the learner to develop a strong sense of self-worth and well-being, so that the learner continues to use the technology on a regular basis, takes ownership of it, and is able to self-advocate (in the present and in the future).

7.1.2. Identify research questions which address the diversity of learners

The field of EdTech and disability research needs to pose more pertinent questions. Research is needed to understand *how* and *which* technology is the most useful when it comes to facilitating the learning process. Robust research is needed to evaluate the conceptualisation, design, testing, and impact of appropriate technology within different environmental conditions (such as gender, age, location — urban, peri-urban, and rural, public / private schools, curriculum area) to meet the needs of the full range and diversity of learners with disabilities in LMICs.

7.1.3. Robust research designs

Research designs, including RCTs and strong participatory user-based methods, with sufficient sample sizes, conducted over longer time frames are needed to put forward more robust results to inform effective policymaking and programme developments.

7.1.4. Need for more sophisticated research designs acknowledging intersecting variables

There is a significant disparity in the evidence base across different impairment groups, which needs to be recognised and addressed. Additionally, more thought needs to be given to intersecting variables, such as gender, location (rural / urban), and socio-economic status of learners, which can have a pronounced impact when designing new EdTech interventions in LMICs.

7.1.5. Greater involvement with user groups

Learners with disabilities and their teachers should be consulted in the design and implementation of EdTech studies (for example, purpose of study, type of technology, integration into learning situation, and relevance to the curriculum) and EdTech initiatives. This includes discussions about the viability of the proposed EdTech in the learning settings (for example, to what extent can apps or software be installed on devices where there is a lack of power supply), which can form the basis of moving from small-scale, design-centred studies, to larger-scale, multi-country studies that measure the impact of technology on learning outcomes.

7.1.6. Developing research capacity in LMICs

To generate new EdTech research that responds to the needs and is sensitive to context, funders will need to allocate sufficient funding and time for the development of research capacity within research institutions, particularly those in low-income countries where evidence has been limited. While we are unable to reflect critically on the nature of North–South partnerships in this review given the lack of information, there is a need for research capacity building in many LMICs. Researchers should be encouraged to publish in recognised international, peer-reviewed journals through open-access routes.

7.2. Recommendations for policy

7.2.1. Greater investment in mobile and portable devices

With a growing shift from using PCs to mobile and portable devices, investing in apps for phones, when sustainable, has additional benefits for learners with disabilities. The same technology can be used to support daily living activities at home and increase opportunities for independent living. Governments should invest in more technology that encourages greater opportunities for ubiquitous learning opportunities within different learning and social arrangements (schools, residential settings, and / or the home). There is a need for a more expanded, holistic, vision, which allows for both mobile and more fixed technologies to be used interchangeably within both education and home settings. This creates greater flexibility where the technology moves with the learner, rather than the learner being restricted to where the technology is located all the time.

7.2.2. Keep the cost of assistive technology affordable

A significant barrier to accessing technology, as noted in this review, is the consistent high cost of AT, especially for learners with sensory impairments. Thus, there is an urgent need to seek formal agreements with specialist suppliers of AT to find solutions to keep the cost of AT at affordable levels. There is also a need to source AT more locally in order to reduce additional import taxes and develop reliable supply chains within country.

7.2.3. High-quality competency skill training on EdTech for teachers

A consistent theme across the review was the lack of awareness, confidence, and inadequate training among teachers. Teacher development programmes therefore need to incorporate high-quality competency skill training to improve their digital literacy (such as looking at ways to use mobile technology more creatively within the core and expanded core curriculum) and also provide practical experience. This is particularly important in instances where there is a need to apply more complex AT to provide increased learning opportunities and effective learning experiences for children with disabilities in different settings.

7.2.4. Strong government incentives to subsidise costs of appropriate EdTech

There are greater benefits to be achieved by ensuring that the needs of persons with disabilities are being met in the new influx of mobile phones, tablets, and AT apps in LMICs. For example, the proliferation of mobile phones and apps are having a positive impact on how the curriculum is being re-conceptualised and delivered to deaf and hard-of-hearing learners but unless there are strong government incentives to subsidise costs, there are considerable cost implications for schools and learners.

