WORKING GROUP 02

CHAPTER

6

Education technology

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This chapter assesses how technological innovations are emerging as one type of solution to the global educational challenges of the 21st Century. It surveys across a broad typology of technologies in the information and communication domain, discussing their scope and affordances in traditional and non-traditional learning, curriculum design and instruction. With an overview of trends, benefits, and risks posed by recent technological advances in education, the aim of the chapter is to present a balanced view of the education technology (EdTech) field, highlighting the relevant and necessary concerns within the different spheres of EdTech. Specifically, the chapter discusses critical issues of the digital divide, equitable access to EdTech, privacy and security concerns, the role of teachers and real-world classrooms in an increasingly digitized education setting, and debates concerning the ethical use of artificial intelligence, big data analytics and machine learning. The assessment supports an optimistic but cautionary role for EdTech in addressing education challenges when coupled with continued social and cultural context-driven research. With respect to policy, the assessment concludes that it is worthwhile to encourage innovations and implementations of EdTech globally, accompanied by sensible regulatory guidelines on data sharing, breach of privacy, security, misuse and misrepresentation of claims about what EdTech can and cannot do.

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WORKING GROUP 02

6

CHAPTER

6.1 Introduction

Throughout history, technology has played an instrumental role in the development of humanity – from cave paintings to the development and use of tools, from the printing press and the telephone to the internet connecting billions across time and space. Having entered an age of profound environmental and social change, technology has become a pervasive context across all education settings **(Spector, 2001)**. Education technology (EdTech) holds many promises for addressing longstanding educational debates and technical problems: allowing access to quality educational resources for individuals with specific disabilities or challenges that impact their learning in traditional

> **Like many human endeavours, technological advances and solutions hold both promise and peril when applied to educational contexts.**

school settings, to communities that are geographically remote, to populations in economic need; enhancing the role of teachers and other educators in supporting human learning; or bringing balance and harmony to the sometimes discordant philosophies of education as engines of economic prosperity versus education as an ecosystem of human flourishing. Thereby EdTech plays its part in promoting diversity, lifelong learning and equitable quality education for all individuals.

There is an inherent tension among stakeholders of education that devolves into debates about trade-offs, constraints and limitations: to achieve gains in one direction requires losses in the other. However, this need not be a zero-sum game, and careful planning and consideration can achieve a balance between the two. Technology-enhanced systems can be such game-changers.

It is, however, noteworthy that, despite the optimism of some promoters and enthusiasts, EdTech alone is not a panacea for all the obstacles facing education. Like many human endeavours, technological advances and solutions hold both promise and peril when applied to educational contexts, depending on the thoughtfulness and care brought to the application and implementation in real life. For example, EdTech promises to increase the efficacy and value of teachers, revolutionize individualized learning, reduce administrative burden, and improve overall retention and learning of students with the aim of promoting human learning and achievement. At the same time, it also proves often to be just the opposite, disrupting traditional roles and responsibilities, increasing administrative burden and surveillance, and distancing teachers from the traditional social interactions with students. In this chapter, we keep these two counterfactual forces at the forefront as we review different types of EdTech. We present cases where EdTech is used, for example, to achieve a balance between human learning towards

Many scholars have argued that rather than tools and gadgets, technology is both human and a fundamental driver that transforms societies and values experience.

an end of increasing human capital versus human flourishing; and assess the critical issues that need to be considered, debated and resolved by the human actors entangled in the design, development, diffusion and use of EdTech.

How do we define technology and, specifically, EdTech? Many scholars have argued that rather than tools and gadgets, technology is both human experience **(Heidegger, 1977; Ihde, 1993; McCarthy and Wright, 2004)** and a fundamental driver that transforms societies and values **(Ellul, 1954/1964)**. Consequently, EdTech becomes conducive to changing and enhancing the learner experience while materializing human flourishing. However, for every enhancement brought about by technology, there is a risk of displacement, disruption or destruction of some kind; every magnification can be accompanied by a reduction **(Ihde, 1993)**, so there will always be the need to consider alternatives or monitor unintended consequences in order to minimize anticipated and unanticipated risks of introducing EdTech in an educational context.

This chapter acknowledges that technologies can be tools that transform education, and discusses the adaptation, opportunities and challenges they pose to educators and learners **(Fishman and Dede, 2016)**. The chapter simply and broadly defines EdTech as any technology applied in an educational context or as a solution to an educational problem. By this definition, any process or tool may become EdTech through its purposing and use. While many of us may automatically think of the internet and the laptop as EdTech, it is important to remember that a textbook is a traditional EdTech designed for the purpose of teaching a topic or subject area, while an ancestral technology could be rituals around the fire – learning about humanity's relationship with nature **(Macintyre et al., 2019)**. We describe a range of technologies that are widely discussed in EdTech research, with special attention given to information and communication

technologies (ICTs) as instantiated with digital tools, artifacts, networked communications platforms, and cloud-based computing and storage. Our focus on digital technologies is underlined by the speed and volume with which they are occupying the educational space and the rapid and uncertain ways with which they are influencing human development and the environment. However, we do not neglect brief reviews of less well-publicized technologies that are emerging in research and development (R&D) centres across the world, such as various new forms of artificial intelligence (AI)-augmented learning, lest their infusion into products, processes and services and their consequent impact are not noticed or debated by education stakeholders until they are already integrated and transforming educational ecosystems.

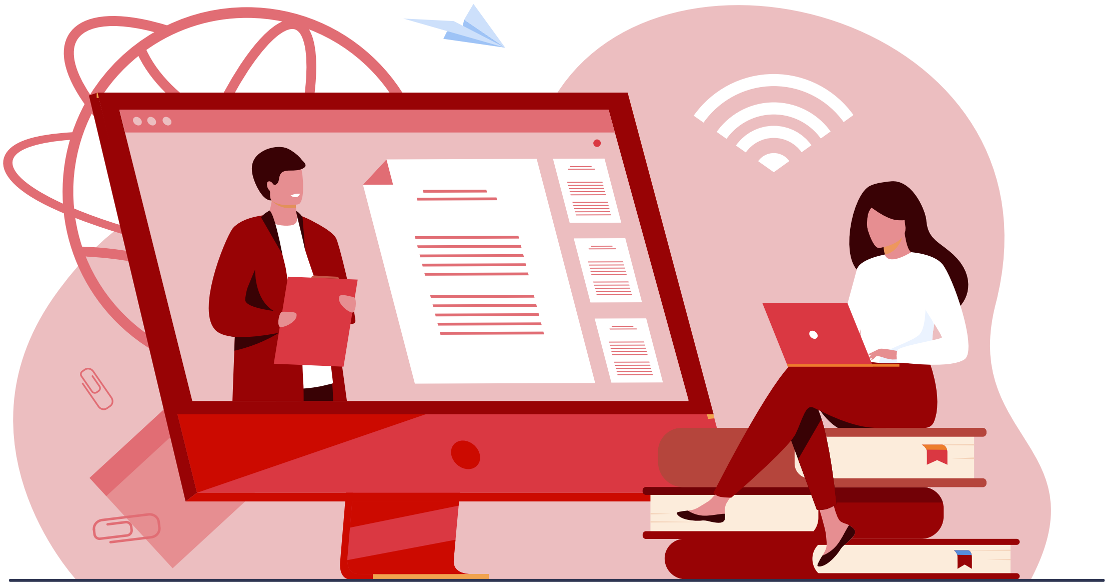
The chapter starts with a brief history of EdTech, followed by a typology and scoping of technologies. We then examine EdTech in education proper, identifying emerging themes and issues of application, and sampling recent developments in EdTech along with descriptions of how these technologies are being researched and applied to

... we must acknowledge that journals and reports on EdTech stemming from development and research in Western countries exert a strong influence on which questions are asked and most studied.

education. Following this review, we take a critical lens to synthesize some of the issues that reveal both the promises of and future challenges for EdTech.

A methodological note is in order at this point. In this chapter, we take a multidisciplinary approach and attempt to be inclusive of research and contexts from around the world, bearing in mind the shadow on the research literature known as the 'WEIRD problem' (the dominance of samples from Western, highly educated, industrialized, rich and liberal democratic countries and regions). That is, the majority of psychological and educational research in journals **(Arnett, 2008)** employs college-level student samples that 'not only fail to generalize to the world at large but also are especially atypical and unrepresentative' **(NASEM, 2018, p. 317; see also Henrich, Heine and Norenzayan, 2010; Rad, Martingano and Ginges, 2018)**. The chapter contributors have collaborated across different academic fields in the natural and social sciences to formulate the integration and synthesis of multidimensional perspectives on EdTech. We also believe that the multicultural background of the authors, spanning four different continents, contributes significantly to the development of a more holistic assessment of EdTech in the global space. That said, we must acknowledge that journals and reports on EdTech stemming from development and research in Western countries exert a strong influence on which questions are asked and most studied **(Arnett, 2008; Thalmayer, Toscanelli and Arnett, 2021)**.

This chapter is neither a meta-analysis nor an exhaustive literature review but rather a broad perspective on EdTech in anticipation of future application and diffusion into education systems. Our approach to this chapter also reflects the uneven diffusion across the world of both EdTech itself and research about it, coupled with a recognition that there is limited generalizability of research conducted in one setting, context, social or historical moment and culture **(NASEM, 2018)**.



6.2 History of EdTech and the Delors Report

One can trace the intertwining of technology and literacy and learning through innovations in writing and mathematical notation systems and various inventions; notable examples are affordable paper production, moveable type, the printing press, the slide rule, the calculator and the ballpoint pen. However, the history of EdTech coincides with modern (twentieth century to the present), formal training and schooling contexts. The earliest example of EdTech using electronic and digital media/tools was educational radio prior to the First World War **(Bates, 1984)**. Early innovations in broad consumer and military technologies such as slide shows and retro-projectors were readily adapted for use in education in the early twentieth century **(Saettler, 1968; De Vaney and Butler, 1996)**. The inception of EdTech as a main instructional delivery modality came with the foundation of Open University in the United Kingdom (UK) in the early 1970s, and the use of computers in education with programming, drill and practice became widespread **(Manguel, 1996)**. The use of 'computer technologies' to support learning was pioneered and reported by Atkinson and Shiffrin as early as 1968 **(see Bransford, Brown and Cocking, 2000)**. The late 1980s to early 1990s witnessed the popularization of computer-based training with multimedia (e.g. CD-ROM) in schools and universities. Internet-based instruction started in the 1990s, which was followed by e-learning well into the early 2000s **(Fletcher, 2009; Graesser, 2013; Weller, 2018)**.

Today, we cannot take for granted that the network neutrality of the internet and its influence on education will remain as it is now..

A plethora of new technologies, such as open-source, social media, virtual environments and AI, have been adopted by education, and are turning education into places and spaces of technological convergence **(see WG3-ch7** for further discussion on digital places in education). That is, there is a tendency towards the integration of previously unrelated technologies and participatory culture **(Jenkins, 2007)**. The very systemic structure of technology has been going through a steady stream of radical changes. Today, we cannot take for granted that the network neutrality of the internet and its influence on education will remain as it is now, such as the case of blockchain, which will increasingly affect financing and investing in education, implementing instructional projects, certification/accreditation systems and the monitoring of learning outcomes with distributed ledgers **(Cacioli, 2020; Park, 2021b)**.

