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Regular Article

DEIFDC framework: Evaluation of digital education deployment in India in the midst of the Covid-19 pandemic

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ABSTRACT

The Digital Education Index for Developing Countries (DEIFDC) is a compound index that considers nine different variables grouped in three main levers that have been researched relevant to assess the overall state of readiness of Digital Education deployment in a developing country. Digital Education has been approached from an instrumental point of view, focusing on the advantages that the introduction at an early stage of digital tools brings to the teaching and learning processes to ensure children can acquire the required 21st competencies of a future workforce. In the application for the Indian case, social, cultural, economic and educational data obtained through desk research during the first semester of 2021 has been taken into consideration. Despite significant Government efforts on scaling up Digital Education, primarily due to the Covid-19 pandemic school closure, the 0.596 DEIFDC score on a 0–1 possible range has shown Inadequate Digital Education Deployment, derived mainly from poor school infrastructure, limited pedagogical capabilities and modest students' skills. Furthermore, the socio-demographic differences observed among school children and the existent digital divide in rural and urban areas demonstrate that major effort needs to be undertaken to ensure vulnerable Indian population does not lag behind under the new rules of the Digital Economy.

1. Introduction

Education is a human right (United Nations, 1948) and one of the most potent instruments for development as it contributes to reducing poverty and improving health, equality and peace (Alvarado, 2019). For individuals and societies, education promotes employment, poverty reduction, economic growth and social cohesion (World Bank, 2020b). The importance of education has also been reflected in the Agenda 2030 for Sustainable Development Resolution adopted by the United Nations General Assembly, where the specific development goal number 4 (Boeren, 2019) has been dedicated to education to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Target 4.4, described as substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship, is directly related to Digital Education (United Nations General Assembly, 2015) as a means to prepare students with the skills required in a 21st-century workforce (Internet Society, 2017; World Economic Forum, 2020a, 2020b).

As primary school children will enter the labour market in ten years' time, they will need to have acquired the essential competencies of Digital Literacy: use of computers and digital equipment, ability to use online applications, find and qualify online information, make use of it in daily life and be ready to later deploy a career in programming, data analysis, cybersecurity or cloud management (Olszewski et al., 2020). Therefore, building these skills is crucial for developing countries and should be included in the curricula and assessed in the same manner as other basic competencies like reading, writing and mathematics (Ministry of Human Resource Development, 2020; Unesco, 2022; Unicef, 2020).

At the beginning of 2020, 1,6 billion children and youngsters were displaced out of school in 190 countries with diverse consequences in terms of their learning progress, nutrition support and subsequent enrolment stability (Unesco, 2020a, 2020b, 2020c). Most Governments used Digital Education as a backup response to ensure learning continuity at all levels of education (Selim, 2020; Lennox et al., 2021, p. 102429; Unesco, 2015). However, the current digital divide (World Bank, 2020c) made evident that Digital Education was very poorly developed; in vulnerable environments, those with less technical resources had greater challenges to follow up with lessons as more than

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two-thirds of children aged 3–17 years worldwide lacked internet access at home (Unicef et al., 2020).

India is a vast country, with a huge variety in terms of social differences, geographic constraints and cultural and religious complex diversity (World Bank, 2018). Although challenging, the Government of India, through the coordination of the Ministry of Education and the Ministry of Electronics and Information Technology, has established digital national policies, transversal institutions and multilingual platforms that have facilitated the later acquisition and deployment by the States and the Union Territories (Ministry of Electronics and Information Technology, 2021). However, the existing digital divide, primarily due to the lack of infrastructure in terms of internet connection in rural areas, is causing the most disadvantaged Indian citizens to lag in equal digital development (Telecom Regulatory Authority of India, 2020, 2021) and important differences are still present for the most vulnerable population, especially children attending to schools in rural areas (Wang et al., 2019) and disadvantaged clusters. The Indian Government has launched several Digital Education programs for primary schools during the last ten years with diverse degrees of implementation (Gond et al., 2017) and the sanitary crisis boosted the usage of digital platforms and online resources from home to be able to keep up with the lessons during the school closure (Indian National Commission for Cooperation with Unesco, 2020). However, only the privileged ones counted with an internet connection, a quiet place to study and a computer for schoolwork, key to properly follow with the learning process (Ikeda, 2020; Muthuprasad et al., 2021; Meena et al., 2021).

Due to the Covid-19 pandemic, recent studies are trying to evaluate how countries coped with the interruption of face-to-face learning interactions thanks to digital technologies (Sá et al., 2020; Arora et al., 2020; Maity et al., 2021; Kapila, 2021) and how the education systems will be shaped by Digital Education moving forward (Rahardja et al., 2020; Maity et al., 2022). Moreover, the level of digital deployment has been thoroughly researched by introducing country comparisons and trend analysis of digital performance (Foley et al., 2018; Hanafizadeh et al., 2009), cross-country examination of digital divide (Mardikyan et al., 2015) and the possibilities of lifelong learning digital education upscale (Beblavý et al., 2019). Still, there is no framework to assess the current state of deployment of Digital Education at early stages of schooling (Heckman, 2017) to orientate public education policies and establish a common ground of comparison and paths for future evolution among developing countries, so their future workforce is prepared for the 21st-century challenges.