7.2.5. Investment in EdTech infrastructure and technology for schools

Evidence from the review indicates a lack of infrastructure (such as reliable supply of electricity) and availability of AT in schools, which is evidence of under investment even when EdTech is highlighted as a priority. Governments need to commit to better resourcing of appropriate EdTech for children / young people with disabilities, if we are to deliver on promises of inclusive and quality education.

7.2.6. Clear guidelines on who is responsible for sourcing technology

An emerging tension noted in few of the studies was around who pays for some of these technologies, for instance mobility devices (such as wheelchairs, walkers, crutches, and callipers, etc.), which will enable some children / young people to access school. There were clear differences in opinion about who is responsible for sourcing some of these devices, i.e., the school or the parents / carers, and indeed whose remit did it fall under nationally, i.e., the Ministry of Education or the Ministry of Health. Therefore, clear guidelines are needed at a national level, which will also allow for transparent budget lines and appropriate allocation of funds.

7.2.7. Conduct a four-stage consultation to create a priority list of assistive technology and a support training package

Given the significant need but lack of spread of EdTech, in the longer term, there is a need to build on the World Health Organisation's GATE initiative. This initiative is currently focused on Universal Health Coverage but could be expanded to improve access to high-quality, affordable, and appropriate AT in education. We propose that this could be a four-stage process, which involves:

1. Carrying out a robust mapping of the efficacy of AT in maintaining or improving an individual's functioning, independence and well-being.
2. A Delphi exercise, which involves diverse stakeholders, such as international organisations, donor agencies, professional organisations, academia, and user groups to agree on a list of high-priority devices, which cover the range of low- to high-tech.
3. Focused national surveys to capture the opinions of a larger population, especially those of learners with disabilities and their families.
4. A consensus meeting between diverse stakeholders, which will agree on a training package including four essential steps of service provision: assessment, fitting, training, and follow-up and repair.

This will ultimately require the generation of a list of reputable, affordable, and reliable national and international suppliers of AT, being particularly mindful of issues of sustainability and effectively using local resources.

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9. Appendix

9.1. Appendix A: Example of a SPuD search query

Query: SELECT COUNT(*) AS "__count" FROM "publications" INNER JOIN "gd" ON ("publications"."id" = "gd"."id") LEFT OUTER JOIN "p1" ON ("publications"."id" = "p1"."id") LEFT OUTER JOIN "p2" ON ("publications"."id" = "p2"."id") LEFT OUTER JOIN "te" ON ("publications"."id" = "te"."id") LEFT OUTER JOIN "tt" ON ("publications"."id" = "tt"."id") INNER JOIN "relevance" ON ("publications"."id" = "relevance"."id") WHERE ("publications"."tsv" @@ websearch_to_tsquery('deaf') AND ("gd"."developing_context" > 0 OR "gd"."developing_countries" > 0 OR "gd"."developing_country" > 0 OR "gd"."developing_nation" > 0 OR "gd"."developing_region" > 0 OR "gd"."developing_state" > 0 OR "gd"."developing_world" > 0 OR "gd"."global_south" > 0 OR "gd"."less_developed_countries" > 0 OR "gd"."lmic" > 0 OR "gd"."low_income_countries1" > 0 OR "gd"."low_income_environment1" > 0 OR "gd"."low_resource_countries1" > 0 OR "gd"."low_resource_environment1" > 0 OR "gd"."low_income_countries2" > 0 OR "gd"."low_income_environment2" > 0 OR "gd"."low_resource_countries2" > 0 OR "gd"."low_resource_environment2" > 0 OR "gd"."middle_income_country" > 0 OR "gd"."middle_income_environment" > 0 OR "gd"."third_world" > 0 OR "gd"."under_developed_countries" > 0 OR "gd"."under_developed_nation" > 0) AND ("p1"."classroom_assistants" > 0 OR "p1"."classroom_instruction" > 0 OR "p1"."early_childhood_development" > 0 OR "p1"."early_childhood_education" > 0 OR "p1"."educators" > 0 OR "p1"."headteacher" > 0 OR "p1"."junior_middle_school" > 0 OR "p1"."junior_school" > 0 OR "p1"."k_12" > 0 OR "p1"."kindergarten" > 0 OR "p1"."middle_school1" > 0 OR "p1"."middle_school2" > 0 OR "p1"."nursery" > 0 OR "p1"."pre_primary1" > 0 OR "p1"."pre_primary2" > 0 OR "p1"."pre_school" > 0 OR "p1"."primary_education" > 0 OR "p1"."primary_school" > 0 OR "p1"."principal" > 0 OR "p1"."private_school" > 0 OR "p1"."school" > 0 OR "p1"."school_head" > 0 OR "p1"."school_principal" > 0 OR "p1"."school_teacher"