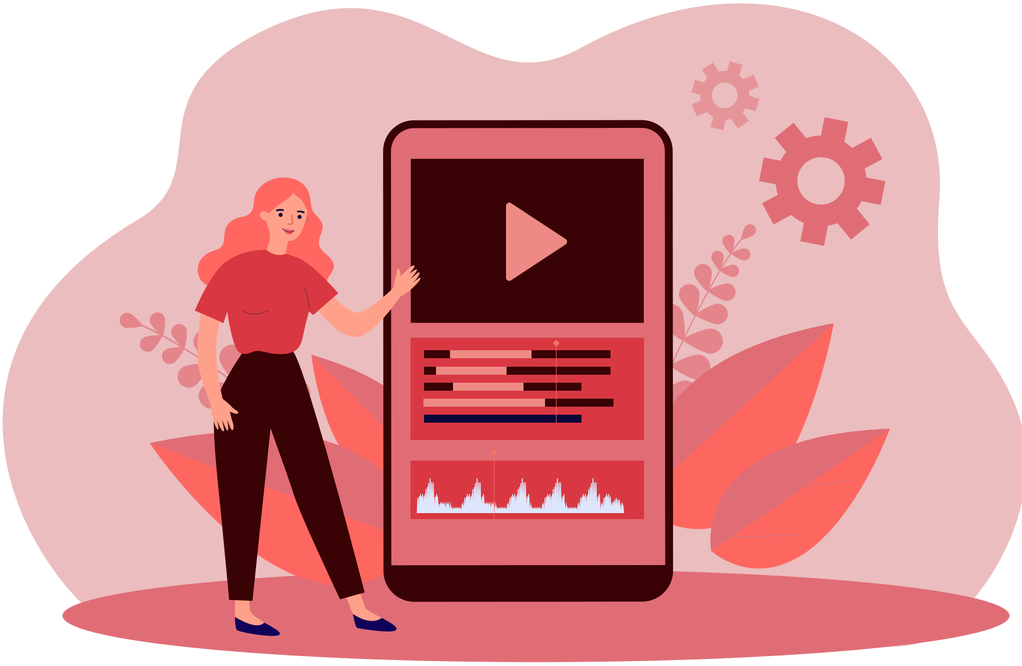
ICTs are one of the central themes of the **'Delors Report'**, a landmark report to UNESCO of the International Commission on Education for the Twenty-first Century **(International Commission on Education for the Twenty-first Century, 1996)**. While ICTs and peripherally related digital technologies stand out, it is important to acknowledge the legacy of multimedia technologies that continue to be used around the

world for education delivery. For example, the infrastructure built to support educational television and radio programmes established over several decades remains important in several societies. India's NCERT, for instance, has a large, channel-like structure which still offers extensive programming today. Nepalese radio education also has a long tradition **(Holmes, Karmacharya and Mayo, 1993; Pradhan, 2012)**. Community radio programmes produced by disadvantaged children in Senegal and South Africa contribute to their identity formation while promoting peace and reconciliation **(Bosch, 2007)**. In Afghanistan, UNICEF is using radio to teach children in violence-affected zones. In the United States (USA), the public broadcasting service (PBS) has provided children's educational television programming since 1969 when it debuted Sesame Street; this has resulted in multiple international co-productions, and PBS continues to develop televised and internet hybrid programmes to support children's learning

While there has been an impressive growth in ICTs, related disparities such as the digital divide between the rich and the poor has resulted in problems of access and quality of usage that continue to pose challenges for global education.

(Mares and Pan, 2013; Fisch, 2014; Kearney and Levine, 2015). More recently, during the COVID-19 pandemic, a number of governments have used television channels to air educational programmes **(Alvi and Gupta, 2020; Özer, 2020; Ramabrahmam, 2020)**.

Returning to the **Delors Report**, we acknowledge three key facets of technology – ICTs in particular – reported by the Commission that deserve to be revisited and reassessed: (1) the crucible of knowledge production and dissemination in science and technology; (2) the tension between technology and social justice; and (3) the centrality and future direction for education systems and international cooperation surrounding EdTech. The Commission identified technology as a currency and an instrument in the push and pull inherent to economies amidst fast globalization. Aiming at international cooperation, for example, the Commission highlighted the importance of 'the quantity and quality of traditional teaching materials such as books, and on new media such as information technologies, which should be used with discernment and with active pupil participation' **(International Commission on Education for the Twenty-first Century, 1996, p. 31)**. While there has been an impressive growth in ICTs, related disparities such as the digital divide between the rich and the poor has resulted in problems of access and quality of usage that continue to pose challenges for global education **(Scheerder, van Deursen and van Dijk, 2017; Yuen et al., 2017; Park, 2021a)**. The science and technology gap between 'developed' and 'developing' countries **(International Commission on Education for the Twenty-first Century, 1996, p. 34)** is still being breached today. The infrastructure for ICTs, especially a stable, reliable internet, is not a universal, worldwide achievement, within or across regions. Until such a time that societies provide such universal access and coverage, technologies will need to be adapted to address local inequities in infrastructure and service.



6.3 Types and scope of EdTech

A selective and non-exhaustive typology of technologies relevant to EdTech can be organized around their efficacy and impact while being mindful of fast-paced technological innovations with their affordances, opportunities and risks, and often unpredictable and transformative consequences. An illustration of a transformative innovation might be the keyboard for typing, which accelerated the spread and use of print literacy in comparison to handwriting. Another example is the touchscreen or finger-driven display. After its invention by Johnson in 1965, Samuel Hurst's resistive touchscreen, developed in 1970, provided the foundation for the later innovation and adoption of smartphones and tablet devices **(Ion, 2013)**.

In EdTech, one driver of inventions, innovations and adoptions has been the desire to serve those with individual differences that interfere with participation in customary social or educational settings. Both

Through assistive technology, for example, children with special education needs are able to access the general education curriculum.

perceptions of and responses to digital device environments have been adapted and enhanced by attending to individuals with physical and mental disabilities **(Wehmeyer et al., 2012; Meyer, Rose and Gordon, 2014)**. Through assistive technology, for example, children with special education needs (SEN) are able to access the general education curriculum **(Chambers, 2019; Vincent-Lancrin and van der Vlies, 2020)**. There are different kinds of assistive technologies that can be adjusted to inclusive classroom settings, for example, if a child has a visual impairment, they can opt to use text-to-speech functionality to gain skills and independence **(Maich and Hall, 2016)**. Other notable examples of assistive technologies for those with SEN are tactile interfaces for the blind or visually impaired, visual displays for the deaf or hearing-impaired, and alternative response modalities for those with loss of or limited mobility or movement **(Hersh, Leporini and Buzzi, 2020)**. The evolution of universal design principles, which codify how and when to apply EdTech to support learning, represents the state of the art in aspiring to technologies that do not exclude based on individual differences but rather attempt to circumvent such differences **(Al-Azawei, Serenelli and Lundqvist, 2016; Capp, 2017)**.

We now turn to a discussion of ICTs, which serves as a convenient shorthand typology in organizing the review that follows. We review current developments in ICTs in reverse order – technology, communication, information – expanding on each category as warranted.

6.3 .1

TECHNOLOGY: HARDWARE/DEVICES/ROBOTS/VIRTUAL WORLDS

At the outset of the computing era, large, centrally located mainframes (computation and data storage) were accessed via a distal terminal consisting of an input (keyboard, programming card) and output (initially a printer, later a monitor screen). Ironically, we have almost come full circle, with computing power distributed across networks, allowing for the sharing of computation between a local device and distal servers. Similarly, storage is shifting to 'the cloud', a euphemism for external server storage of data. This allows for a variety of user interface devices ranging from classic (though thinner) high-definition monitors, tablet-sized screens, phones, watches, eyeglasses and virtual-reality goggles, the latter creating a simulation of three-dimensional (3D) space for the wearer. Research is underway using a computer-vision-driven system that runs a 3D 'digital twin' of the classroom **(Zhang et al., 2014)**. Thus, a teacher can see a whole class without instrumenting any of the occupants to obtain it. Researchers are implementing this in both controlled studies and real-world classroom deployments with promising results **(Anonymous, 2018)**.

An emerging area of EdTech research concerns the impact of 3D printing on education **(Szulzyk-Cieplak, Duda and Sidor, 2014; Papp, Tornai and Zichar, 2016; Song, 2018)**. Through different digital interfaces, 3D printers facilitate expression of learners' experience of a multidimensional world and allow them to emulate and (re) create it. There is evidence of 3D printers' impact in diverse education contexts and regions, for example, as an instructional tool for teachers **(Song, 2018)**; for special education **(Buehler, Kane and Hurst, 2014; Buehler et al., 2016)**; and in arts-restoration education **(Short, 2015)**.

Another branch of technological innovation has been directed at perception and motoric functions, with increasing advances in both sensitivity and precision, as well as intelligent feedback looping that mimics advanced cognition **(Goldberg et al., 2017)**. At the basic end of this spectrum, nearly all digital devices now come standard with audio-video embedded in their hardware. While these innovations can support various

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individual differences that impact learning (e.g. for the blind/visually impaired or the deaf/hearing - impaired), they can also be used as management, surveillance and control tools that raise issues of confidentiality and privacy. Whether an individual is assured of when they are being recorded is not always transparent to the user. Eye-tracking technology **(Anonymous, 2018; Ashraf et al., 2018)** is relatively cheap and easy to install on a laptop computer, giving perhaps an ominous cast to the notion that eyes are the windows of the soul. For example, D'Mello et al. **(2012)** developed a system that tracked whether the learner was paying attention to the computer screen while learning and automatically gave feedback to the learner when the eyes went off-screen **(Hutt et al., 2017)**. Of course, even legacy broadcast technologies can be reversed – using cameras or audio-recording to monitor students, teachers and classrooms. Fingerprint identification serves both a privacy/security function for the individual, but also creates the risk of confidentiality and privacy invasion. Motion detectors, analyses of facial expressions and biometric sensors are used to infer our mental and emotional states **(Calvo and D'Mello, 2010; D'Mello and Graesser, 2010)**, benignly for engagement and motivation, but other less admirable applications are easily imagined.

In addition, social robotics is an emerging field, opening up a world of human-like physical and emotional tutors and companions **(Breazeal, 2009; D'Mello and Graesser, 2012; Breazeal et al., 2016)**. Biometric sensors and global positioning system locators extend technologies not only to anywhere we happen to be but make inferences to our emotional states as we learn and experience. These seemingly science-fiction-inspired devices are currently being researched in laboratories, but there is every reason to believe that creative engineering applications will, in the coming decades, bring consumer or open-source programs that will accelerate wider dissemination.

6.3 .2

COMMUNICATION AND COLLABORATION

Despite decades of distance education models and implementation, the reality of enforced distance learning has caught many educational providers, parents and communities by surprise.

As we write this chapter, the world continues to be in the midst of a pandemic that has, in many countries, resulted in the closing of schools and a move to the virtual, remote classroom, or a hybrid model that combines the two (virtual or distance education and in-person, classroom learning) **(Cox and Laferrière, 2021)**. Despite decades of distance education models and implementation, the reality of enforced distance learning has caught many educational providers, parents and communities by surprise **(Education Week, 2020)**. In addition, where technological infrastructures support it (such as in the USA and South Korea), the presence of communication platforms such as Zoom has engendered creative and arguably productive continuity in the face of crisis. Hybrid models of in-person and remote/virtual education have been trialled. Higher education institutions, in particular, have increased training courses for faculty in the use of effective instructional design principles for delivering content and maintaining student engagement and self-directed learning in computer-mediated environments **(Rashid and Asghar, 2016)**.

