Assessing the Digital Transformation of Education Systems

An International Comparison

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Abstract

The digital transformation of education has been underway for decades at differing paces across the world. In this chapter, an education digitization index is proposed in order to assess the extent of digital transformation in various countries. The education digitization index is composed for four variables: digital assets, digital use, digital labor, and digital outcomes. While a lot of research and practice in education has been on digital use – applying particular digital educational technologies – countries with substantial digital assets and a commitment to digital labor are able to transform education systems more readily. Digital assets and digital labor have become more important during the pandemic.

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Introduction

Digital transformation is the degree to which digital technologies are being used within educational systems. All education consists of groups of people, organizations, and processes configured to help individuals learn in an organized setting. Digital transformation is the extent to which digital technologies are used by people and organizations in the processes and goals of learning in an organized setting. Common examples of digital transformation include institutions offering courses partly or fully online, digital open educational resources (OER), students or teachers using digital platforms to collaborate, and curriculum designed to foster digital skills and competencies as learning goals.

There are several key issues about the digital transformation of education systems including:

- What is the digital transformation?
- How can the extent of digital transformation be assessed?
- How extensive is digital transformation of education systems in various countries?
- How has the pandemic affected digital transformation?

This chapter focuses on what digital transformation is and how education systems in various countries are. The countries discussed have seen documented substantial recent changes in their educational systems (Qayyum & Zawacki-Richter, 2018). An educational digitization index is proposed to assess and compare the extent of digital transformation in countries, an index that can also be used to assess countries' digital readiness for emergency situations like pandemics or climate threats. In doing so, major research will be reviewed on the topic of digital transformation of education systems. The references in this chapter highlight important research about digitization of education in numerous countries, beyond the important comparative work done by international organizations like the Commonwealth of Learning, the Organization for Economic Cooperation and Development (OECD), the World Bank, and UNESCO.

Education Systems

From an educational systems perspective, inputs and processes combine to create educational and social outcomes. Inputs in education are financial resources (e.g., public and private funding), physical resources (e.g., buildings, infrastructure,

materials), and human resources (e.g., teachers, administrators). Inputs also include education policy and legislation required to allow educational processes to occur (OECD, 2019). Processes are the activities (e.g., teaching, design, learning) and institutions (e.g., school boards, schools, and classes) that are commonly associated with education. Outcomes include the educational goals for learners (e.g., skills and competencies of individuals) and economic and social goals for society (e.g., developing human capital, fostering citizenship, social sorting).

Formal education dominates the education system in all countries, and, indeed, is often synonymous with the term education system in many countries. Formal education in all countries requires or offer participation and progression through structured learning environments at the primary, secondary, and tertiary levels. Countries also have nonformal education – education which is not necessarily for accreditation and is often short term. Nonformal education is sometimes articulated with formal education. In countries like Indonesia and Turkey, it is relatively easy to transfer from nonformal education to formal education. In Indonesia recognition of prior learning is well-established within the education system (OECD, 2020). Turkey has long recognized and supported nonformal education alongside the formal system (Kondakci, Bedenlier, & Aydin, 2019, p. 106).

Formal education differs among countries in the starting and ending age of compulsory education, number of years for primary and secondary education, routes for progress through formal education, recognized exit points, options for vocational and higher education, and types of certification (OECD, 2020). Countries also differ in the amount of government regulation and active involvement in education, the extent of public and private education provision, and options for access and participation in education. Participation is at least partly affected by financial, administrative, and physical barriers to education. At the primary, secondary, and tertiary levels of formal education, the classroom is the most common type of physical setting, but this can vary in countries from a room with walls to an outdoor space under a tree. Digital technologies can challenge the physical access barriers to education participation, financial costs, policies, public and private provision, the relationship between formal and nonformal education, as well as pedagogy, teaching, design, and quality.