> 0 OR "p1"."teacher_candidates" > 0 OR "p1"."teachers" > 0 OR "p2"."accessible_learning" > 0 OR "p2"."at_risk_population" > 0 OR "p2"."disabilities" > 0 OR "p2"."disability" > 0 OR "p2"."education" > 0 OR "p2"."in_service_training" > 0 OR "p2"."science_and_technology" > 0 OR "p2"."special_educational_needs" > 0 OR "p2"."sen_learner" > 0 OR "p2"."sen_student" > 0 OR "p2"."special_educational_needs_and_disabilities" > 0 OR "p2"."special_needs_students" > 0 OR "p2"."students" > 0 OR "p2"."students_with_disabilities" > 0) AND ("te"."smart_board" > 0 OR "te"."smartboard" > 0 OR "te"."electronic_textbook" > 0 OR "te"."etutor" > 0 OR "te"."free_digital_resources" > 0 OR "te"."intelligent_tutoring_system" > 0 OR "te"."online_textbook" > 0 OR "te"."school_website" > 0 OR "te"."edtech" > 0 OR "te"."educational_innovation" > 0 OR "te"."educational_technologies" > 0 OR "te"."emerging_education_technologies" > 0 OR "te"."emerging_education_technology" > 0 OR "te"."ict_in_classrooms" > 0 OR "te"."ict_in_the_classroom" > 0 OR "te"."technology_at_school" > 0 OR "te"."technology_in_education" > 0 OR "te"."technology_in_school" > 0 OR "te"."technology_use_in_education" > 0 OR "te"."adaptive_learning" > 0 OR "te"."asynchronous_learning" > 0 OR "te"."computer_managed_instruction" > 0 OR "te"."computer_mediated_learning" > 0 OR "te"."computer_supported_collaborative_learning" > 0 OR "te"."computerised_learning" > 0 OR "te"."differentiated_learning" > 0 OR "te"."digital_learning" > 0 OR "te"."distance_education" > 0 OR "te"."distance_learning" > 0 OR "te"."distance_learning_program" > 0 OR "te"."e_learning" > 0 OR "te"."electronic_classroom" > 0 OR "te"."free_digital_learning" > 0 OR "te"."gamification" > 0 OR "te"."hybrid_learning" > 0 OR "te"."individualised_learning" > 0 OR "te"."instructional_technology" > 0 OR "te"."interactive_learning_environment" > 0 OR "te"."learning" > 0 OR "te"."media_literacy" > 0 OR "te"."mobile_education" > 0 OR "te"."mobile_learning" > 0 OR "te"."multimedia_instruction" > 0 OR "te"."online_course" > 0 OR "te"."online_learning" > 0 OR "te"."open_education" > 0 OR "te"."personalised_learning" > 0 OR