Two lines of research have been drawn upon to support the massive efforts of virtual and remote learning in the face of the pandemic. Firstly, decades of research on distance education, including massive open online courses (MOOCs), have led to insights into the affordability and challenges of learning at a distance **(Gaševic, Dawson and Siemens, 2015; Qayyum and Zawacki-Richter, 2018; WG3-ch7)**. Secondly, research into computer-supported collaborative learning (CSCL) has focused on the quality of interactions when learners are brought together to learn. Järvelä and Hadwin **(2013)** note that CSCL technologies, when carefully designed using collaborative learning principles, Not to be overlooked in this regard is the voluminous sharing of content, lessons and activities by and for educators.

are effective in enriching learning interactions and creating opportunities for sharing and constructing knowledge among group participants **(Ludvigsen et al., 2010)**; they have also been associated with changes in both individual and collective collaboration outcomes **(Salomon, Perkins and Globerson, 1991; Sottilare et al., 2018)**. Not to be overlooked in this regard is the voluminous sharing of content, lessons and activities by and for educators. For example, the University of Colorado Boulder hosts the PhET Interactive Simulations project, which according to the University's website, provides over 150 free interactive mathematics and science simulations, over 2,500 lessons submitted by teachers, translations into 94 languages and over 784 million simulations delivered **(PhET, 2020)**.

It is difficult to draw conclusions from the forced, global social experiment in remote learning, and it is even daunting to comment upon it. What we can hope for is a change or shift in mindset from believing that all education must take place face-to-face to designing what affords the best opportunity and context for student learning. Some will no doubt wish to go back to the traditional, in-person school and classroom structures as the sole or primary location for learning. But this industrial-era model of education delivery has not been working for specific subpopulations in most country settings. For example, in the USA, the disparity in reading performance between African-American children and their white peers has persisted for over thirty years, despite numerous technological enhancements in schools **(McFarland et al., 2019)**. The traditional classroom and school model was built upon assumptions of societies that existed over a century ago, and economic and technological change has shifted those assumptions. Many social and commercial institutions have already shifted towards accommodating remote workers and workplaces. The dominance of a socio-economic system where caretakers go to a workplace is shifting, which offers the

The explosion of information in the digital age has arguably been accompanied by an explosion in the means for generating, sharing and evaluating knowledge.

opportunity to reconsider whether children going to a physical school is the only or best option for learning.

6.3 .3

INFORMATION: THE INTERNET

The World Wide Web was invented in 1989; the first browser and version of HyperText Transfer Protocol and the first browser and version of the HyperText Markup Language occurred in 1990. By 2005, there were over 1.1 million websites, by 2013 there were over 600 million, and by 2016 there were over 1.7 billion.

The explosion of information in the digital age has arguably been accompanied by an explosion in the means for generating, sharing and evaluating knowledge. To take one critical example, for decades, education reformers have been attempting to move teachers away from the primary role of knowledge conveyer or 'sage on the stage' towards a role of fostering a more student-centred 'guide on the side'. Perhaps this paradigm shift is attributable, at least partially, to the sheer volume of information that is currently available and still growing exponentially. For example, while Wikipedia as an information source enjoys different rates for reliability and credibility depending on the age and professional profile of its users, it is increasingly respected for its very open system of editors and source citations to update and amend errors **(Korfiatis, Poulos and Bokos, 2006; Flanagin and Metzger, 2011; Fitterling, 2014)**. Its policy of allowing its users to create, edit, contest and revise the content may not be perfect, but it approaches trustworthiness reasonably and transparently, according to a philosophy of participatory and peer-reviewed content.

In our information-intensive society, every human can be regarded as a 'station' in a network of knowledge, either decentralized or distributed, partaking in

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the collective intelligence and capacity-building in a networked society **(Castells, 2009; Cornu, 2005; Siemens, 2005)**. Skills and strategies of search, navigation and evaluating source relevance and credibility are thus foregrounded in any information-processing task **(Rouet and Britt, 2011; Britt and Rouet, 2012)**. In education, the ability to properly handle information is known as 'information literacy' and it involves the ability to:

- determine the nature and extent of the information needed;

- effectively and efficiently access information that is required;

- evaluate information and its sources critically and incorporate the information into the personal knowledge base and value system;

- summarize and synthesize the main ideas to be extracted from the information and construct new concepts;

use information effectively to accomplish a specific/ethical purpose **(American Library Association, 2000)**.

The circumstance of the twenty-first century is that multiple source evaluation is a prerequisite to learning and understanding; information must be evaluated, cross-validated and integrated, aligned with an epistemology that gaining knowledge is a work in progress and never universal and, hence, open to falsification **(Popper, 2002)**. This modern context has significant implications for how we prepare students to access and understand information **(Bråten et al., 2011)**.

6.3 .4

BEYOND ICT

The influence of AI and other advanced digital technologies on EdTech requires careful attention because there is widespread uncertainty about and speculation on how these new technologies will influence people's lives and education **(Elliott, 2017; Yang, 2019; Aiken and Epstein, 2000)**. It is beyond

the scope of this chapter to cover the rapid and dynamically changing landscape of new digital technologies evolving in the EdTech world, but we identify the following four loci to monitor.

6.3 .4 .1

DATA SCIENCE AT SCALE

The collection of data through EdTech is dramatically increasing in volume, breadth and depth **(NAEd, 2017)**. Further, EdTech enhances the organization and materialization of data collection **(Lefever, Dal and Matthíasdóttir, 2007; Leonardi and Vaast, 2016)**. At the upper bound, one can imagine a data repository for millions of students and citizens, each of whom has an associated comprehensive learner model of knowledge, skills, abilities and achievements that have accrued over years of a person’s life (much like a quantified digital learning portfolio). This upper bound is actually being achieved to sell products in the commercial world (using the data collected from customers), but the world of education research has barriers that observe privacy, and ethical and legal constraints that prevent the sharing of datasets among

There has been an emphasis in recent years on personalized learning whereby the learner has some agency in selecting what to learn and the learning environment, thus delivering the right learning activity to the learner at the right time (NASEM, 2018).

research communities. However, steps have been taken towards the upper bound in education **(Rus et al., 2020)**.

6.3.4.2

INTELLIGENT ADAPTIVE TUTORING SYSTEMS

Intelligent tutoring systems keep a detailed record of students' knowledge, skills and psychological characteristics (called a student model) and use that model to generate adaptive responses to help students learn or stay engaged **(Woolf, 2009; Graesser, Hu and Sottilare, 2018; GIFT, 2020)**. These systems have shown promising learning gains compared to conventional learning activities (lectures, reading) presumably because of their interactive nature **(Kulik and Fletcher, 2015)**. AI-based assessment in tutoring systems can also rigorously, continuously and stealthily evaluate student progress/levels in learning, and provide timely information for different stakeholders **(Shute and Kim, 2014; Luckin, 2017)**.

6.3.4.3

INTERACTIONS WITH THE LEARNER IN NATURAL LANGUAGE

Revolutionary advances in computational linguistics **(Jurafsky and Martin, 2008)** have made it possible to analyse natural language and discourse in visual and spoken text in essays and conversation and written text **(Graesser and McNamara, 2012; Yan, Rupp and Foltz, 2020)**. There are now intelligent tutoring systems that enable students to have turn-by-turn conversations with computers in natural language that yield learning gains equivalent to trained human tutors in computer-mediated communication **(VanLehn, 2011)**. These computer tutors do not perfectly comprehend student contributions but neither do human tutors **(Graesser, Person and Magliano, 1995)**. A conversational interaction can prompt students to become more active learners by asking challenging questions, providing hints and other conversational discourse moves.

New technologies promise to track the knowledge, skills and abilities of individual students at a more nuanced level, with recommendations for learning environments that are tailored to their needs.

6.3 .4 .4

GAMES

Educational games increase learning through a more motivational route. Researchers have designed educational games, digital game-based learning (DGBL) in particular, to optimize learning through motivation **(Tobias and Fletcher, 2011; Wouters and van Ostendorp, 2017)**, to assess learning continuously **(Wang, Shute and Moore, 2015)**, to assess socio-emotional development **(Dishon and Kafai, 2020)**, to cultivate perspective-taking **(Irava et al., 2019)**, and to employ culturally sensitive-differentiated tools **(Park and Wen, 2016; Shadiev, Sun and Huang, 2018)**. Meta-analysis has been conducted and shows mixed success in improving learning but, with further engineering and science, the promise is undeniable **(Wouters et al., 2013; Clark, Tanner-Smith and Killingsworth, 2014)**.

... without safeguards, standards and policies, such student evaluation information could be used as reasons to limit students' choices and opportunities about what to learn, because algorithms predict their low probability of success.

6.3 .5

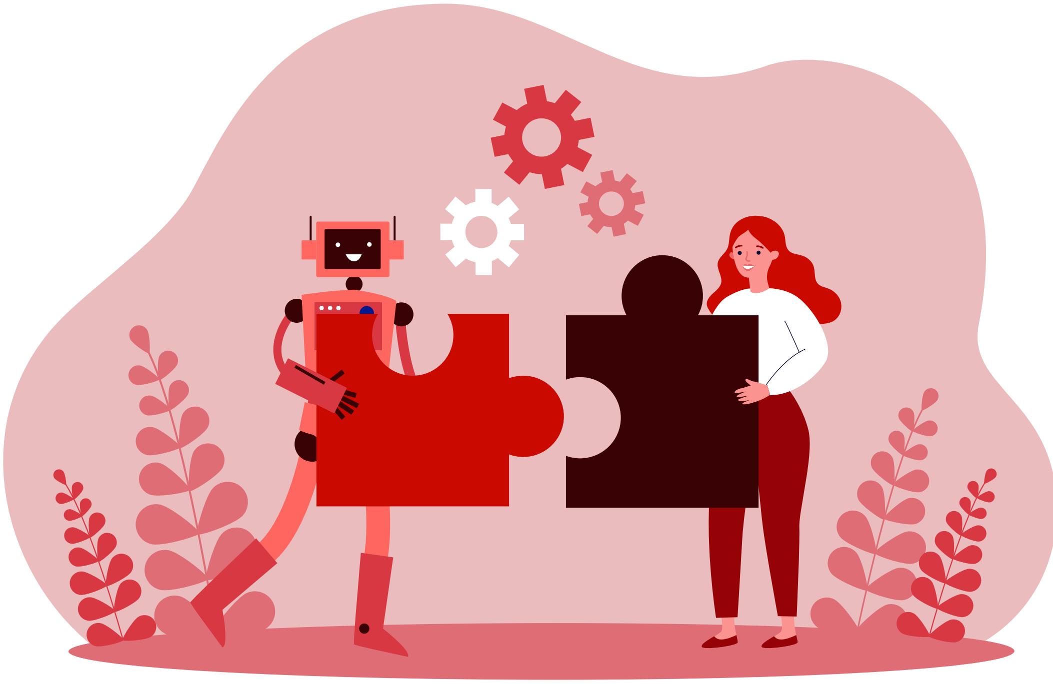
ENHANCEMENT OF LEARNING EXPERIENCE

There has been an emphasis in recent years on personalized learning whereby the learner has some agency in selecting what to learn and the learning environment, thus delivering the right learning activity to the learner at the right time **(NASEM, 2018)**. This is very different from the current, but elusive, model of effective intervention applied uniformly to all students in a classroom **(Lortie-Forgues and Inglis, 2019)**. New technologies promise to track the knowledge, skills and abilities of individual students at a more nuanced level, with recommendations for learning environments that are tailored to their needs. This is the vision of intelligent tutoring systems and other adaptive instructional systems that tailor instruction to individual learners **(Woolf, 2009; Graesser, Hu and Sottilare, 2018; also critical views, e.g. Selwyn, 2019)**.