Digital Transformation

The digital transformation of education systems is not the same as the growing use of educational technologies. Educational technologies have been around for over a century, since before Edison's use of film in classrooms. Print, radio, and television are technologies used for education that predate the first digital technologies (see Fig. 1). In India some of these are referred to as on-air, as opposed to online, educational technologies (India Ministry of Human Resource Development, 2020, p. 6). During the pandemic, on-air technologies have become crucial to deliver educational content in many countries that sought to ensure "no learners were left behind" (Bozkurt et al., 2020, p. 10).

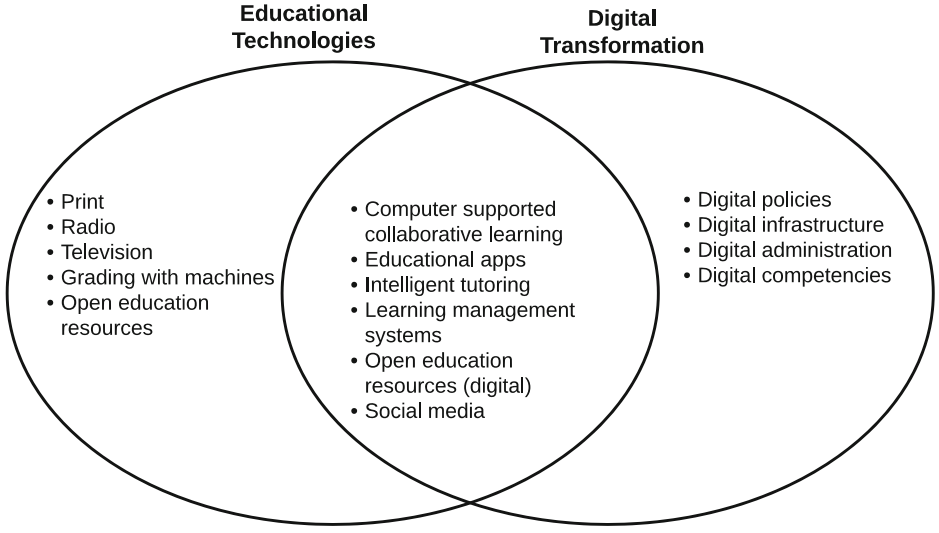

Fig. 1 Examples of educational technologies and digital transformation

Certainly, educational technologies are a part of digital transformation of education systems. These are important tools for teachers, designers, and learners. However, the digital transformation of education systems is broader than educational technologies because education systems are about more than teaching and learning processes. Educational technologies are an important but not exhaustive part of the digital transformation of education systems. Digital transformation involves both digital educational technologies and non-technology initiatives.

Inputs and outcomes, as well as processes, are part of the digital transformation of education systems: inputs include policies and physical and human resources; processes include recruitment, providing access and flexibility to students, and retention, as well as all curriculum, teaching, and learning with digital interaction and content; outcomes include providing learners with digital skills and competencies. For examining digital transformation, these other dimensions of education systems are important. Not including these dimensions can substantially limit digital use that occurs in the "classroom" for teaching, learning, assessment, and other core functions of education.

Another useful way to think about the dimensions of the digital transformation is categories developed by Baker and Smith (2019) for the field of artificial intelligence for education: learner-facing, teacher-facing, and system-facing perspectives. In artificial intelligence for education, learner-facing perspectives focus on tools that students use: to receive information, content, and feedback, to collaborate with students, and to improve their learning. Teacher-facing tools help teachers "to reduce their workload, gain insights about students and innovate in their classroom" (Baker & Smith, 2019, p. 12). This can include insights about student progress, organizing students, methods of teaching, and automating assessment, feedback, and administration. System-facing tools often require sharing data to administrators, managers, and policymakers for insights about enrollment, progression, retention, and attrition (e.g., via learning analytics). Identifying system-facing tools, policies, and initiatives requires acknowledging a broader perspective for assessing digitization beyond digital educational technologies.