"te"."personalised_teaching" > 0 OR "te"."synchronous_online_learning" > 0 OR "te"."technological_pedagogical_content" > 0 OR "te"."technology_assisted_learning1" > 0 OR "te"."technology_enhanced_learning" > 0 OR "te"."technology_integration" > 0 OR "te"."technology_assisted_learning2" > 0 OR "te"."tele_education" > 0 OR "te"."virtual_classroom" > 0 OR "te"."virtual_learning" > 0 OR "te"."virtual_learning_environment" > 0 OR "te"."virtual_school" > 0 OR "te"."web_based_instruction" > 0 OR "tt"."access_to_computers" > 0 OR "tt"."accessible_technologies" > 0 OR "tt"."alternative_communication" > 0 OR "tt"."android" > 0 OR "tt"."app" > 0 OR "tt"."apple" > 0 OR "tt"."assistive_technology" > 0 OR "tt"."audio_recording" > 0 OR "tt"."augmentative_communication" > 0 OR "tt"."bada" > 0 OR "tt"."bandwidth" > 0 OR "tt"."barriers_to_technology" > 0 OR "tt"."clicker_technology" > 0 OR "tt"."clickers" > 0 OR "tt"."computational_thinking_literacy" > 0 OR "tt"."computer" > 0 OR "tt"."computer_illiteracy" > 0 OR "tt"."computer_literacy" > 0 OR "tt"."computerised" > 0 OR "tt"."computers_on_wheels" > 0 OR "tt"."digital_communication" > 0 OR "tt"."digital_content" > 0 OR "tt"."digital_divide" > 0 OR "tt"."digital_exclusion" > 0 OR "tt"."digital_inclusion" > 0 OR "tt"."digital_literacy" > 0 OR "tt"."digital_native" > 0 OR "tt"."digital_resources" > 0 OR "tt"."digital_scrapbook" > 0 OR "tt"."digital_skills" > 0 OR "tt"."digital_storytelling" > 0 OR "tt"."digital_technology" > 0 OR "tt"."digitalised" > 0 OR "tt"."digitised" > 0 OR "tt"."dvd_player" > 0 OR "tt"."e_book" > 0 OR "tt"."e_reader" > 0 OR "tt"."earphones" > 0 OR "tt"."ebook" > 0 OR "tt"."ereader" > 0 OR "tt"."hardware" > 0 OR "tt"."headphones" > 0 OR "tt"."i_pad" > 0 OR "tt"."ict" > 0 OR "tt"."inclusive_technologies" > 0 OR "tt"."information_communications_technology_literacy" > 0 OR "tt"."information_literacy" > 0 OR "tt"."interactive" > 0 OR "tt"."ipad" > 0 OR "tt"."iphone" > 0 OR "tt"."information_technology" > 0 OR "tt"."keyboard" > 0 OR "tt"."laptop" > 0 OR "tt"."microsoft" > 0 OR "tt"."mobile_phone" > 0 OR "tt"."new_technologies" > 0 OR "tt"."offline" > 0 OR "tt"."online" > 0 OR "tt"."online_discussion" > 0 OR "tt"."open_source_software" > 0 OR "tt"."podcast" > 0 OR "tt"."radio" > 0 OR "tt"."single_board_computer" > 0 OR "tt"."social_media" > 0 OR "tt"."software" > 0 OR "tt"."supportive_technology" > 0 OR "tt"."tablet" > 0 OR "tt"."technological_literacy" > 0 OR "tt"."technology_enhanced" > 0 OR "tt"."telephone" > 0 OR "tt"."television" > 0 OR "tt"."video_recorder" > 0 OR "tt"."virtual_peer" > 0 OR "tt"."virtual_reality" > 0 OR "tt"."web" > 0 OR "tt"."wechat" > 0 OR "tt"."whatsapp" > 0 OR "tt"."youtube" > 0) AND "relevance"."relevance" > 10)

9.2. Appendix B: Data extraction form for EdTech disabilities and technology literature review

General Information

Paper's title *(title of paper / abstract / report that data are extracted from)*	
Authors	
Institutional / Affiliations (Countries)	
Funder	
Reference details	
Publication type *(e.g., conceptual paper, policy, position, opinion, meta-analysis, empirical research, literature review, edited book chapter, etc.)*	
Name of peer-reviewed journal and link to paper	

Eligibility

Main Themes	Insert details	Yes / No / Unclear	Location in text *(pg & / fig / table)*
Type of technology (access, disability, gender, age group)			
Level of education (pre-primary, primary)			
Type of school (primary, special, resource base, other)			
What type of study and how successful were they in terms of: 1) viability 2) participation 3) improving learning outcomes (literacy, numeracy) (learning to access, access to learning)			
What is the potential for further development of this field, particularly in terms of scalability?			
What specific responses to Covid19 are reported?	·		

General Characteristics

Provide overall data and, if available, comparative data.