The promise of such EdTech is obvious, but developing standards and safeguards is equally important at the development and research level. For example, what happens once an upper bound of learner data are collected? On the positive side, the data can be mined for patterns that reflect success in learning and motivation. Machine learning techniques, such as multilayered neural networks in deep learning **(LeCun, Bengio and Hinton, 2015)**, can automatically identify the patterns that predict learning and engagement gains, including an estimate of how well the patterns generalize from one niche of learning activity to others. On the negative side, without safeguards, standards and policies, such student evaluation information could be used as reasons to limit students' choices and opportunities about what to learn, because algorithms predict their low probability of success. Further, without safeguards, broaching privacy and confidentiality, such

decisions could be made without their knowledge **(e.g. Drachsler and Greller, 2016)**.

The above survey of existing and emerging EdTech reveals an accelerating R&D context that is overwhelming in its diversity, complexity and promise. But how do stakeholders make sense of all of this when deciding what is best for teaching and learning in educational settings? To address this question, we take a more conceptual approach, examining the literature on how people learn



6.4 How people learn, affordances of EdTech, and tailoring to individuals and groups

Deciding how and when to use EdTech requires an understanding of the different types of learning that may occur in formal and informal learning environments. In turn, EdTech-augmented learning environments need to be aligned with the goals and types of learning. For example, drill and practice is fine for certain basic mathematical computation operations (implicit pattern

Observational learning may be influenced by many factors such as the individual's perception of themselves relative to those modelling the behaviour, be they teachers, caretakers, authority figures or peers.

learning) in children but not for building mental models of how a nuclear reactor works in adults (mental models with inferences). This is the nexus at which the learning sciences intersect with EdTech to inform decision-making. As we look to the future, research is revealing new affordances of EdTech and how it can be aligned not only to the content being learned but also to individual differences in learners or to groups learning together.

6.4 .1

HOW PEOPLE LEARN

The second edition of *How people learn* **(NASEM, 2018)** identifies types of learning, noting that multiple types of learning are integrated or orchestrated in acquiring new knowledge, skills or strategies, and are influenced by the learner's context, culture and individual characteristics. The types of learning identified include:

Habit formation and conditioning. Conditional learning is gradual, often unconscious and self-reinforcing. Habits may have positive or negative dispositions and may be deployed automatically, that is, with ease, fluency and relatively little cognitive effort, when environment conditions cue their use.

Observational learning. Imitation, interpretation, modelling and inference may all be called upon when learning by observation. Observational learning may be influenced by many factors such as the individual's perception of themselves relative to those modelling the behaviour, be they teachers, caretakers, authority figures or peers.

Implicit pattern learning. Sometimes called 'statistical learning', this involves the learning of regular patterns in a particular environment without actively intending to do so. This kind of learning is akin to observational

How to optimize learning of any specific skill or topic is a central question explored in the learning sciences, and almost always involves a mixture of types of learning to achieve complex goals or expertise in a domain.

learning but is characterized by the unconscious recognition of regularities or patterns in an otherwise irregular context, without conscious attention and reflection being directed to the regularity or pattern by direct instruction.

***Perceptual and motor learning*.** Learning through perception or sensory experiences can be characterized as perceptual or motor learning. Complex physical skills such as learning to play a musical instrument, sport or manipulating a game console are examples where percepts and actions are developed to work in coordinated ways with high levels of sensitivity and specificity required to attain expertise.

***Learning of facts*.** Facts or information can be learned in a single trial or over repeated exposure, incidentally or intentionally (studying, memorization). One might distinguish facts (which have a positive truth value) from data. Facts can be learned from external sources or generated by elaborating on what one already knows.

***Learning by making inferences*.** Inference-making captures a wide range of cognitive operations including, but not limited to, reasoning, analysis, synthesis, abduction, evaluation, elaboration, model-making and creativity. It enables generalization and transfer of learning to new contexts and situations.

How to optimize learning of any specific skill or topic is a central question explored in the learning sciences, and almost always involves a mixture of types of learning to achieve complex goals or expertise in a domain. For example, when learning a complex array of facts, the learning sciences point to spaced practice over massed practice and memorization. Learning to play a musical instrument, on the other hand, favours an environment with more perceptual and motor learning practice. Duly selected EdTech can facilitate different types of learning by intensifying exposure to sensory stimuli, experience and iterations.

An optimal learning context occurs when existing knowledge is able to be compared, contrasted or applied to novel situations, that is, the cognitive process of drawing upon existing knowledge in the 'long-term store' (**Atkinson and Shriffin, 1968**). Evidence from research on cognitive load indicates that due to the ephemeral nature and limited capacity of the 'short-term store' or 'working memory', its overloading with multiple sources, all at once, of visual, auditive and textual information can lead to a state of divided attention and lack of effective learning (**Sweller, 1994; Sweller, Ayres and Kalyuga, 2011; Kalyuga, 2015**). Cognitive capacity can therefore be undercut by cognitive overload caused when sensible instructional design does not take human-processing capacity limitations into consideration. For example, the mere presence of a smartphone (not in use) could diminish cognitive performance if it is a source of distraction – splitting attention or depleting working memory resources on content not relevant to learning objectives. An extreme case of this is 'smartphone dependence', a habitual state of distraction whenever one's smartphone is present (**Ward et al., 2017**). Thus, from the perspectives of pedagogy and instructional design – EdTech inclusive – planning the dynamics among different levels of cognitive processing is paramount.

Thus, from the perspectives of pedagogy and instructional design – EdTech inclusive – planning the dynamics among different levels of cognitive processing is paramount.

6.4 .2

AFFORDANCES OF EDTECH

In any topic or domain, knowledge, skills, strategies and disposition (KSSD) need to be learned, and each is likely to require one or more types of learning activity. Curriculum, instructional designers and teachers have expertise in understanding, developing and delivering instruction to help learners build KSSD. EdTech is one of the tools in a toolkit of instructional design. Towards this end, we can analyze technologies from the perspective of their affordances. The second edition of *How people learn* **(NASEM, 2018, pp. 165–66)** identifies some of the affordances of learning technologies to help guide this alignment between KSSD and EdTech.

Interactivity: the technology systematically responds to the actions of the learner.

Adaptivity: the technology presents information that is contingent on the behaviour, knowledge or characteristics of the learner.

Feedback: the technology gives the learner information about the quality of their performance and how it could improve.

- Choice: the technology gives learners options on what to learn and how to regulate their own learning.

Nonlinear access: the technology allows the learner to select or receive learning activities in an order that deviates from a set order.

Linked representations: the technology provides quick connections between representations for a topic that emphasizes different conceptual viewpoints, media and pedagogical strategies.

Open-ended learner input: the technology allows learners to express themselves through natural language, drawing pictures and other forms of open-ended communication.

Communication with other people: the learner communicates mediated by technology with one or more people or agents.

The combinations of learning that need to complement a particular curriculum or instructional standard require the joint responsibility of learning scientists, curriculum and instructional

The combinations of learning that need to complement a particular curriculum or instructional standard require the joint responsibility of learning scientists, curriculum and instructional designers, and teachers.

designers, and teachers. Almost every complex skill (reading, mathematics, writing) will require a combination of different types of learning at different stages of skill acquisition. Understanding the stage in which the target is learning facts, or forming habits and disposition, or implicitly learning the different patterns, will help decision-makers to choose appropriate EdTech solutions to aid in that learning.

There exist a score of frameworks or theoretical models to support technology integration into teaching, notably:

TPACK, that is, technological, pedagogical and content knowledge on different dimensions and types of knowledge mediated by technology;

SAMR (substitution, augmentation, modification and redefinition), which is a four-level, taxonomy-based technology integration in primary and secondary education;

TIM (technology integration matrix), an EdTech model which is the result of intersecting five levels of technology integration (entry, adoption, adaptation, infusion and transformation) with five types of learning environment (active, collaborative, constructive, authentic and goal-directed);

RAT (replacement, amplification, transformation), which is a theoretical construct on the effect of technology on pedagogy; and

PICRAT, a passive, interactive or creative relationship between student and technology which encompasses the RAT construct **(FCIT, 2005; Mishra, Koehler and Zhao, 2007; Hamilton, Rosenberg and Akcaoglu, 2016; Harmes, Welsh and Winkelman, 2016; Kimmons, Graham and West, 2020).**

In order to adjust EdTech to diverse types and areas of support need such as for intellectual and/or physical disabilities, it is important to abide by the principles of universal design …

6.4 .3

EQUITABLE ACCESS TO DIFFERENT LEARNERS

The United Nations (UN) Sustainable Development Goal 4 (SDG 4) aims to 'ensure inclusive and equitable quality education and promote lifelong learning opportunities for all' **(UN, 2015, p. 14)**. It presents 'a new vision' for education that is 'comprehensive, holistic, ambitious, aspirational and universal, and inspired by a vision of education that transforms the lives of individuals, communities and societies, leaving no one behind' **(Knox, Wang and Gallagher, 2019, pp. 2–3)**. Here, we focus on inclusive education for persons with disabilities and some of the assistive technologies that work to achieve this. In order to adjust EdTech to diverse types and areas of support need such as for intellectual and/or physical disabilities, it is important to abide by the principles of universal design, that is, a common instructional design – for curriculum and pedagogy – that accommodates students with different support needs **(Wehmeyer et al., 2012)**.

EdTech has led the way in providing opportunities for differently abled students to learn **(Fichten et al., 2009)**. It has been used to support individuals with special needs to concentrate on tasks; it has also been used to provide opportunities for these individuals to try simulations, basic drill or practice, communication or explanatory activities, and increase higher-order thinking skills **(Edwards, Blackhurst and Koorland, 1995; Yeni and Gecu-Parmaksiz, 2016)**.