Hence, the following research questions were formulated: *RQ1*. What are the main variables that affect the implementation of Digital Education in a developing country? RQ2. What is the state of readiness of Digital Education deployment in India?

The methodology used proposes the definition of a Digital Education Index for Developing Countries (DEIFDC) as a geometric mean of nine different variables (school net enrolment, persistence to last grade of primary, literacy and numeracy skills, digitally teaching practices, digital learning resources, personal and adaptive learning, electricity access, broadband coverage and LMS availability) that have been grouped into three levers (students' readiness, pedagogical capabilities and IT infrastructure development) and assigned a different weight based on the perceived importance to assess Digital Education deployment in a developing country. In the application of the DEIFDC for the India case, an overall score of 0.596 situates India in the countries with insufficient deployment and therefore, significant reforms need to be undertaken to properly plan the introduction of Digital Education in schools. The DEIFDC application is also under study in additional developing countries, for example, preliminary results leave Kenya with a lower score on digital education deployment and Peru with a greater score than India.

The rest of the article is organised as follows; the first part reviews the existing literature approaching Digital Education from an instrumental point of view, focusing on the advantages that different digital tools bring to the learning process. In the second part, there is a detailed description of the methodology and research procedure to depict the levers and variables that compose the index. In the third part, the Indian context is introduced in terms of social, cultural, economic and educational characteristics as well as the digital programs deployed and results obtained in the application of the index. Lastly, the final section includes a summary of the results, encountered limitations and lines of future research.

2. Literature review

Digital Technologies have been progressively introduced at a different scale in most Education Systems, even if traditional textbooks and chalk and board lessons were the mainstream (Karunanayaka et al., 2020; Selwyn, 2010). In 2020, Digital Education was revealed as a potent enabler during the pandemic crisis (Monirujjaman et al., 2021); however, empirical findings (Riviello, 2020; Olszewski et al., 2020) demonstrate that it should not be considered as a backup instrument to respond only in case of school closure but as a means to prepare children at early stages of education to acquire the competencies that will be needed in a new Digital Economy (Unicef, 2020). In addition, Digital Education prepares children to develop the digital competencies required in a 21st-century workforce like digital literacy and computational thinking (World Economic Forum, 2020a, 2020b).

Nonetheless, these skills cannot be considered isolated, and it is necessary to use a holistic approach in which the new ways of teaching and learning will also help them to acquire a series of soft skills that have been analysed in several forms, such as the four C's (Ruhl, 2015): critical thinking, creativity, communication and collaboration; the ABCs (Wilson-Body, 2020): adapt, be resilient and communicate or the four Pillars of Education: learn to know, learn to do, learn to live and learn to be (Unesco, 2015). On the other hand, the ISTE framework proposes the following set of skills for students: Creativity and Innovation, Communication and Collaboration, Research and Information Fluency, Critical Thinking, Problem Solving and Decision Making, Digital Citizenship and Technology Operations and Competencies (International Society for Technology in Education, 2007). As stated by the Reimagine Education program (Unicef, 2020), the availability and potential of technology mean that digital learning should be part of a basic basket of essential services for every child to build and accredit basic skills. These skills include reading and writing, problem-solving, creativity, and critical thinking needed for work, starting a business, and engaging productively in their communities. Recent studies (Ganimian et al., 2020) suggest four different ways to realise the potential of Digital Education to accelerate student learning and focus on potential uses of technology: scaling up quality instruction, facilitating differentiated tutoring, expanding opportunities to practice and increasing learner engagement through videos and games.

In this research, Digital Education has been studied as an enabler to improve learning practice and prepare children with the required 21st-century skills (Larson et al., 2011). When studying individually, pupils use digital learning tools on computers, tablets or mobile phones by accessing different educational content available from the internet or previously downloaded and made available offline (Jaya et al., 2020). This way of working is differential because it extends the boundaries of knowledge acquisition, especially if children can conduct their own research and take advantage of the access to an infinite library where unorganised data are available (Mitra, 2003). At the same time, it enables learning personalisation and the ability of the educational resources to adapt to the current capacities and abilities depending on the student level, its achievements and misconceptions (Luckin et al., 2016; Luckin, 2018), and it facilitates evaluation and assessment (Raaheim et al., 2018) as different types of tests and questionnaires can be applied to verify students' levels at various stages of the learning process. Additionally, it simplifies the individual certification or warranty of proficiency in specific subjects or matters that can be used to access higher education or specialised jobs (Beblavý et al., 2019).

Collective learning digital tools also bring a new way of working soft skills that allow teachers to introduce complementary forms of interaction among students. It changes the course of communication in a classroom from a teacher-centred approach to a student-centred approach (Ruhl, 2015). These tools can be interactive whiteboards (IWB) or projectors, but also more advanced systems such as Virtual Learning Environments (VLE) or Learning Management Systems (LMS) deployed either locally or connected to the internet (Light, 2015), among others, they enable teamwork and collaboration by grouping students in smaller clusters to develop different subjects, research together or complete tasks that involve thinking out of the ordinary (Scheuer et al., 2010), peer evaluation by allowing the students to assess the work of their peers and help them create a collaborative environment where everyone learns from both producing and reviewing the work of others and introduce gamification, helping students' motivation with the creation of avatars and game-related content that can be used to study a specific matter deeply, children will get higher scores depending on how they dominate the subjects and how they perform compared to others (Freitas, 2011).