Education Digitization Index

Digital transformation is a topic of importance not just for education systems but also for nearly every sector of society. In fields like health care, government, and business organizations, there is ongoing research and discussion about the extent to which digitization has been and should be undertaken. These fields have developed ways to measure the extent of digital transformation. Gandhi, Khanna, and Ramaswamy (2016) created a digitization index of 27 indicators organized into three groups: digital assets, digital usage, and digital labor. Digital assets refer to physical resources and infrastructure like computers, mobile devices, networks, software, and IT services. Digital usage is how much digital engagement there is in processes such as transactions, interactions, organizational dynamics, and outreach (e.g., marketing using social media). Digital labor measures how digitized work is,

including how many jobs are digital occupations, and how much is spent supporting workers' digital skills and capacity.

A digitization index can be helpful for assessing and comparing the extent of digital transformation in various countries. However, for the field of education, some of the digitization indices used in other sectors are useful and some are not. Digital assets are certainly crucial. Digitization is not plausible or perhaps even desirable if there are more accessible and viable non-digital options for education systems. Digitization can be costly both for initial and ongoing investment of money and people. In many countries, digitization initiatives redirect efforts and resources from more accessible and affordable options for creating structured learning, so digital asset is a necessary but not sufficient major index for analyzing the extent of digital transformation.

Digital labor is certainly relevant to education. For example, while the field of instructional design existed before digitization, it has emerged as a mainstream educational occupation in many countries in the past 25 years. Instructional design (or learning design) is digital labor that is necessary for digitization in education. There is an unfortunate and long history in the field of education where the use of educational technology has been encouraged and undertaken without recognizing the importance of training and support of educators. Cuban is perhaps most renowned researcher about how teachers have not always accepted the use of machines for teaching (Cuban, 1986), and digital technologies are oversold and underused because of the lack of support and buy-in by educators (Cuban, 2001). Educational technologies often do not gain traction because there is not enough teacher-facing support for education workers to become digital workers who can develop their knowledge, skills, and capacity to use these technologies.

Digital use is heavily researched in education. The use of digital tools for education, especially for teaching and learning in western countries, is well-enumerated and forecasted. (See websites about the most used digital technologies for learning such as www.toptools4learning.com and Educause's *Horizon Report* of tech trends.) Digital use of learner-facing technologies has been extensively researched. (For example, Tamim, Bernard, Borokhovski, Abrami, and Schmid (2011) have written a second order meta-analysis of all the meta-analyses about the effectiveness of using learning technologies.) There is an immense amount of research about the effectiveness of digital technology A used in educational setting B to achieve learning outcome C. However, even here, much of this digital use research about learning effectiveness is not connected to assessments about digital assets, digital labor, and digital outcomes. In the language of evaluation, the research is about the merits of digital use but not the worth.

Finally, the digitization index for other sectors misses an important category which is perhaps unique to education: outcomes. Education is not as transactional as many other sorts of services or products in society. All formal and much of nonformal education involves middle to long-term relationships among participants (e.g., teachers and learners; learners with each other) in order to foster the learning and economic goals of education (e.g., knowledge, skills, citizenship, human capital). Introducing digitization into educational relationships and processes can change

the learning, economic, and social goals of education. The outcomes and goals of education usually fall into three categories, sometimes called the iron triangle: access, quality, and cost (Porto, 2013). While digitization can be interesting to try, it must eventually have some larger purpose if it is to move beyond experimentation toward efforts to change education systems. Does digitization help change access and participation barriers? Does it increase the quality of learning and teaching, by improving or changing the learning experience or outcomes in positive and meaningful ways? Is digitization worth the usually heavy cost investment, especially compared to other sorts of ways to support and improve education systems? If digitization does not address one or more of these three sets of goals, then the merit and worth of digital initiatives will rightly be questioned.

A more useful set of digitization indices in education should account for the unique outcomes, as well as the inputs and processes of education systems. Based on existing work, the following indices can be useful for assessing the extent of digital transformation in education systems: digital assets and infrastructure, digital labor, digital use, and digital outcomes. To fairly compare countries with some rigor, there needs to be a point of reference or common denominator. Raivola (1985, p. 363) calls this point of reference a *tertium comparationis* or third comparison. The education digitization index can serve as the tertium comparationis to compare countries with common variables.