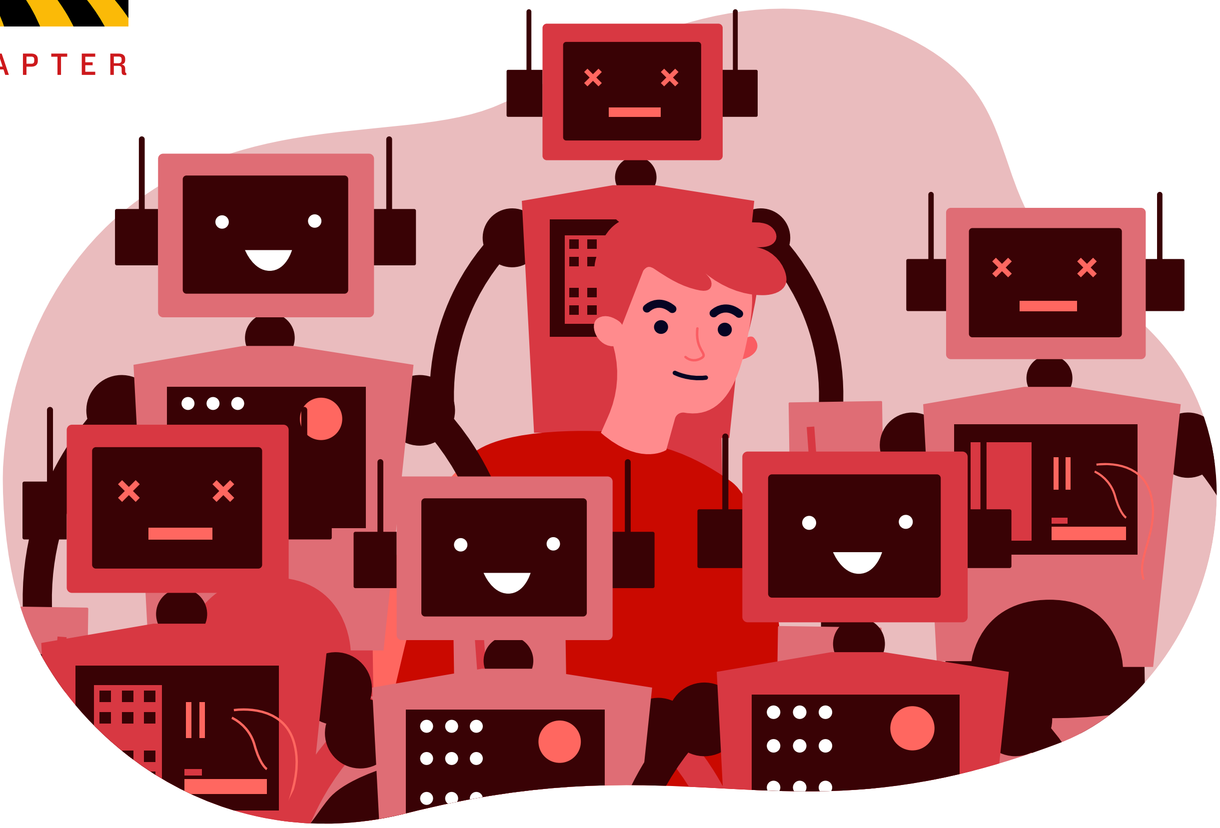
Arkorful and Aibadoo **(2015)** discuss the advantages of e-learning, including flexibility, improved access, the ability to overcome systemic barriers, and personalization. They also discuss e-learning's disadvantages, such as the lack of direct social interaction, inefficient explanations compared to traditional methods, and the

AI in educational development (AIED) provides robust tools for the development of personalized learning for the atypical dimensions of inclusive education …

requirement of strong self-control and discipline on the part of the student **(Bandalaria, 2018)**.

EdTech also comes with several strengths that can aid pedagogical practices in the education of differently abled individuals. For example, AI in educational development (AIED) provides robust tools for the development of personalized learning for the atypical dimensions of inclusive education including students with social anxiety, autism spectrum disorder (ASD) and specific learning difficulties such as dyslexia and dyscalculia **(Vincent-Lancrin and van der Vlies, 2020)**. Additionally, emerging development in robotics has allowed the design of AI social robots to provide valuable tools for social and emotional learning in the atypical student population **(Vincent-Lancrin and van der Vlies, 2020)**. Data collected from facial recognition (emotion, eye-tracking) and speech recognition (feedback, emotion, assessment, etc.) are used in training of AI-enabled EdTech to develop a user-oriented approach for creating adaptive learning environments **(Mohammed and Watson, 2019)**.

As previously noted **(see section 6.1)**, an issue in the AI field is how the cultural and social biases in the data collected and used to train AI-enabled machine learning systems make the system inherently biased towards inequalities already existing in societies from where the data are derived. AIED is heavily influenced by WEIRD samples, with 82 to 95 per cent of all research coming from high-income countries, showing clear global imbalance in datasets used in models and systems **(Mohammed and Watson, 2019)**. The ultimate success of AIED will be achieved through an integration of multiple, plural world views and contextualized datasets used to train the AI.



6.5 Critical issues

In the following section, we spotlight current and future priority issues for research, policy and practice in the social and cultural context of EdTech's application in educational systems. We introduce each issue with a literary allusion or a historical figure to draw attention to different points of view on the interplay of history, culture and technology, as a reminder that human agents need to play the lead role in the drama of how EdTech will unfold in the years to come.

> ... the existence of a digital divide in education based on societal advantage/disadvantage presents an educational moral imperative to address the problem of access as a right, not a privilege.

6.5 .1

MAHATMA GANDHI AND CONFRONTING THE DIGITAL DIVIDE

Mahatma Gandhi forewarned us of a world sustainably divided into those in necessity and those in abundance, adding a note of hope and admonishment: 'The world has enough for everyone's need, but not enough for everyone's greed'. While we have posited that EdTech is not a panacea for all the ills of education, it has the potential to be the great equalizer, moving the world towards 'enough' for everyone's educational needs. But for this promise to even have a chance, we must address the issue of the digital divide.

Scheerder, van Deursen and van Dijk **(2017, p. 1608)** define the digital divide 'as inequalities in access to and use of ICTs, mostly the Internet'. We expand on this definition to broadly include the broader range of EdTech we have been discussing in this chapter. In education, the digital divide is currently discussed at three levels: (1) access/infrastructure; (2) skills/uses; and (3) mastery/outcome **(e.g. Yuen and Park, 2012; Yuen et al., 2016a, 2016b, 2017; Park, 2021a).**

While an individual or group may choose to opt out of some or all of our technology-driven cultures, governments should not be able to deny access or infrastructure to some groups as policy. This speaks concretely to the digital divide in education, because access/infrastructure is unevenly distributed, along the lines of the persistent inequities we face within and across societies and countries.

That is, the existence of a digital divide in education based on societal advantage/disadvantage presents an educational moral imperative to address the problem of access as a right, not a privilege **(Park, 2021a).** One cannot promise 'separate, but equal' opportunity when the advantaged have access to all that technology promises, and are pitted against

The lack of technological infrastructure in the form of stable electricity, internet connectivity and bandwidth, and software and hardware results in a widening of the inequality gap in education across nations.

the disadvantaged (defined differently in each society) who only have 'basic' education and resources, given that the students must compete economically and flourish independently in a tech-rich, adult society. This is a version of institutional discrimination. An individual may reject technology, but the 'state' should provide equitable opportunities to use it.

The lack of technological infrastructure in the form of stable electricity, internet connectivity and bandwidth, and software and hardware results in a widening of the inequality gap in education across nations **(Aduwa-Ogiegbaen and Iyamu, 2005; UNESCO, 2015; Eze, Chinedu-Eze and Bello, 2018)**. This is also the case locally, with reports demonstrating the EdTech constraints in low- and middle -income countries (LMICs), where most EdTech infrastructure is concentrated in urban centres **(Delponte et al., 2015)**. Surveys have found that only a minority of children have access to 'learning continuity' in LMICs in Africa; in Senegal, less than 11 per cent of children accessed technological tools to continue their studies during the pandemic **(Le Nestour et al., 2020)**. A technology infrastructure is therefore a necessary, though not sufficient, condition to take advantage of EdTech innovations as they emerge. That is, it affords opportunity, but does not guarantee its integration **(Fishman and Dede, 2016)**.

The good news, to which we have alluded, is that EdTech can be an equalizer in the distribution of educational resources. Paraphrasing an old proverb: give a child a traditional book and they can read one author for about a week. Give a child an ebook and they will have a library of authors to read for a lifetime. That is, the question of priorities within education leans heavily towards investing in infrastructure over traditional print materials. Economically and environmentally, digital is cheaper and cleaner than paper-based materials to distribute and update. With respect to cost and diversity of delivery, EdTech is more portable, reaches remote

With respect to cost and diversity of delivery, EdTech is more portable, reaches remote areas and can be used to reduce the constraints of geography. By accessing remote areas, it can help expand perspectives.

areas and can be used to reduce the constraints of geography. By accessing remote areas, it can help expand perspectives. The rationale is that an enhanced infrastructure affords greater access to better education for all. However, for many, EdTech solutions, such as ebooks, are still neither affordable, nor feasible. Even if they were, what would happen when the ebook malfunctions – where is the technical support? What if there is not ready electricity for charging devices? What happens when system upgrades render earlier hardware obsolete? Investments need to be designed for sustainability and not for simple short-term gratification and impressions.

Economically, several studies corroborate the 'leapfrog' effect of EdTech on national growth and development, when adequately planned and financed **(e.g. Sepehrdoust, 2018; Adeleye and Eboagu, 2019)**. In sum, the ethical argument may align with the economic – although EdTech investment is expensive, the state has a moral duty to ensure equal EdTech access to its citizens, thus providing opportunities for marginalized populations to partake in the digital revolution.

The guiding principle of eliminating the digital divide, however, is only the starting point for a series of challenging questions. Yes, there is a need for governments to invest in EdTech infrastructure and to build robust and efficient technology-driven policies **(Kamperman Sanders et al., 2018; Tauson and Stannard, 2018)**. But how is this accomplished?

For example, there are opportunity cost considerations for countries to invest in expensive EdTech infrastructure. With some LMICs short of basic education, health care, electricity and clean water, the question is not only whether scarce financial resources should be allocated to EdTech setup, but also whether the returns are sufficient to justify the investment. On one hand, there are reports that ICTs/EdTech infrastructure does not always contribute to human capital formation, for example, in some African contexts

To provide some nuance to the arguments above, we view the multiple results not as pointing to inconsistencies, but rather to the underlying difficulty of measuring the impact of ICTs.

(Ngwenyama et al., 2006; Ejemeyovwi, Osabuohien and Osabohien, 2018). On the other hand, there is sizable evidence that social media and big data analytics are strongly linked to public education, for example, in health care **(Kamel Boulos and Wheeler, 2007; Moorhead et al., 2013; Murdoch and Detsky, 2013; Raghupathi and Raghupathi, 2014)**.

To provide some nuance to the arguments above, we view the multiple results not as pointing to inconsistencies, but rather to the underlying difficulty of measuring the impact of ICTs. It has been argued that the effectiveness of EdTech on development might be based on specific parameters that account for categorization (e.g. country, economic capabilities). For instance, Sepehrdoust **(2018)** suggests the real impact of technology can be determined by comparing countries with comparable socio-economic indicators on a specified time lag. Differences across countries would provide a vivid and accurate diagnosis of the impact of EdTech and thus inform government policies. While we may debate the means of addressing the digital divide, it is difficult to imagine a future where technology does not figure prominently in a country or region and therefore, a time when EdTech is not a necessary element of a quality education system. Consequently, bridging the digital divide is imperative.