In a new Digital Economy, developing countries must aim to become not only countries of manufacturing outsourcing but also move into services with customer call centres, data entry facilities and higher-skilled professional jobs ranging from engineering to artificial intelligence (Lieberman, 2004). Likewise, it has been demonstrated through recent research that inequalities in education may limit the positive economic outcomes and benefits derived from the use of ICT (Billon et al., 2017). For example, the recent pandemic crisis showed that only those with jobs adopted to the current digital economy could introduce massively home working. Furthermore, lower-income economies have a lower share of jobs that can be done at home (Dingel et al., 2020). Also, at a micro-level, workers from developing regions and lower wages had a more challenging time continuing to work during the pandemic, increased overall economic vulnerability and worsened inequality in lower-income households (López-Calva, 2020). Therefore, it is relevant for developing economies not only to ensure economic growth but also to build a more resilient and inclusive society. In developing countries, Digital Education is pertinent because it can not only improve the teaching and learning processes but also introduce at school the necessary competence acquisition for producing a technologically proficient workforce (Kalolo, 2018) that might change in the next 10–15 years the composition of the labour market (Kask et al., 2021).

3. Methodology

3.1. Research model and procedure

The Digital Education Index for Developing Countries (DEIFDC) is a geometric mean of nine different variables that have been grouped into levers and assigned a different weight based on the implications to deploy Digital Education in primary schools of Developing Countries. The selection of levers have been carried out based on the detailed overview of supporting literature, mainly professional journals, expert think-pieces, case studies, interviews, systematic reviews, comparative studies and policy statements included in the references section. Two main digital indices have supported the framework: the Index of Readiness for Digital Lifelong Learning (Beblavý et al., 2019) and the International Digital Economy and Society Index (Foley et al., 2018).

As exposed in Fig. 1, the literature reviewed suggests that the main levers to assess Digital Education deployment in developing countries are: Students' Readiness (L_1), Pedagogical Capabilities (L_2) and IT Infrastructure Development (L_3). To support the weights of variables within each lever, a quantitative survey was launched to educational experts world-wide, including senior public officials from international organizations, NGOs leaders working on developing countries and EdTech executives. The survey has served to gain their insight on the importance they assign to the variables on a 1–4 scale (see Table 1):

As suggested by the central limit theorem (Kwak et al., 2017) the objective was to count at least with thirty responses, however the responses received were thirty three. To establish the variable weights the following equations were established, where $GM(V_{i,j})$ is the geometric mean of all the responses obtained and $W_{i,j}$ is the calculated weight for each variable:

Table 1
Variables' metric distribution. Source: Authors' elaboration.

Relevance	Description	Metric
Irrelevant	The variable has no relevance in the deployment of Digital Education	1
Important	The variable is important in the deployment of Digital Education	2
Decisive	The deployment of Digital Education is largely affected by this variable	3
Critical	No Digital Education deployment will be possible without the adequate placement of this variable	4

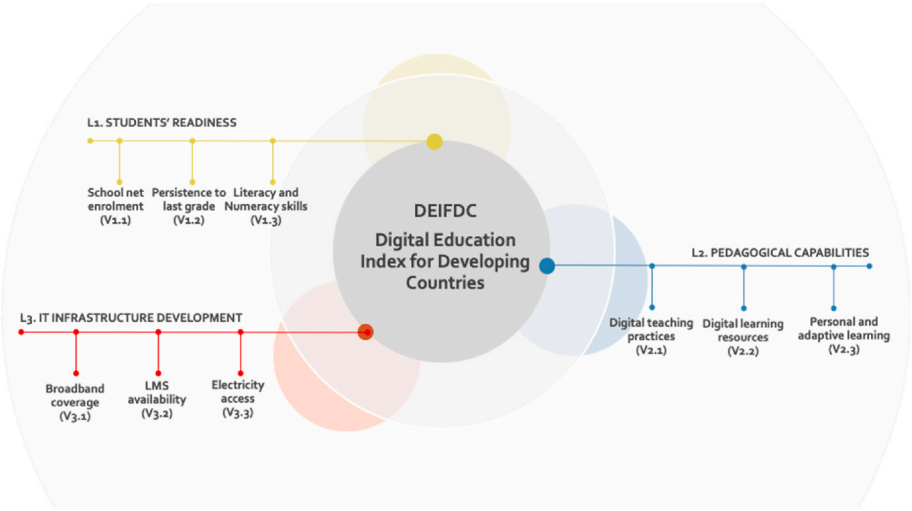

Fig. 1. Digital Education Index for Developing Countries (DEIFDC) Schema. Source: Authors' elaboration.

$$GM(V_{i,j}) = \sqrt[n]{\prod_{k=1}^{n} A_{i,j}^{k}}$$

Where n is the number of responses obtained and $A_{i,j}^{k}$ are the responses obtained for the variable $V_{i,j}$

$$W_{i,j} = \frac{100 \times GM(V_{i,j})}{\sum_{j=1}^{3} GM(V_{i,j})}$$

The equations defined to calculate the DEIFDC are as follows, where each variable has been given a 0–1 scale:

$$L_i = \sum_{j=1}^{3} W_{i,j} V_{i,j}$$

This will result in an index calculated on the geometric mean of the three different levers previously constructed:

$$\mathbf{DEIFDC} = \sqrt[3]{\prod_{i=1}^{3} L_i}$$

Depending on the DEIFDC score, the developing countries understudy will be grouped according to one of the categories defined in Table 2:

The following Table 3 summarises all levers and their assigned variables and weights:

The justification of each lever will be described in the following subsections.