Digital Transformation in Education Systems

Digital Assets and Infrastructure

Certainly, Altbach, Reisberg, and Rumbley (2009) were correct that, to varying degrees, all countries are encountering digitization. Countries differ in how much of their education system (i.e., inputs, processes, outcomes) has encountered digitization. Digital assets are recurringly the biggest concern in many countries. Limited digital assets and infrastructure is an access barrier that precludes digitization outside of developed and developing countries with established or emerging digital policies and infrastructure. The International Telecommunications Union profiles over 180 countries for access and use of computers and mobile phones, broadband availability, bandwidth use, and Internet use. Globally, over 55% of households have Internet access at home (ITU, 2021a, p. 13). In developed countries, 80% of people are online, while in developing countries, 45% of people use the Internet. However, in the 47 Least Developed Countries, "four out of five individuals (80%) are not yet using the Internet" (ITU, 2018, p. 2).

None of the UN-classified 47 Least Developed Countries have the physical digital infrastructure for substantial digital transformation of their education systems. Certainly, there are important individual digital initiatives in less developed countries. For example, the African Virtual University has been operating for over 20 years, initially as a World Bank project and now as an intergovernmental organization involving 15 African countries. Nafukho and Machuma (2013) claim that the

e-learning activity from the African Virtual University has led to a growth of interest in e-learning and even growth in telecommunications infrastructure in sub-Saharan Africa. In other words, educational digital use has helped expand digital assets. It has also led to increased interest in digital initiatives among less developed countries like Uganda, for example, which recently saw the launch of Royal Open University, a fully online institution. There are also digital initiatives in and for less developed countries by educational institutions, governments, businesses, and international development organizations. (See, for example, the Commonwealth of Learning's video on demand MOOCs for low bandwidth regions, including less developed countries, www.col.org/news-type/mooc/.) While there are a lot of digitization initiatives, they are not the necessary digital assets and infrastructure for substantive digital transformation of education systems in most Least Developed Countries. In these countries, there tends to be more focus on non-digital initiatives often using analog and on-air technologies. Unfortunately, then, most discussions about digital transformation of education systems are conversations about developing and developed countries. Before the pandemic, discussions on digital transformation of education systems in Least Developed Countries were likely imprudent and impractical.

For purposes of brevity and sampling, comparisons will focus on a handful of developed and developing countries. Most developed countries have the necessary physical digital infrastructure for transformative educational digitization. There is substantial Internet access in countries like the United Kingdom (92.9% of households), Germany (90.8%) (ITU, 2021c, p. 9), and Canada (89%) (ITU, 2021a, p. 15). However, even in some of these countries, there is an important rural-urban access divide (ITU, 2021a, p. 1). So, nearly all developed countries have formal policies and funding at the national or regional levels for digital infrastructure initiatives. These are usually not initiatives solely for education but for digital connectivity more broadly.

A forward-looking example for digital assets is South Korea. Nearly all households (99.7%) have access to the Internet, and nearly all people there (96.2%) were regularly using it as of 2020 (ITU, 2021b, p. 18). South Korea has extensive physical digital infrastructure based on a combination of government policies and a strong telecommunications sector. Government policies like Cyber Korea in 1999, e-Korea in 2002, u-Korea in 2005, and a "Master Plan in Preparation for the Intelligent Information Society" more recently (Korea MSIP, 2016) have promoted strong links between government, businesses, and research communities to foster a sophisticated and responsive digital infrastructure. The government has initiated several systems-facing policies that have created assets needed for transformation of the education system. At the tertiary level, the Korean National Open University has been operating since 1972 as an open and distance education institution. A national education TV channel, EBS – Education Broadcasting System – was launched in 1980 to promote lifelong learning for adults but also to supplement school education (Jung, 2019, p. 101). The South Korean government also allowed for private institutions to be certified to provide e-learning when online classes began to emerge in the 2000s (Lim, Lee, & Choi, 2019, p. 93). At the same time, the government established plans

to support campus-based universities to offer distance and blended learning. Digital and educational policies and funding created strong digital assets and infrastructure in South Korea.