6.5 .2

ZHUANG TZU ON THE VIRTUAL AND THE REAL

A special affordance of technology has been to bridge the gap between the real (in-person) and the virtual or remote, blurring the boundaries between objectivity and subjectivity, calling to mind this quote: ‘Once upon a time, I, Chuang Tzu, dreamt that I was a butterfly, flitting around and enjoying myself. I had no idea I was Chuang Tzu. Then suddenly I woke up and was Chuang Tzu again. But I could not tell, had I been Chuang Tzu dreaming I was a butterfly or a butterfly dreaming

I was now Chuang Tzu' **(Zhuangzi and Palmer, 2006).**

The COVID-19 pandemic has transformed the world at times into a dire and surreal place. Traditional classroom learning has been forced to move to the virtual, facilitated by ICTs. Countries have adapted to the crisis and strive to provide learning continuity to millions of students. In Nepal, for example, online learning platforms have allowed students and teachers to remain connected with opportunities for teachers to provide moral and emotional support to students **(Surkhali and Garbuja, 2020).**

Despite the necessity of online learning platforms, there has been a backlash from diverse groups of teachers, students and parents to virtual learning. For example, the massive open book online examinations administered by Delhi University in India resulted in failure due to the existing digital divide, lack of textbooks for all students, and no prior teaching or training on the new format **(Iftikhar, 2020; Pande and Marathe, 2020; Scroll Staff, 2020; TeamCareers360, 2020).** As discussed in the previous section, the COVID-19 pandemic has shone a glaring light on the digital divide that exists between and within countries. Additionally, there is accelerated commercialization of new EdTech platforms alongside a lack of pedagogical/curricular rigour and continuity and a lack of ethnic and culture-based adjustments coupled with the rapid switch to virtual learning **(Zhang, Ordóñez de Pablos and Xu, 2014; Williamson and Hogan, 2020).**

...there is accelerated commercialization of new EdTech platforms alongside a lack of pedagogical/curricular rigour and continuity and a lack of ethnic and culture-based adjustments.

Yet opportunities lie in every crisis. Distance learning is characterized by an information delivery mechanism whereby the educator and learner are separated in both time and space **(Billings, 2007).** Virtual learning thus has proven to be the only readily available avenue during the crisis through which to connect people and ideas across time and space, bridging local/community learning and engagement. These virtual learning models could even be adapted to place-based learning contexts, in which teachers and students learn

There is an opportunity to promote the best of both worlds – blended learning which combines traditional classroom learning methods with online learning modalities.

and connect in situ to surrounding communities **(Sobel, 2004)**.

It should not have required a crisis to recognize the need to address the above challenges through creative and sustainable technology-guided policy decisions, which take into account the social and cultural contexts of learning. There is an opportunity to promote the best of both worlds – blended learning which combines traditional classroom learning methods with online learning modalities **(Green and Whitburn, 2016)** allowing knowledge from all over the world to be accessed by place-based, real people in experiential ways. Evidence from meta-analysis shows a larger effect size of learning when 'a blended rather than a purely online condition was compared with face-to-face instruction; when the online pedagogy was expository or collaborative rather than independent in nature; and when the curricular materials and instruction varied between the online and face-to-face conditions' **(Means et al., 2013, pp. 35–36)**.

However, we should not ignore critiques of these changes and the possibility that the current forms of online learning will exacerbate the negative facets of social distancing, not just physically, but emotionally. In medical education, for example, the task of identifying different types of cognitive overload **(see subsection 6.4.1)** among learners, namely, reduced performance, non-verbal cues, verbal utterances and interpersonal interactions (e.g. lack of responsiveness) are far more challenging during the pandemic **(Rajput, 2020; Sewell, Santhosh and O'Sullivan, 2020)**. Our modern and emerging technologies are requiring that we ask ourselves deep questions about what it is we value in our human learning experiences and environment, for example, the link between EdTech and cultural values **(Yuen et al., 2017; Irava et al., 2019)**, versus what might be learned or experienced via the remote, virtual or simulated worlds we may inhabit in between.

Disruption of the definition and role of teachers, while playing out differently across the world, has been underway for years.

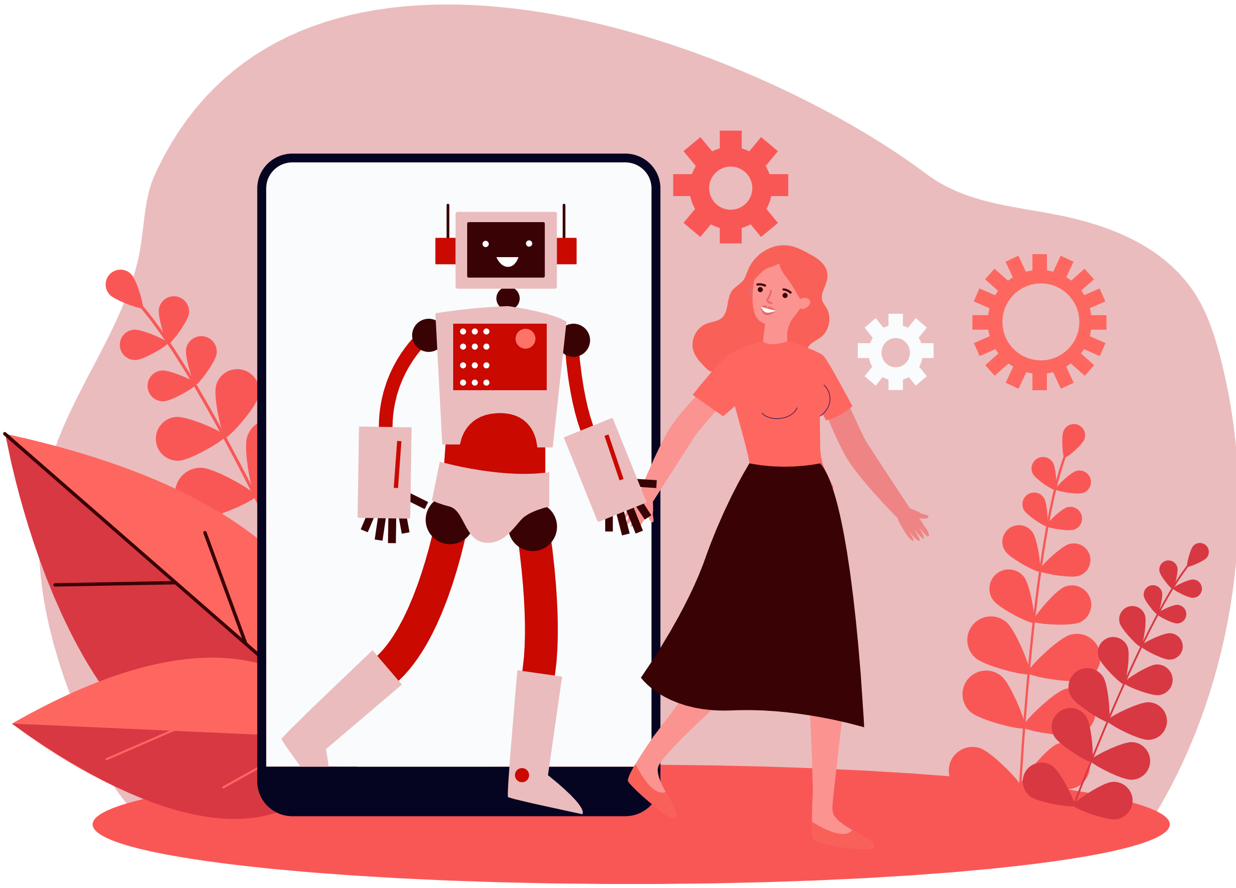
6.5 .3

JOHN HENRY AND THE ROLE OF THE TEACHER IN THE TWENTY-FIRST CENTURY

The American folktale of John Henry tells of a powerful nineteenth-century railroad worker whose livelihood is challenged by the invention of a riveting machine. John Henry challenges the machine to a head-to-head contest and wins, but the strain results in his immediate death from a burst heart **(see also Fishman and Dede, 2016 for another application of this tale).**

The teacher figure is archetypal in human history, although the definition and characteristics of a teacher vary across cultures and countries. There is no reason to doubt the continued role of teachers in education, but, heeding the warning of the John Henry folktale, battling EdTech at what it does best is not a winning strategy. Disruption of the definition and role of teachers, while playing out differently across the world, has been underway for years. The quality of the learning that children experience will be highly dependent on how teachers approach their role, and increasingly how they see that role vis à vis EdTech. Given that technology integration is not prioritized in most teacher preparation programmes, increasing pre-service teachers' levels of readiness to the use of EdTech is necessary **(Cuhadar, 2018).**

Most individuals consider the increasing role of EdTech in the teaching-learning process as a significant upgrade to the existing traditional face-to-face standard **(Mikre, 2011).** Although teaching and learning have traditionally been considered activities that predominantly occur within the four walls of a classroom, a significant shift in digital technology seems to have broken this confinement and transformed teaching into a



ubiquitous exercise. Nevertheless, evidence from large-scale, meta-analytical comparisons between technology-mediated instruction and teachers' pedagogical interventions (e.g. providing feedback, teacher–student relationships, metacognitive strategies and direct instruction) indicate an effect size in learning that is about twice as large for teachers' quality interventions **(Hattie, 2009)**. The effect size of fully online learning is similar to that of face-to-face learning, while blended instructions have a greater effect size than a solely face-to-face mode **(Means et al., 2013)**.

EdTech's role need not be to replace teachers but to inform their professional judgement and enhance their pedagogical interventions.

This is not to deny the ubiquity and importance of EdTech but to underscore that EdTech has the highest effect on actual learning when:

- there is a diversity of teaching strategies bringing exciting curricula based on real-world problems into the classroom;

- there is pre-training in the use of computers as a teaching and learning tool (teacher learning inclusive);

- there are multiple opportunities for learning (e.g. deliberative practice, increasing time on task) in addition to scaffolds and tools to enhance learning;

- the student, not the teacher, is in 'control' of learning through feedback, reflection and revision;

- peer learning is optimized (e.g. grouping, cooperative learning structure); and

- feedback is optimized (upon challenging tasks) **(Bransford, Brown and Cocking, 2000, p. 207; Hattie, 2009, p. 221; Means et al., 2013)**. EdTech's role need not be to replace teachers but to inform their professional judgement and enhance their pedagogical interventions: 'Technology can extend the reach of great teaching, recognising that value is less and less created vertically, through command and control, but increasingly horizontally, by whom we connect and work with' **(Schleicher, 2018, p. 263)**. This is why in the fast-changing environment of EdTech, teachers' (re)training is paramount.

According to Bashir et al. **(2018)**, there is a need to create a platform for school teachers to be intensively trained in technologies to sustain effective use of EdTech in teaching. Turning teachers into 'technology integrationists' requires meeting standards that increase the inculcation of such processes into actual teaching and learning. As part of the lessons drawn from their study on developing countries (Nigeria and Senegal), McAleavy et al.

EdTech has the potential to transform the traditional role of the instructor because, with proper EdTech applications, instead of being the main source of information and power, the teacher becomes a facilitator in the learning process.

(2018) emphasize that the use of technology for teacher training needs to be considered for effective professional development.

Another important aspect of the relationship between teachers and EdTech is power dynamics. Barak **(2006)** argues that EdTech has the potential to transform the traditional role of the instructor because, with proper EdTech applications, instead of being the main source of information and power, the teacher becomes a facilitator in the learning process. With greater access to information and media of exchange across geographic space, there are possibilities for the democratization of knowledge. An illustration of this is a case study in Colombia in the form of a community-based course called Koru involving three grassroots initiatives. Through the video conferencing platform Zoom, a virtual space was established whereby participants from Indigenous, Afro and Campesino communities carried out a virtual discussion around Colombian ecotourism. The possibility for the participants to be the protagonists of the discussion, talking and sharing with people ethnically, culturally, ontologically and geographically distant from one another was a strength of the course, as shared in later focus groups **(Macintyre et al., 2020)**.