3.1.1. Students' readiness (L_1)

One of the main challenges to apply Digital Education in developing countries is the fact that enrolment ($V_{1.1}$ Weight: 30.26%) in certain areas is still a challenge, without school attendance, persistence, and continuous guidance, the benefits of introducing 21st-century skills in primary schools, can be reduced.

It is also crucial that children stay in Primary School and keep on studying until the last grade ($V_{1.2}$ Weight: 32.68%), this is beneficial in terms of individual progress but also in terms of society as additional years of schooling have proved to be central for employment, poverty reduction, economic growth, and social cohesion. Moreover, it has been demonstrated that there is a 9% increase in hourly earnings for one extra year of schooling (Psacharopoulos et al., 2018). At the same time, evidence on the importance of early environments on a spectrum of health, labour market, and behavioural outcomes suggests that focus must be put at early stages of education (Heckman, 2007) rather than on secondary or lifelong learning opportunities.

Among the benefits of introducing Digital Education at an early stage is the reduction of learning poverty (World Bank, 2019), which is mainly measured by the capacity of students to read and write and solve mathematics problems related to daily life ($V_{1.3}$ Weight: 37.07%). Although there are several countries that have been measuring the impact of education, the most extended analysis is based on PISA, the Programme for International Student Assessment that measures the 15-year-olds' ability to use their reading, mathematics and science knowledge skills to meet real-life challenges.

Table 2
DEIFDC Score Distribution. Source: Authors' elaboration.

Grade	Description	Score Range
Excellent	Digital Education is incorporated at all levels in the education system	0.9–1
Good	Digital Education is properly planned and needs to expand on a massive rollout	0.8–0.9
Adequate	Digital Education is at an early stage of deployment with areas of improvement	0.6–0.8
Insufficient	There is little use of digital technologies in the classroom	0–0.6

Table 3
DEIFDC Weight variables Summary. Source: Authors' elaboration.

Lever/ Variable	Name	Description	Weight
L_1	Students' Readiness	Students ready to be digitally exposed	
$V_{1.1}$	School net enrolment	Adjusted net enrolment rate (% of primary-school-age children)	30.26%
$V_{1.2}$	Persistence to last grade	Persistence to last grade of primary (% of cohort)	32.68%
$V_{1.3}$	Literacy and numeracy skills	Proportion of children achieving a minimum proficiency level in reading and mathematics (%)	37.07%
L_2	**Pedagogical Capabilities**	**Digital Education integrated into the learning process**	
$V_{2.1}$	Digitally teaching practices	Teachers who have received the minimum organised teacher training pre-service or in-service capable of introducing Digital Education in the classroom (%)	34.5%
$V_{2.2}$	Digital learning resources	Students with access to digital learning resources (%)	33.5%
$V_{2.3}$	Personal and adaptive learning	Students with access to electronic devices to perform digital learning (%)	32%
L_3	**IT Infrastructure Deployment (L_3)**	**Infrastructure deployment to meet Digital Education demands**	
$V_{3.1}$	Electricity access	Schools with electricity access to ensure availability of ICT hardware (%)	38.87%
$V_{3.2}$	Broadband coverage	Schools with internet access for pedagogical purposes (%)	34.39%
$V_{3.3}$	LMS availability	Schools with LMS installed (%)	26.73%

3.1.2. Pedagogical capabilities (L_2)

Within this section, the variable with the most significant importance is the training of teachers ($V_{2.1}$ Weight: 34.5%), as it is considered critical to the success of introducing Digital Education in the schools (Panagiotis et al., 2015). In this sense, it is not only necessary to teach them how to use the new ICT tools but also to provide pedagogical support and continuous professional development to ensure they can apply innovative methodologies in the school and work on the competencies that Digital Education facilitates as several frameworks have proposed (Béteille et al., 2018; Light, 2015).

The second variable in terms of importance is the availability of suitable content ($V_{2.2}$ Weight: 33.5%). Advanced digital resources have traditionally been exploited by EdTech companies that made the content available through web access, applications and different types of licences. However, new regulations on Open Educational Resources (Unesco, 2019) have made plenty of digital content available, especially after the Covid-19 crisis and to students and teachers with an Internet connection. Although this is a progression that can make a difference in developing countries, it is necessary to adapt it to the specific curricula of each environment (Trucano, 2010), local languages, contexts without an Internet connection or specific devices different from laptops like tablets or mobile phones.

The penetration of electronic devices per student ($V_{2.3}$ Weight: 32%) has been considered of less relative relevance as it has been proven that deployment of ICT labs and equipment sharing is also a good practice to introduce Digital Education in the education process. However, it is essential to ensure unique login to identify students' sessions and relevant to apply some of the advantages that Digital Education provides in terms of personalisation (Lucking, 2016), gaming and certification.