In developing countries (UN DESA, 2020, p. 166), household Internet access ranges from a high of 88.3% in Turkey to 67% for Brazil and around 60% for South Africa and China to 23.8% in India (ITU, 2021b). Importantly, in developed and especially developing countries, there is far more Internet access via mobile phones than computers. This is revealed in data showing more people use the Internet than have access at home (e.g., Brazil has 70% Internet use with 67% Internet access at home (ITU, 2021a, p. 15).

Digital assets include policies that recognize there is no universal digital access and use. For example, the Chinese Ministry of Education created policy documents in 2018 like the Education Informatization 2.0 Action Plan (in Yan & Yang, 2021). Informatization refers to the use of all information technologies (Xiao, 2019, p. 516). It includes digital technology initiatives like supporting the "steady development of online distance education" (China Ministry of Education in Yan & Yang, 2021, p. 412). However, informatization can also consist of non-digital technologies like radio for education. Non-digital options are included and continue to be important in the education system such as the development of the broadly defined "information literacy" (Yan & Yang, 2021, p. 420). The need for and use of digital technologies is a subset of the larger initiative of "informatization." As digital technologies are not universally accessible, there is an acknowledgment of working with current assets, while initiating strategies like "Internet Plus" to expand digital access (Zhang, 2019, p. 24).

Digital Use

Digitization has permeated all stages of education systems in some countries. This digitization involves technologies and non-technologies outside the "classroom." In tertiary education in most western countries like Australia or Germany, most functions are deeply digitized beyond teaching and learning, including administration (i.e., marketing and recruitment for universities, registering, enrolling, and managing students, etc.), libraries (i.e., online journals and books), research (i.e., data gathering, storage and analysis, writing and publishing reports and articles), and, of course, communication among students, instructors, administrators, and researchers (Selwyn, 2014).

For teaching and learning, online and hybrid course delivery (including MOOCs), learning management systems, digital OER, e-portfolios, digital badges, web resources for videos and podcasts, digital gaming, personalized learning content via learning analytics, artificial intelligence for auto-grading and personal tutoring, and thousands of educational apps are all digital educational technologies that have grown in the past 25 years since the web became a part of education. It is important to identify which digital technologies are used and how. For example, in India, digital tools used in primary and secondary education included e-books (used in

31 out of 36 states and territories), e-content repositories (30 states), interactive resources online (in 29 states), digital classrooms (live synchronous education broadcast via television) (in 26 states), and e-learning portals (26 states) (India MHRD, 2020, p. 25). In Germany, constant digital connection and use has changed the teaching and learning experience in physical classrooms. University students revealed that during class they used mobile phones to access course learning management systems (78% did this), send emails to teachers (74%), send mail to fellow students(73%), search the Internet during lessons (74%), research exam papers and presentations (69%), and review grades (69%), among many other digital uses. They also disclosed that they use their mobiles during studies to use instant messaging (88%) and take photos (78%) (Zawacki-Richter, 2020, p. 5).

While such digital use data is important and insightful, to assess digital transformation, what matters is not the specific digital tools but the type of digital use. As Xiao points out, digitization can mean using digital technologies in the classroom without necessarily changing access or quality. He contends that China's 5-year plans for digital transformation show "scanty evidence of open, flexible, distributed, and disaggregated learning encouraged in these plans" (Xiao, 2019, p. 515). For substantive digital transformation, why digital technologies are used matters more than the specific digital technologies used. Using social media in ways that may change quality, access, or cost matters more than whether educators in countries are using WeChat or Facebook.

Online education mainstreams distance education. Among the most transformative digital uses has been online and hybrid education commonly used to deliver education at the tertiary level. Online education has not been transformative for primary and secondary education, as there is little evidence of substantial enrollments before the pandemic. Historically, distance education, especially the open university movement, had important goals for access to higher education. However, distance education was tolerated as *apart from* mainstream education. With online education, distance education became *a part of* mainstream education. Before the pandemic, in countries like Australia, Brazil, Canada, and the United States, nearly 20% or more students were enrolled in an online course (Qayyum & Zawacki-Richter, 2018, p. 130). Historically, distance education was offered by open universities – often mega universities with massive enrollments – and some campus-based universities, as part of their continuing education and extension divisions. With the advent of online education, many conventional onsite universities started to offer distance education online. The practice continued to grow in developed countries and has increased in developing countries. In 2002, 25 institutions were allowed to offer distance education in Brazil. As online education started to grow by 2012, 150 institutions were given permission to offer online education. By 2016, 331 institutions were allowed to offer distance education online (Litto, 2018, p. 31). Online education was offered by many established mainstream educational institutions, even before the pandemic.