	Description as stated in report / paper	Location in text *(pg & / fig / table)*
Study Aim		
Description of type of research (i.e, case study, comparative, intervention)	.	
Country(ies) / regions included		
Key words		

Methods

	Descriptions as stated in report / paper	Location in text *(pg & / fig / table)*
Name of method		
Design		
Sample (population, size)		
Stakeholder group from which data has been collected / Who is being interviewed about the research interventions?		

Duration *(length of study or intensity of intervention)*		
Strengths		
Limitations		

Other information

	Description as stated in report / paper	Location in text *(pg & / fig / table)*
Key conclusions of study authors		
References to other relevant studies		

9.3. Appendix C. List of funders from different countries

Table 6. *List of funders from different countries.*

No.	Country of Study	Funder and country	Authors and years
1.	China	This research was supported by the 2019 Comprehensive Discipline Construction Fund of the Faculty of Education, Beijing Normal University, China.	Hu (2019)
2.	China	This research was supported by the 2019 Comprehensive Discipline Construction Fund of the Faculty of Education, Beijing Normal University, and Natural Science Foundation of China (Grant No. 61602043); and Beijing Education Science 'Thirteen Five' Plan (Grant No. CAEA18082), China.	Hu (2020)
3.	Bangladesh	Ministry of Science, Technology and Innovation, Malaysia for providing e-Science Fund, SF 06-01-02-SF0960 for this research. In addition, the first author would like to extend her gratitude to UKM for the financial support it provided through the Research University Zamalah Scholarship, Malaysia.	Nahar (2015)
4.	India	This work was funded by Tech-BridgeWorld's V-Unit program, the IFYRE program, and the National ScienceFoundation's IGERT fellowship in assistive technology (DGE-0333420).	Kalra (2009)
5.	Brazil	Brazilian agency CNPq (National Counsel of Technological and Scientific Development) under process number 442456/2016-6 and by Convênio Sesacre-FMABC (Faculdade de Medicina do ABC) under process number 007/201, Brazil.	Martins (2019)
6.	Indonesia	Directorate General of Higher Education of Indonesia for the financial support of this research under Penelitian Strategi Nasional Institusi scheme 2018, Research agreement number: 028/K6/KM/SP2H/PENELITIAN/2018, Indonesia.	Muljono (2019)

7.	Peru	Universidad Peruana de Ciencias Aplicadas (UPC), for the partial funding of the present investigation; the ENSEÑAS PERÚ association, and Bryan Berrú, for providing us their Peruvian sign language gestures dataset, Peru.	Ramos-Ramirez (2019)
8.	Morocco	This study was supported by the Speech-Language Pathology service-Health center, El Jadida and Speech Therapy center Verdun, Casablanca, Morocco.	Benmarrakchi (2017)
9.	Malawi	This work was supported by Voluntary Service Overseas [grant number MWI-14/0019 Unlocking Talent through Technology Improving Learning Outcomes of Primary School Children in Malawi], UK.	Pitchford (2018)
10.	Thailand	This research was supplied with tools and equipment by the Department of Occupational Therapy, Faculty of Associated Medical Sciences, Chiang Mai University, Thailand.	Lersilp (2018)
11.	Philippines and Canada	This work was supported by the Natural Sciences and Engineering Research Council of Canada [NSERC RGPIN 2016-04669], Canada.	Lopez (2019)
12.	India and UK	The study was funded by the British Council for the Prevention of Blindness. Through its corporate social responsibility scheme, Apple Inc. provided the iPads for the site in India, a Dictaphone, and a contribution towards the hire of assessment rooms. This work was further supported by the Moorfields Eye Charity (Grant No. R190013A), UK.	Gothwal (2018)
13.	Malawi	Funding from the Commonwealth Secretariat and the British Academy as well as funding and logistical assistance from Sightsavers Malawi Country Office, UK.	Lynch et al. (2014)
14.	India	IEEE RAS-SIGHT	Nanavati (2018)