3.1.3. IT infrastructure deployment (L_3)

The adequate deployment of infrastructure is key to ensure that children can receive the initial instruction required in developing countries schools as family technical support, which is usually the first step of Digital Education introduction in developed countries, cannot be

ensured. Electricity access ($V_{3.1}$ Weight: 38.87%) has been given the most relevant load as the ICT equipment (computers, tablets, routers or projectors) must be charged appropriately. When no standard electricity access is possible due to geographic or economic conditions, there are other ways to ensure batteries can last during the school day, and several deployments have been proved successful such as solar panels or solar chargers for specific equipment; however, typically, their capacity is conditioned to weather circumstances and the quality of the equipment provided. Other renewable energy technologies like wind turbines, small-scale hydroelectric projects and other forms of self-sufficient energy can provide rural communities in the developing world with the electricity they need to power schools (Solar Energy International, 2018).

Even if educational resources can be made available and previously uploaded, internet access ($V_{3.2}$ Weight: 34.39%) ensures that broad knowledge and content can be used in the classrooms (International Telecommunication Union, 2013). In addition, a broadband connection is particularly relevant in contexts where advanced individual or collective learning tools are being introduced, such as adaptive learning and gamification (Internet Society, 2017).

Although it seems Digital Education deployments should start with the delivery of a laptop or tablet to children in school for individual use, the standard approach that has been carried out in more advanced Education Systems is through the usage of Interactive White Boards, Learning Management Systems and projectors in the classroom ($V_{3.3}$ Weight: 26.73%). This introduction allows the Primary Education teachers to expose content and familiarise the children with Digital Education. Particularly, educators can use IWBs to empower students with 21st-century skills and create exciting new learning opportunities for promoting STEM education, problem-solving, critical thinking, and collaboration skills among their students (Yinghui et al., 2012).

3.2. Research context

The Republic of India is located in South Asia, land bordering China, Bhutan, Nepal, Afghanistan, Pakistan, Bangladesh and Myanmar. It is also one of the countries with a long shoreline in the Indian Ocean and a maritime exclusive economic zone.

India is the seventh biggest country in the world and, with a population of almost 1400 million, is the second most inhabited country, accounting for 17.7% of the total world population (United Nations, 2020). India can be considered a subcontinent with 28 States and 8 Union Territories that count with a diverse cultural, ethnic and religious background significantly influenced by their past as a British colony until 1947 and many remaining conflicts among political and cultural groups.

As per the 8th schedule of the Indian constitution, there are 22 official languages in India and demands understudy for the inclusion of 38 more languages or dialects (Department of Official Language, 1963). Hindi, Bengali, Telugu and Marathi are the languages most widely spoken, but the variety is such that more than 60% of the Indian population speaks a language different from Hindi as a mother tongue (Ministry to Home Affairs, 2001). Moreover, even if English is the language used for commercial and political purposes, only 12% of the Indian population can speak English as a second language.

India is the world's fifth-largest economy by nominal GDP; however, on a per capita income basis, India is the 142nd country in the world (International Monetary Fund, 2020) where the 10% richer accounts for 56% of the national income (World Inequality, 2019). At the same time, India ranks 131 in the Human Development Index with an IDH of 0,645 considered within the medium group of Human Development (United Nations Development Program, 2020). The overpopulation severely affects the country, and about a quarter of the population is too poor to be able to afford an adequate diet (Food and Agriculture Organization of the United Nations, 2017). Moreover, stunting affects 39 per cent of all children and 60 per cent of children in poor households (World Bank, 2018). During the last decades, a major improvement of bringing the population out of poverty has been made, and it is expected that by 2047, 100 years after independence, at least half of Indians could be considered middle class in terms of access to housing, health care, education, clean water and reliable electricity (World Bank, 2018).

India's economy is very varied, composed of agriculture, handicrafts production, modern industries, and international services. As one of the BRICS (Brazil, Russia, India, China, and South Africa) emerging economies, India needs to maintain sustainable growth to be able to meet the path to prosperity and ensure at least an 8% GDP growth over the next three decades. However, the economy was already contracting, from an average of 7.4% in the last four years to 4.2% in 2019, when the Covid-19 pandemic crisis broke out, causing a non-precedent contraction of −23.9% year on year in Q1 FY21 (World Bank, 2020a).

The Indian Government has established different measures "to build back better" while keeping on reducing inequality (World Bank, 2018). In this aspect, the impact of Digital Education will be analysed in a profound manner at early stages of schooling. As the conformation of a digital high productive and high waged labour (Wijayanti et al., 2021) will be key for the future of an India free of inequalities.

As of the beginning of 2021, there were 9,430,839 teachers, 2,483,385,584 students, and 1,551,000 schools, from which 69,91% are Government schools and 84% are in rural areas (Ministry of Education, 2021a). The Ministry of Education, previously known as the Ministry of Human Resource Development, is divided into two central departments in charge of different stages of education: The Department of School Education and Literacy, responsible for Primary, Secondary, Adult Education and Literacy and the Department of Higher Education responsible for University and Vocational or Technical Education.

Following the Right to Education Act (Right to Education, 2009), education is free and compulsory for children aged between 6 and 14, and it is the responsibility of the Government to ensure enrolment, attendance, and completion. However, the deployment of the Act is still undergoing as the segregation in private and public schools (Indian Institute of Management Ahmedabad et al., 2015) has not improved the inequalities even after the 25% seat reservation law for disadvantaged children (Scheduled Castes, Scheduled Tribes and Other Backward Classes) was imposed.