It is known that online communication may reduce the transactional distance between student and instructor **(Attardi, Barbeau and Rogers, 2018; Stone and Barry, 2019)**, hence, it should bridge such a gap in order to achieve the instructional goal. A strong offline teacher–student relationship might also result in students feeling more comfortable while engaging with online communication platforms **(Griffiths and Graham, 2009; Rose, 2009)**.

There are many conservative forces and social mores that might seek to preserve the classic role of teachers, and therefore not adapt learning environments to be inclusive of EdTech innovations. For example, the traditional teaching method – where teachers teach and students listen – is

...there is an opportunity for EdTech to act as a bridge between students and teachers, whereby teachers facilitate the exchange of information and experience between participants who use the knowledge as it suits their context and needs.

strongly rooted in African teaching and learning practice **(Akano, Ugwu and Ikuanusi, 2016)**. Many African teachers are 'digital immigrants' and they wish to maintain the status quo in regard to EdTech due to their fear of unwarranted conditions that changing teaching methods might bring **(Ghavifekr and Rosdy, 2015)**. Teacher training can help them to overcome such fears and transform their practice. This is again not an argument against the value of teachers, but rather a call to consider the consequences of different approaches to address the problem of technologies' disruption in existing economic and social systems.

In summary, there is an opportunity for EdTech to act as a bridge between students and teachers, whereby teachers facilitate the exchange of information and experience between participants who use the knowledge as it suits their context and needs. A challenge to this changing role of the teacher is the necessity (and the consequent challenges) to train teaching professionals in new technologies.

A threat could also emerge from inbuilt cultural norms in which traditional teacher–student hierarchical relationships are difficult to change.

6.5 .4

FRANKENSTEIN AND THE ETHICS OF EDTECH

Mary Shelley's **(1823)** novel *Frankenstein or the modern Prometheus* is a time-honoured narrative about individuals innovating oblivious of the negative consequences in the realm of morality. The 'modern Prometheus' in the full title refers to the Greek myth of Prometheus who steals fire, a divine property and prerogative, to give to humanity, only to be endlessly punished for transgressing the boundaries between gods and humans. Most cultures have variations on this theme, for example, in Slavic mythology

The ability to identify patterns in student learning through analysis of 'learning process data' promises adaptive learning environments tailored to individuals.

there is Kryshen (god-giver of fire) and in the Chinese tradition, we find Shennong, the Divine Peasant (the origin of agriculture and medicine).

There are currently multiple entities amidst the swirl of technological development, reflecting upon and attempting to come to terms with ethical considerations to unbridled progress **(Aiken and Epstein, 2000; Smith, 2018; Selwyn, 2019)**. Beyond individual scholars and writers, there are organized groups developing standards for privacy, security and confidentiality. Often policy, industry, citizens and academics comprise these groups. Whether and how other public policies, governments, or businesses heed or comply with recommendations or standards is a separate issue.

The dual-edged sword of unbridled technological progress is exemplified by the emergence of big data analytics, where the systematic analysis of large datasets helps extract patterns, information and trends in a range of student learning behaviour and interactions. In education, these analytics can result in a reduction in administrative work through collection, analysis and interpretation of data. The ability to identify patterns in student learning through analysis of 'learning process data' promises adaptive learning environments tailored to individuals. Big data can thus lead to enhanced pedagogical practices through learning analytics – gauging students' engagement in learning – and in crafting future educational policies **(Picciano, 2012; Ellis, 2013; Regan and Jesse, 2019; Kuromiya, Majumdar and Ogata, 2020)**.

Selwyn **(2019)**, however, discusses a range of ethical issues that challenge these potential positive outcomes of learning analytics including: reduced understanding of 'education' to those data points we can collect; ignoring the broader social contexts of education, such as nuances of contextual interaction and language; reducing teacher and student capacity for decision-making, by making decisions

Ethical issues of EdTech are likely to continue surfacing in the future as we conduct research on potential risks resulting from people being exposed to technology from birth to death.

for them; using the data as a means of surveillance to monitor and control teacher and student behaviour; increasing the 'high stakes' evaluation of performance; and the risk of continuing to reproduce inequalities in disadvantaged groups, thus primarily serving the needs of the institution over those of the individual.

These issues raised with respect to data analytics are common across multiple types of EdTech, for example, privacy risks for children including issues of choice, consent and transparency **(Davenport and Bean, 2018)**; denying choice to users to remain anonymous or obscure in the face of increased surveillance and tracking; and increasing the opportunity to employ discriminatory practices of datafication on marginalized populations **(Macgilchrist, 2018)**. There is a perpetual risk stemming from the tracking and collection of student data required and used in data modelling and developing machine learning algorithms. These records are a part of the entirety of students' careers and potentially can be misused to replicate existing social discrimination or create new discriminatory variables, for example, profiling and discrimination based on race approximation and accentuation of social stratification **(Regan and Jesse, 2019)**.

Ethical issues of EdTech are likely to continue surfacing in the future as we conduct research on potential risks resulting from people being exposed to technology from birth to death **(Radich, 2013)**. This brings with it a multitude of concerns about the well-being of young children, including addiction, online risk-taking behaviour, cyberbullying, health concerns, including a greater risk of obesity, sleep disorders, bad posture, plagiarism and mental health problems **(O'Keeffe and Clarke-Pearson, 2011; Lau, Yuen and Park, 2013; Richards, Caldwell and Go, 2015; Woods and Scott, 2016)**. There are guidelines for the proper use of technology for young children, though they rest on uncertain empirical foundations. More

... educational courses (similar to mandatory courses on sex education and the health risks of drinking) could be created to teach appropriate use of EdTech that protects children against abuse and minimizes risk.

research is necessary to understand and communicate risk factors, balanced against the promise of the ethical use of EdTech to support learning. With such evidence, educational courses (similar to mandatory courses on sex education and the health risks of drinking) could be created to teach appropriate use of EdTech that protects children against abuse and minimizes risk.

Cultural and group differences also need to be considered in ethical inquiry **(Lau, Yuen and Park, 2013; Yuen et al., 2016b)**. For example, critics of EdTech have pointed out that the increasingly personalized and often individualistic forms of learning that the digital revolution promotes is contrary to the philosophy of education derived from the collectivist nature of cultural identity **(Gibbons, 1973; Smeyers and Depaepe, 2007)**. Alternative development paradigms have been developed as a response to what could be called a digitalized, mechanistic worldview of EdTech.

This raises the even broader issue of the aims of education across the world. The UNESCO **(2015) Rethinking Education** report, for example, emphasizes 'acknowledging the diversity of worldviews in a plural world' **(p. 29)**, noting the concept of *sumak kawsay (buen vivir* in Spanish; good living in English), which is rooted in the worldview of the Quechua peoples of the Andes in Ecuador. In educational terms, focusing on the human–nature interconnectedness of *buen vivir* allows us to question and critique excesses in specific aims of education systems, for example, aims solely or predominantly directed towards providing the skills and dispositions necessary to get a job, increase salaries and/or enhance status based on a human capital approach to development **(Brown and McCowan, 2018)**. With humanity teetering on the edge of irreversible climate change, the question of our time is how we can lean towards a more sustainable future **(Wals, 2007)**. Although education plays a central role in this question, as demonstrated by its inclusion in SDG 4, exactly what education is needed is by no means clear or agreed upon. The current dominant trend, brought about by the digital revolution, is to assume that enhanced digital skills are needed to participate fully in society. Perhaps the question needs to be reversed: what kinds of societies are sustainable and valued, and how can EdTech be entrained to help develop the knowledge, skills and dispositions in our children so that they may make sound choices in actualizing these kinds of societies?

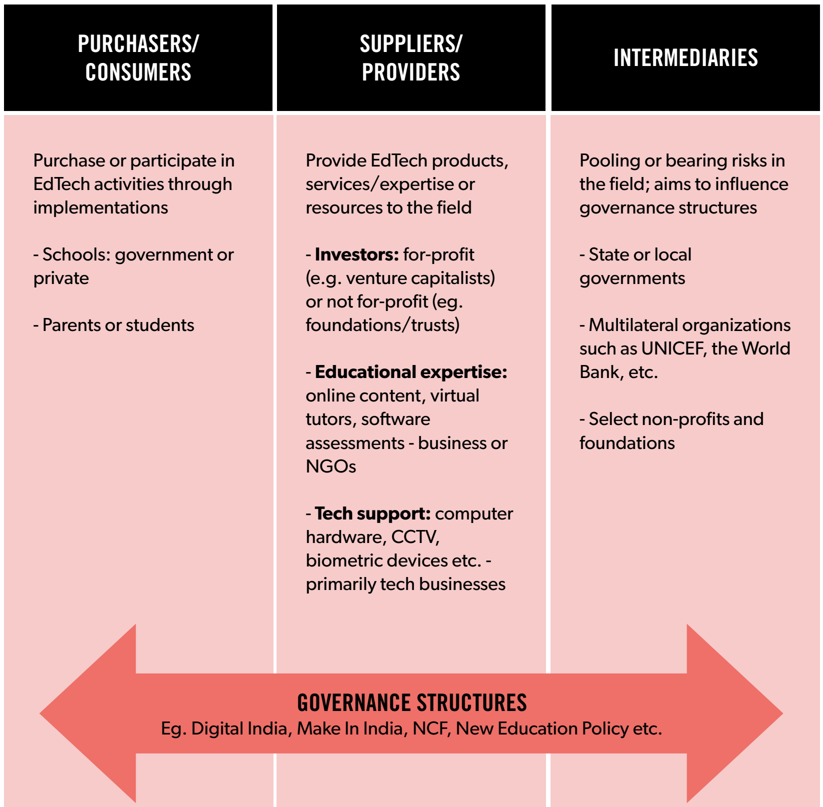
6.5 .5

GABRIEL GARCÍA MÁRQUEZ AND WHO OWNS THE FUTURE OF EDTECH

... the increasingly personalized and often individualistic forms of learning that the digital revolution promotes is contrary to the philosophy of education derived from the collectivist nature of cultural identity

Gabriel García Márquez **(2003)**, in Love in the time of cholera, says 'Wisdom comes to us when it can no longer do any good'. This sentiment points to the elusiveness of authentic knowledge that leads to wisdom, but also perhaps to the simpler notion that we often learn our lessons only after we have allowed preventable mistakes to occur. The future of EdTech and how it will impact our educational systems is not yet known, and yet it sometimes seems as if it has its own invisible momentum, out of the control or regulation of collective human action, much less human wisdom. The scale of its impact on student experience and life is an open-ended question that will depend, on the one hand, on the rate of both societal and EdTech development and, on the other hand, how and to what ends that technology is applied. Will it foster effective and lasting knowledge in students, and support teachers' mastery in helping students build that knowledge and the wisdom to use it productively for personal and societal aims **(see subsection 6.5.3) (Fishman and Dede, 2016)**? Or will it only benefit specific stakeholders, leaving others frustrated, or simply left out? Therefore, one critical question is: who is in control?