Parity of online education. Acceptance of online education by educators and employers has been transformative in many countries. In developed countries, there is usually not less legitimacy to a degree done via distance online. Employers

recognize online education often as much as other educational formats. This has broken barriers of legitimacy that education systems in countries like Spain and the United Kingdom historically had against distance education. However, not all places have accepted online education, particularly in developing countries. In India, education from onsite schools and universities is given more esteem than online education and other forms of distance education (Panda & Garg, 2019, p. 39). In Turkey, most employers still prefer education from residential programs over online programs (Kondakci et al., 2019).

Nonformal education growth and acceptance. The growth of online education has also occurred in nonformal education. In particular, the rise of MOOCs has been important for growing and changing educational provision. While many MOOC offerings are by established educational institutions, they are often offered as nonformal education. Nonformal education seems to have more interest from education systems when offered in digital formats like MOOCs and other online education offerings. In Russia the growing use of MOOCs has led to policies that articulate nonformal MOOCs into formal education (Zawacki-Richter, Kulikov, Püplichhuysen, & Khanolainen, 2019, p. 58). The South Korean government has a goal of creating an "intelligent information society" (MSIP, 2016). Part of this plan is to "have universities grant students credits for K-MOOCs they complete" (p. 51). Nonformal education via K-MOOCs is changing part of the formal education system by harnessing Prior Learning Assessment that has existed for decades. Digitized nonformal education allows for more self-directed learning by learners, partly changing the role of students and institutions in education systems.

Online education brings new educational providers. Online education is offered not only by public institutions but by private companies. Brazil in particular stands out for a huge growth in private online education, as nearly 90% of online education enrollments are from companies (Litto, 2018). For example, Anhanguera Educacional owns Cogna Educação (formerly Kroton), the largest education provider in the world. Anhanguera, along with UNOPAR, Estácio, and Universidade Paulista, has nearly 60% of all online enrollments in Brazil. The large number of enrollments from private companies suggests that there is an educational demand and access issue that public education is not addressing. New private online providers have joined the formal education system.

Learning management systems "platforming" education. Learning management systems are commonly used both for online and onsite education. The extensive use of learning management systems has created the "platformization" of education, particularly tertiary education. Platformization is the penetration of digital platforms to the point where the practices of a sector become reorganized around the platform (Poell, Nieborg, & van Dijck, 2019, p. 6). Platforms complement or replace teaching at schools and campuses depending on if they are part of onsite, online, or blended education. Whether it is Moodle, Google Classroom, Coursera's platform, Yuanfudao in China, or DIKSHA in India, platforms as integrated online services for learners or teachers have become the norm in many countries. This did not exist 25 years ago before the growth of the digitization of education.

Open Educational Resources changing costs and practices. OER have existed before digital education. However, since digitization OER have had substantial impact in education systems, nearly every developed and developing country has or uses OER. Institutions in Australia, Canada, and the United States have been pioneers in OER and have actively built repositories. Countries like Germany have started to build extensive digital infrastructure to allow for OER use. One of the eight actions in China's Education Informatization 2.0 Action Plan is to build "a national public service system for educational resources" (Yan & Yang, 2021, p. 417). India has a National Repository of Open Educational Resources. In South Korea, the Korea Education Research and Information Service (KERIS) organizes and makes accessible OER. OER have reduced costs for students and learners to use learning materials. They have also changed the discussion about public and private access to knowledge and information to the point where high-profile organizations like the Gates Foundation and the World Bank support OERs at primary, secondary, and tertiary levels of education provision. As many governments decline their investment in education, OER have become more important for education systems.