In July 2020, a new National Policy on Education was approved (Ministry of Human Resource Development, 2020c) to replace the former policy from 1986, which dedicated most of its reforms to inclusion (Ministry of Human Resource Development, 1986). Although the National Policy on Education relies on the different States and Union Territories for its application and deployment, still it concentrates the decisions on the curriculum at a national level through the National Council of Educational Research and Training (NCERT) and the national examinations on grades 10th and 12th on the Central Board of Secondary Education (CBSE).

The new policy pays attention to necessary reforms in the Indian Education system, considering the particularities of both School Education and Higher Education (Figs. 2 and 3), mainly:

1) School Education: Major importance has been granted to early childhood education following the SDG 4 recommendations to ensure children are well prepared to start primary school, in terms of their capacity to learn, their physical health and their psychosocial well-being (United Nations, 2015). The highest priority of the education system will be to achieve universal foundational literacy and numeracy in primary school by 2025 that can ensure future readiness to learn at later stages of education. Special measures consisting of the improvement of school infrastructure and the participation of social workers in the communities will try to ensure retention as Gross Enrolment rates are as high as 90.9% for early grades, but they significantly drop after grade 5th with rates of 79.3% and 56.5% for 6th and 8th grade. The role of the teachers is also considered a critical factor in the transformation process, giving importance to

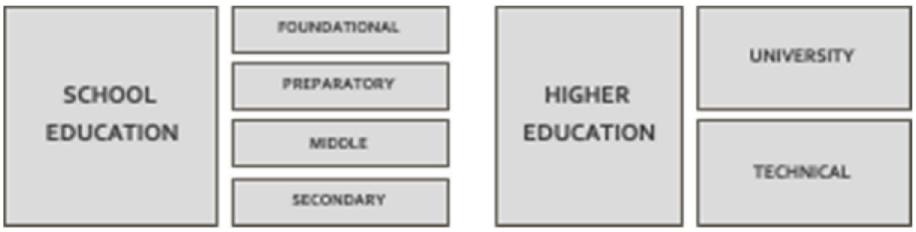

Fig. 2. Indian Education System. Source: Author's elaboration with data from the National Policy on Education (Ministry of Human Resource Development, 2020a, 2020b, 2020c).

Fig. 3. Indian Education System, School Education. Source: Author's elaboration with data from the National Policy on Education (Ministry of Human Resource Development, 2020a, 2020b, 2020c).

their training, enrolment, capacity to teach in local languages and continuous development to motivate in the children the willingness to learn and develop, mostly in disadvantaged contexts.

2) Higher Education: One of the main challenges that the current Universities and Colleges are facing is the great fragmentation in small centres throughout the States. The Government will thus encourage the creation of Higher Education Institutions that work from a holistic, multidisciplinary, inclusive and high-quality perspective. Vocational Education has been underdeveloped in India mainly because it has been considered a failure path for those who are not capable of reaching University education. Therefore, significant efforts will be developed to change perceptions towards Vocational Education and ensure exposure during School Education that can awaken students' interest in technical training. The main goal is to increase the Gross Enrolment Ratio in higher education, including Vocational Education, from 26.3% in 2018 to 50% by 2035.

It is worth pointing out that the curriculum proposed in the National Policy on Education considers the competencies required for the 21st century, emphasising not only transversal knowledge in different areas but also enabling the acquisition of creativity, critical thinking, collaboration, communication, cooperation, teamwork, resilience, multilingualism and ethics values. Furthermore, technology is contemplated to be a key enabler to improve educational processes and outcomes, and the extensive use of ICT both in teaching and learning will be promoted through the improvement of digital infrastructure, ensuring availability of Learning Management Systems (LMS) in schools, multilingual content creation, availability of virtual labs and incentives for digitally innovative prepared teachers (National Mission on Education through ICT, 2021).

The Indian Government has been introducing ICT in the teaching and learning processes through various programs during the last decade (Department of School Education and Literacy, 2020; Roy, 2012). However, the Covid-19 pandemic lockout has boosted the deployment of Digital Education to ensure scholars could receive lessons and access educational content in varied formats depending on the degree of connectivity available: online, online with limited access (depending on electricity or internet availability) and offline (Indian National Commission for Cooperation with Unesco, 2020). In addition, the Governmental Institutions and the States and Union Territories, responsible for the execution of the guidelines, have made a significant effort unifying ICT tools for cross country use given the 4450 EdTech start-ups operational in India (Shah et al., 2020).

The main initiatives undertaken directly impacting the DEIFDC can be summarised as follows:

1) Diksha (Digital Infrastructure for Knowledge Sharing): Launched in 2017, this LMS is considered as the "one nation one digital platform" for grades 1st to 12th by the Government's authorities (Department of School Education and Literacy, 2020). It has been built based on the modules of an open-source platform called Sunbird, also developed in India, with the purpose of universalising both online and offline access in multiple local languages and accessible from several devices. It allows the usage of QR enhanced textbooks, the training of both teachers and children with digital credentials and a question bank tool with several curriculum-based tests. The most powerful feature of the platform is that it enables the curation and sharing of local content in 18 languages uploaded by teachers, organizations or Government institutes organised through the VidyaDaan (Ministry of Human Resource and Development, 2021) program. During the lockdown period, the 80,000 contents available have been accessed nearly 215 million times. Additionally, since the Covid-19 lockdown, it has had more than two billion-page hits and six million course completions.
2) Swayam (Study Webs of Active-Learning for Young Aspiring Minds): It is a MOOC oriented platform launched by the Ministry of Human Resource Development in 2017 (Ministry of Education, 2020). It offers a set of free online courses targeting students on School Education from 9th grade onwards, Out of School Education and Under/Post Graduate Education. The courses are organised based on video lectures, downloadable reading material, self-assessment tests, and a learning community to attend to doubts and misconceptions. The Government has set up a program to transfer credits obtained with these online courses and specific fees for in-person exams to obtain the corresponding certification. The course catalogue is very extensive, covering eleven domains of knowledge. It has been produced and delivered by National Coordinators with 203 partnering institutes and the collaboration of Google. As of April 2020, there were 4024 courses, 18,470,424 students enrolled and 850,924 successful certifications.

3) Swayam Prabha: This initiative aims to reach remote areas with no internet connectivity by providing 34 DTH (Direct To Home) non-stop educational channels through GSAT-15 satellite technology in the whole country (Ministry of Education, 2021c,d). Every day new content is broadcasted and then repeated another five times so students can follow the lessons at the most appropriate time for them. It covers several curriculum-based subjects for different education stages, mainly: Higher Education like arts, science, commerce, performing arts, social sciences and humanities, engineering, technology, law, medicine and agriculture, school education for grades 9th-12th, aimed to both teacher's training as well as learning aids for children with national exams preparations and life-long learning courses for Indian citizens.
4) Operation Digital Board: It is one of the country's most ambitious programmes for boosting quality K-12 education in the country (Ministry of Human Resource Development, 2019). This program will digitise 700,000 classrooms with a digital board to facilitate blended and flip class learning transforming standard classrooms into digital classrooms (Jha, 2019). A complimentary dish antenna will also be included in the school package, and, in the cases where schools do not have connectivity, a pen drive with educational contents for grades 1st to 12th will be used. It will also be possible to watch the Swayam Prabha educational channels and help in the provision of adaptative learning and intelligent tutoring by exploiting learning analytics technologies.
5) Epathshala: Designed and deployed by the National Council for Educational Research and Training (NCERT, 2021), the multilingual application is available in Android, IOS and Windows and has been downloaded by 4.5 million users. The application is targeted to Teachers, Students, Educators and Parents, and it counts with audios, videos, epubs, and flipbooks. More than 500 textbooks are available for browsing or downloading, and 3886 resources for classes 1st to 12th in different languages, mainly Hindi, English and Urdu, are available online. It is worth pointing out that the students get information on contests, workshops and exhibitions, and tutors get access to learning outcomes, curriculum frameworks, as well as educational journals.
6) National Digital Library: Developed by the Indian Institute of Technology in Kharagpur and sponsored by the Ministry of Education, the "One Library of All of India" integrates under a single repository, contents from a large number of Indian Educational and Research Institutions. It is available both online and through an Android/IOS application. It counts with more than 64 million resources among books, lectures, simulations, questions papers and solutions from Primary to Postgraduate Education. The interface supports leading Indian languages; the content can be browsed by type, subject, source or learning resource or using a powerful search engine with semantic tagging.

India is one of the largest and fastest-growing countries in the Digital Economy, and this has been powered by both public and private sectors alike. The three components of the Digital India program, developed by the Ministry of Electronics and Information Technology, focus not only on providing a stable digital infrastructure but also on delivering Government services digitally and ensuring universal digital literacy (Ministry of Electronics and Information Technology, 2021).

In terms of infrastructure, the increase in telephone and internet subscriptions and data consumption has been growing exponentially (Telecom Regulatory Authority of India, 2020, 2021), reaching 1163.41 million mobile subscribers and 757.61 million broadband users, from which only 22.67 million were wired subscribers, and the rest were relying on the mobile network to provide adequate bandwidth. Still, the degree of inequality among rural and urban areas remains relevant, not only in terms of Internet access but also in terms of computer usage and availability of a mobile phone (Pandey, 2020). According to the 75th round of the National Sample Survey (Ministry of Statistics and Programme Implementation, 2018), just 4.4% of rural households have a computer, against 14.4% per cent in urban areas, with just 14.9% of rural households having access to the internet against 42% households in urban areas. This divide also shows in terms of mobile density as it reaches 139.25% in urban areas and only 59.5% in rural areas.

Regarding digital economic performance, India's economy grew steadily at more than 7% until 2019, when it dropped to 4.7% before the pandemic crisis. Although necessary, in the case of India and other developing economies with high social inequality, under the social mobility theory, the poor population stays poor despite the country's impressive economic growth. According to the World Economic Forum, it will take Indians born in low-income families seven generations to even approach the country's mean income (World Economic Forum, 2020b) and the growth needed will be very much influenced by its digital component.

In this sense, the Indian Government aims to increase the contribution of the digital economy to 20% of the GDP from the current 7% in the next five years (Ministry of Informatics and, 2020), creating up to a trillion dollars of economic value from Digital Economy in 2025. This data (McKinsey Global Institute, 2019) is based on the fact that India counts with the second-largest digital consumer base, and at the same time, the new digital ecosystems come from diverse nature: financial services, agriculture, healthcare, logistics, education and e-government, helping to bridge the digital divide and bringing benefits of technology to all clusters of the population (Ministry of Electronics and Information Technology, 2019a,b). Moreover, compared to the USA in 2018, the digital economy accounted for nine per cent of current-dollar GDP, which amounted for 1.85 trillion US dollars (Nicholson, 2020), which demonstrates for the Indian case an appropriate level of GDP digitalisation.