For example, education systems



Organizations may play multiple roles, such as investor and intermediary or investor and expertise provider

Figure 1. Typology of stakeholders in EdTech. Source: Miglani and Burch (2019, p. 38).

may be the recipients of EdTech solutions, but it is not always clear who is in control of the process and whose interests are being served. There are multiple stakeholders who influence and impact the access, diffusion and application of EdTech in education. Who are the relevant stakeholders and how are EdTech-related decisions made? **Figure 1** provides a simple, three-cluster typology of stakeholders in EdTech, while the text underneath

Open-source hubs (e.g. GitHub), publicly funded research and capitalized businesses are engaged in a tantalizing dance of intellectual property, human capital and code/tech tool production.

illustrate the complexity of human networks that interact, coordinate and hopefully harmonize their activities in support of learning. The road to wisdom may run along the bidirectional arrow at the bottom of the figure, the governance structures that shape, regulate and sometimes control the unbridled development and dissemination of EdTech. These structures are not always or only the work of governments, but also form within technical communities themselves in and outside the EdTech world. Technical or interested communities may be composed of researchers, developers, policy-makers or citizens in academia, government, education, industry, parents, students or advocate groups **(e.g. Bakul, 2016)**. In a sense, everyone has a stake in these issues, and rationale input into decisions about EdTech might sensibly take into account the varied perspectives of these stakeholders.

We would expect that research is a reliable source of information to inform human decision-makers in reasoning and forming sensible standards and policies, not only via scholarly publications, but also by providing more transparency to the public in accessing the technologies, program codes and the data sources that drive them. One interesting development in the EdTech world is the interplay of proprietary versus open source codes and content in the EdTech universe. While some of the largest players may keep some intellectual properties proprietary, much of the code is adapted or reproduced in variations in open source repositories, with industry and public entrepreneurs sharing bits and bytes significantly. Large tech enterprises maintain their market position by combining speed in bringing innovations to the market (products or services) in-house, as well as fostering and buying up innovation from without.

Open-source hubs (e.g. GitHub), publicly funded research and capitalized businesses are engaged in a tantalizing dance of intellectual property, human capital and code/tech tool

The LearnSphere project also serves as a hub to link communities of educational researchers; it provides a repository for researchers to store their data and offers an open analytic method library and workflow authoring environment for researchers to build models and run them across datasets.

production. While it is often unclear whether the capabilities and solutions being generated align with the actual problems of education, the potential of applying these innovations in education is beyond doubt. Further, that these capabilities could be directed towards profit, social control or maintaining the status quo of extant institutions and power structures is equally beyond doubt.

For example, LearnSphere is a multi-university initiative sponsored by the US National Science Foundation ***to create a community software infrastructure that supports sharing, analysis and collaboration across a wide variety of educational data, in an effort to support researchers as they improve their understanding of human learning. It also helps course developers and instructors improve teaching and learning through data-driven course redesign. The goal is to transform learning science and engineering through a large, distributed data infrastructure and develop the capacity for course developers, instructors and learning engineers to make use of (LearnSphere, 2020).***

The LearnSphere project also serves as a hub to link communities of educational researchers; it provides a repository for researchers to store their data and offers an open analytic method library and workflow-authoring environment for researchers to build models and run them across datasets.

A kind of EdTech 'arms race' is being waged between public and proprietary forces. But unlike medicine where expensive developmental, specialized technical processes, and means of production and distribution make it prohibitive to think of locally grown or craft competitors, education is a relatively cheap and easy service industry for creative dabblers, at least with respect to software development and distribution. A prime example of the reality of strange public/private bedfellows is the Generalized

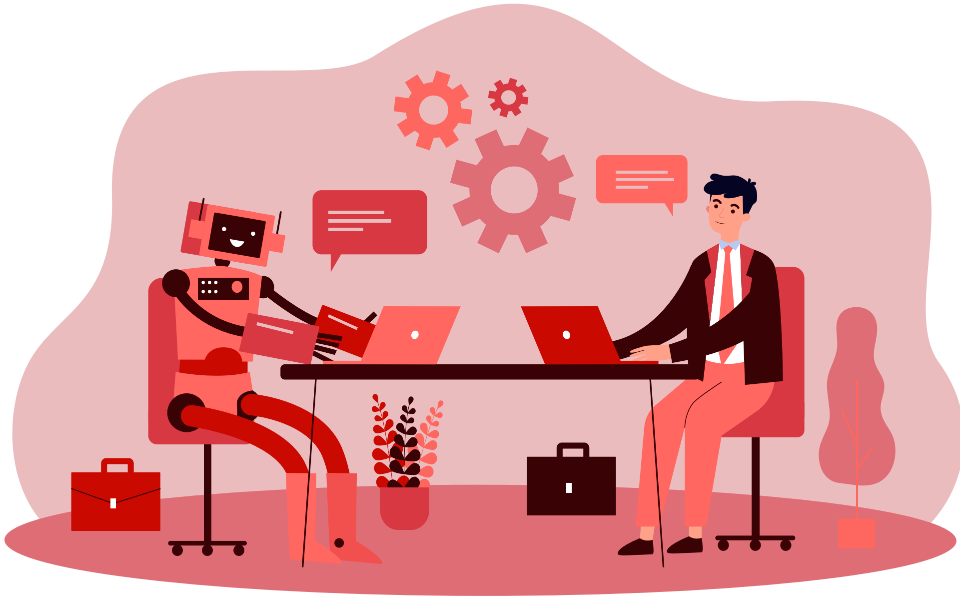
The criticism that access to EdTech is being restricted by the commercial sector or government needs to account for this unprecedented movement to public sharing and transparency.

Intelligent Framework for Tutoring **(GIFT, 2020)**. As described on its website:

'GIFT is an empirically-based, service-oriented framework of tools, methods and standards to make it easier to author computer-based tutoring systems (CBTS), manage instruction and assess the effect of CBTS, components and methodologies. GIFT is being developed under the Adaptive Tutoring Research Science & Technology project at the Learning in Intelligent Tutoring Environments (LITE) Laboratory, part of the U.S. Army Research Laboratory – Human Research and Engineering Directorate (ARL-HRED) …'

While GIFT is being developed to facilitate the use of CBTS by the US Army, the intent is to collaboratively develop GIFT and have it function as a 'nexus' for CBTS research being conducted within government, industry and academia.

Sharing technological innovations is as much the rule as the exception around the world. The criticism that access to EdTech is being restricted by the commercial sector or government needs to account for this unprecedented movement to public sharing and transparency. Also, criticism about whether the technologies themselves are too narrowly defined and focused can be challenged in the face of the reach of R&D into every crevice of learning science and human capital development. Much more relevant may be concerns regarding who has the skills to engineer and apply the technologies; towards what ends; and in service of whom (i.e. clientele/stakeholders). The answers to these questions require the wisdom mentioned in the quote above, but as García Márquez warns us, such wisdom is elusive, suggesting that posing the right questions can be as informative as the answers themselves, and the quest to find such answers even more so.



6.6 Closing thoughts: harambee – the spirit of pulling together

Technology continues to be a driving force that transforms our society and human interactions with the world. Multiple new technological advances are on the brink of maturity – machine learning, large data analytics, virtual reality, natural language and speech technologies, and social robotics to name just a few – and their transformative impact on education is nearly upon us. Such a positive transformation, however, cannot be reified without a spirit of collaboration and a 'pulling together' (*harambee* in Swahili) among all stakeholders of education and EdTech. If there is an aspect of the methodology of this chapter we would like to underscore, it could well be summarized as harambee.

Assessment of the present and near future in EdTech ultimately rests on the question of the nature and aims of education, yet we also see that education as human capital, and as an instrument for emancipation and human flourishing, is inextricably mediated by technology.

Through thoughtful and humane policies and rigorous science – and harambee – we can hope that technology will continue to contribute to human flourishing.

Economic prosperity and gainful occupation are ends sought by governments, commercial enterprises and individuals alike, and education policies working towards this end continue. But to the extent that this is deemed a central aim is an entirely different issue; we might question whether it remains fair and just to continue to educate our children solely in preparation for a future workplace, only to ask them to compete for jobs with the very machines that taught them. In this light, the concept of flourishing and well-being as allied aims seems more promising, lest our children grow only to end up with their hearts burst like John Henry.

We conclude on an optimistic versus a cautionary note. Clearly, the lens one views EdTech through is the filter through which results are to be interpreted. Most research on EdTech is conducted by researchers who accept the premise that technological solutions are appropriate for a given context and problem, and therefore they evaluate its effectiveness in comparison to some other technology-infused solutions. On the whole, EdTech is designed, developed and implemented by diverse, imaginative, educated, well-intentioned humans who wish to foster human development and address related problems and needs. Successes, failures and unintended consequences arise, and these are all part of the human-learning process. Certainly, we have met many technologists who seem to find it easier to teach machines how to learn than humans, but that has not led them or any of us to give up trying to lead our children down a path towards imagining and creating a world that is better than the one we have bestowed upon them. Through thoughtful and humane policies and rigorous science – and *harambee* – we can hope that technology will continue to contribute to human flourishing.

This chapter examines the topic of EdTech, broadly defined as any technology applied in an educational context or as a solution to an educational problem. While there is a strong focus on ICTs and software learning programs, there are also discussions of multiple traditional and emerging technologies that are likely to have a significant impact on education. We discuss both the promise and risks associated with the introduction of new technologies into existing educational ecosystems

6.6 .1

KEY MESSAGES AND FINDINGS

- ***Human information production and dissemination over the internet continues unabated,*** though evaluating credibility (misinformation) has emerged as a new challenge.

- ***Diversity and complexity of the technologies*** that can be applied to educational problems continue to grow.

- ***Traditional learning software is now more tailored and personalized and powered by AI***, machine learning and natural language processing (which enables speech perception and production), but language diversity remains a future issue for worldwide use.

- ***Robotics and biometric sensors*** are being developed as an extension of the human body, learners' affective experience and intersubjective social relations.

- ***The digital divide continues to affect education systems*** across countries and social strata and clusters within countries.

- ***There is a mixture of private/commercial suppliers and public investments in R&D,*** as well as public sharing of innovations, especially with respect to programming and coding.

- ***Much of the development of emerging EdTech is being produced in WEIRD higher education institutions*** and commercial centres, and consequently there is a constant need for research and teacher training in how to adapt and align to specific educational contexts across nations, regions and cultures.

- ***EdTech R&D solutions may be especially well suited for achieving inclusive education for differently abled populations,*** though the risk of over-promising the effectiveness of these technologies to consumers, when unregulated, remains a threat.

- ***Video-conference platforms are now mainstream technologies for larger and larger segments of society*** and can be considered an alternative or supplementary mode of educational delivery to in-person classrooms.

6.6.2

IMPLICATIONS

Ethical and policy issues of privacy, confidentiality and ownership of personal information, and misuse of technology that places children, learners and caretakers at risk, are major issues facing educational policy-makers and administrators **(see WG2-ch8)**.

The low to moderate effect size in learning through EdTech-mediated interventions calls for continuous assessment and monitoring.

The role of the teacher as the delivery system of knowledge faces significant challenges in the face of technological alternatives, and new roles for teachers must be defined, with appropriate professional development, to avoid significant disruption in the profession.

As EdTech products and solutions are typically designed for use by a specific population, in one cultural context, research in understanding how those technologies are effectively deployed, adapted, aligned or redesigned when introduced into other cultures and contexts is a critical, ongoing research need.

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