Digital Labor

Increasingly in most developed and developing countries, teaching is digital work, both for onsite and online education at primary, secondary, and tertiary levels. However, few countries seem to provide adequate training, development, and support for teachers and faculty. Despite large and varied use of digital technologies for learning, there is still surprisingly little support for teachers and faculty. Most of the focus with digital technology initiatives seems to be on the learner-facing dimension with a huge gap in supporting teachers and faculty.

The lack of pre-service and in-service teacher training for using digital technologies is well-chronicled. Bond, Zawacki-Richter, and Nichols (2019) found that "issues of educator professional development with technology has been a particularly recurring theme across the past five decades, with institutions at all levels struggling to find the resources to release educators, or to implement sufficient preservice teacher education with technology" (Bond et al., 2019, pp. 39–40). It is not just a lack of training. They found "a lack of institutional support to provide the space and time" (Bond et al., 2019, p. 12) for technology integration. A similar concern exists for the tertiary level educators. Bates lamented that in Canada most faculty and instructors are unprepared to teach students using digital technologies and to develop "knowledge and skills for a digital society" (Bates, 2020, p. 60).

Many countries have acknowledged this gap. India has created DIKSHA (Digital Infrastructure for Knowledge Sharing), a digital repository for content and courses targeted at teachers and others. The repository has learning materials from experts, including teaching videos, explanation videos, lesson plans, and experiential learning videos among other resources. Given India's diversity, the resources are available in over 30 languages and can be used offline. The European Union has created a digital competence framework for educators (DigCompEdu). It allows educators to

assess their digital competencies, recognize their knowledge and skills needs, and take appropriate training (Redecker, 2017). These are teacher-facing initiatives that became more important since the pandemic.

Digital Outcomes

Digital outcomes are educational goals and outputs that also reflect the extent of digitization in an education system. Educational outcomes are digital outcomes when access, quality, or cost are changed or aspired to via the use of digital technologies. Not all educational outcomes are digital outcomes. Improving learning effectiveness is not an outcome specific to digitization. It can be improved in multiple ways unrelated to digitization (e.g., changing pedagogy). Offering large-scale courses are also not a digital outcome. Broadcast-based courses have reached thousands of students at a time for decades. However, it would be a digital outcome – a measure of the extent of digitization – if personalized learning and feedback was being provided system-wide at scale to thousands of MOOC students via digital use (e.g., artificial intelligence and learning analytics) and digital labor (i.e., personnel to develop and administer digital tools). It is a digital outcome when there is a notable increase in digital competencies among students in an education system. Increasing students' digital knowledge, skills, and abilities requires using and supporting digital technologies and appropriately trained educators. Another digital outcome is creating and accepting new credential options like digital badges and nonformal education certificates. It is a digital outcome when digitization is used to enlarge private provision of education in response to reduced public funding for education (Qayyum & Zawacki-Richter, 2018, p. 129).

Digital outcomes can also include plans to foster digital outcomes in a country's education system. Even before the pandemic, there was an accelerating interest in institutional and government policies in digital outcomes in many countries. China's informatization plan states the importance of fostering digital skills, computational thinking, personalized learning, and autonomous learning (Yan & Yang, 2021, p. 424). European Union policy documents regularly indicate that digital competencies are an important goal to meet the needs of a digitally transforming European economy and society (EU, 2020). In South Korea, the motto "digital education for all" is found throughout government education branches (Korea MSIP, 2016, p. 51). Whether or not this is realized, it shows aspiration to specific digital outcomes.

Digital Transformation After the Pandemic

The pandemic was a black swan – an improbable and unpredicted event – that left most countries scurrying to make emergency provisions in order to keep education systems functioning. However, the pandemic has shown which dimensions are most important for digitization of education if the world or countries encounter gray

rhinos – high impact and likely threats that should not be ignored – like climate disaster or future pandemics.

It is already well-documented and researched how most countries made changes to provide educational access at all levels during the pandemic (Bozkurt et al., 2020; UNESCO, 2020). The limited or closed access to the physical spaces of education immediately tested the digital assets and infrastructure of all countries affected. Covid-19 is a revealer and its biggest revelation has been inequity (El-Erian & Spence, 2020). It has exposed inequities in health care most obviously but also in education. The pandemic exposed inequities in the digital assets of countries' education systems. Digital assets became a sine qua non for education. Developing countries like China, India, and Turkey had moderate levels of digital assets (e.g., Internet access). So, governments in these countries combined digital technologies with on-air technologies to provide education. Developed countries that had digital assets and infrastructure pivoted to "remote teaching," and later to online, hybrid, and "HyFlex," as their main source of education provision. To keep formal education open, schools and universities spent a lot of money and time on digital assets to ensure students at all levels had the physical devices and network connectivity.

However, even in developed countries, many people did not have digital assets such as access to devices and connectivity. In the United States in 2021, nearly one-third of students stated they had unreliable computers, and over 20% said they had glitchy or no Internet access among 1300 higher education institutions that moved to online education (Schnieders & Moore, 2021, p. 4).

There has been no shortage of digital use - digital engagement with the processes of education – as much of the world tried to go online for everything. Synchronous tools became especially common for educational provision, often in attempts to replicate onsite classrooms for better or for worse. Remote education became the norm. In many developed countries like Australia, Canada, and Germany, the digitization of education was growing before the pandemic. Digitization accelerated during the pandemic as the future was pulled forward. Countries that were still mulling digitizing education have been forced to move toward digitization quickly. For example, if there was hesitation in India about online education, there is now commitment to grow digital use for education (India, MHRD, 2020).

Digital labor assesses how digitized work is and how much support there is for workers' digital capacity. Where "work from home" has grown, nearly all work that can be digitized has been. However, teachers and faculty have been unprepared and under-supported for fully remote education. Lack of teacher and faculty training and support is a concern that has heightened during the pandemic (Bates, 2020). Additionally, a key new group of education digital workers has emerged during the pandemic: parents as "proxy educators" (Davis, Grooms, Ortega, Rubalcaba, & Vargas, 2021, p. 61). They too have been under-supported. Lack of support during the initial emergency of March 2020 is understandable. The lack of middle term planning for training and support of educators and parents is more concerning.

Expectations during the pandemic shrunk for the outcomes of education generally and the digital transformation of education specifically. Digital outcomes quickly

lessened to subsistence aspirations. Required to carry the weight of entire education systems, digital provision has had mixed success.

Conclusion and Recommendations for Future Research

Digital transformation as a subject is an understudied area with many topics that are yet to be researched. A few topics are priorities:

- Which education digitization indices are important for particular countries?
- What are best practices for addressing digital labor challenges of digitization?
- What problems in an education system does digitization address?
- What is the impact of digitization on existing open and distance education institutions?

Which education digitization indices are priorities for a given country? The pandemic stress-tested the digital index. Of the four indices, it seems that for many countries digital assets and digital labor have made the crucial difference in keeping education systems afloat. This should give pause to educators and decision-makers about the immense money and resources used to create, implement, and research digital use.

This is a major practice and research issue about digitization. There is no shortage of digital tools and resources for learning. There has been a shortage of resources for digital assets and digital labor. This suggests researchers must focus more on teacher-facing challenges and issues for digitization (e.g., what are best practices for faculty development; is outsourced instructional design a fair opportunity?). If digitization is to address access, cost, and quality inequities revealed during the pandemic, education researchers and practitioners will need focus on digital access and digital labor and not just digital use.

The digital transformation is often portrayed as the future of education and is certainly well underway in many countries. At the very least, the pandemic has evinced that digitization is important during times of emergencies. It may no longer be constructive to ask, "should education systems digitize?" A more meaningful research question is "to borrow from Postman (1993), what is the problem for a country's education system to which digitization is the solution?" This needs to be an ongoing research topic. Finally, as digital transformation continues, what will be the impact on existing open and distance education institutions. What is the value proposition of open and distance education institutions? This is an existential issue.

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