Early Digital Education brings, as a result, the interest of students in pursuing advanced STEM education, the new professions of the future (World Economic Forum, 2020a) require the professional labour to adapt to reality in the new Digital Era. In terms of digital labour, India is better positioned than other developing countries as with 1.5 million engineers graduating every year has a high supply that covers by far the country demand (Aspiring Minds, 2019). However, upgrading India's human capital is essential to ensure a more productive workforce in all economic sectors that is skilled, educated, healthy and entrepreneurial. Therefore, Government efforts will be needed to ensure children receive adequate health care and education, especially in the early years (World Bank, 2018).

3.3. Instrument used and validation

For the purpose of this study, the schools within the Foundational, Preparatory and Middle levels have been considered leaving potential further research for the deployment of Digital Education in Secondary and Higher Education. It has also been considered the importance of Secondary Education, where the main competencies acquired during Primary years are valuated and will serve as an input for the completion of the DEIFDC information.

3.4. Data analysis

The existing data suitable for constructing the DEIFDC was obtained from reputable available national and international sources through desk research during the first semester of 2021. Data sources include global databases like the UIS Unesco Database and the World Development Indicators from the World Bank, as well as local Indian sources like the School Dashboard from the Department of School Education and Literacy and latest reports on performance from All India Survey on Higher Education and the National Learning Assessments. However, it is worth pointing out that India's standard PISA (Programme for International Student Assessment evaluations) results will not be available until the second semester of 2022 as field trials have to be postponed due to

the Covid-19 lockdown (Ministry of Human Resource Development, 2020a).

The use of international databases has been preferred over qualitative analysis as it has proved to be helpful to build a base for comparison among other developing countries where the DEIFDC framework could be applied. Specifically, Kenya and Peru are also being researched and have reached lower and higher scores on Digital Education deployment respectively. However, we still encounter other limitations for future research like the availability of annual data to determine the evolution and the monitorisation of SDG 4 targets at a sufficient disaggregation level that will allow deep dive into a particular social (gender, castes, disabled) or geographic (rural/urban, coastal/mountain) group.

4. Results

The analysis and application of the DEIFDC came with relevant insights on the development of Digital Education in India: with an overall result of 0.596 is situated within the countries with Insufficient Digital Education deployment (Fig. 4). During the last decade, there has been a considerable effort from the Indian Government in terms of policies and programs to introduce Digital Education, but there is still room for improvement, especially in rural areas with low infrastructure development, reduced electricity availability, scarce internet connection and lower rates of retention and performance in school.

The application of the DEIFDC was diverse in terms of the different variables under the study and highly influenced by recent data available from the Digital Education programs put in place due to the pandemic crisis that have accelerated the use of digital resources in 2020.

In terms of Students' Readiness ($\boldsymbol{L}_1$), India has considerable room for improvement in literacy and mathematics proficiency. With a net enrolment in primary schools of 96.82%, India is almost reaching universal education; however, the persistence to the last grade of primary falls down to 91.66% and drops to as low as 73.79% for Secondary School Enrolment. To achieve the goal of universalisation and also to improve attendance and retention in Primary Education, the Indian Government has put in place several programs like the Mid-Day Meal Scheme (Ministry of Education, 2021b). The Scheme has been in place since 1995 in Government and Government aided schools for children between 6 and 14 years. Currently, it provides a free meal to 115.9 million children consisting of grain, legumes and protein, helping not only to increase nutritional levels among children but also to improve their attendance to school and retention to later grades.

The learning outcomes in literacy and mathematics are very poor, and only 44% of children in grade 5 achieve the minimum proficiency level. The available information has been gathered through the National Learning Assessment, so it will be necessary to wait until autumn 2022 to get comparable global figures from the international PISA evaluations. In this sense, the reforms put in place in the National Policy on Education approved in 2020 aim to achieve universal fundamental literacy and numeracy by 2025 (Ministry of Human Resource Development, 2020a, 2020b, 2020c).

This lever brings an important point related to Digital Education and the fact that the introduction of ICT in the education systems has to focus on improving the efficiency of the learning process (Sawaya et al., 2015) as well as the acquisition of complementary competencies like research, organization, problem-solving, collaboration, teamwork and project development (Olszewski et al., 2020). With the current deployment, international experiences are producing the following effects in the primary schools: increased levels of school attendance, decrease in dropout rates, students and teachers producing and sharing information, improvements in educational management and teachers' training, but they are still lagging in the improvement of reading, writing and math skills (Marcone, 2004). Therefore, further research will need to determine the current effects of Digital Education on future evaluations of essential competencies and how Digital Technologies are enhancing the effectiveness of learning (Qureshi et al., 2021).

Regarding pedagogical capabilities ($\boldsymbol{L}_2$), great importance has been given to teachers' preparation, and several formats of lifelong learning have been put in place to ensure they can cope with both Digital Technology and innovative methodologies in their classrooms. In this sense, specific teachers' training is available both in Diksha and Epathsala platforms, ensuring 73.13% of Primary School teachers have

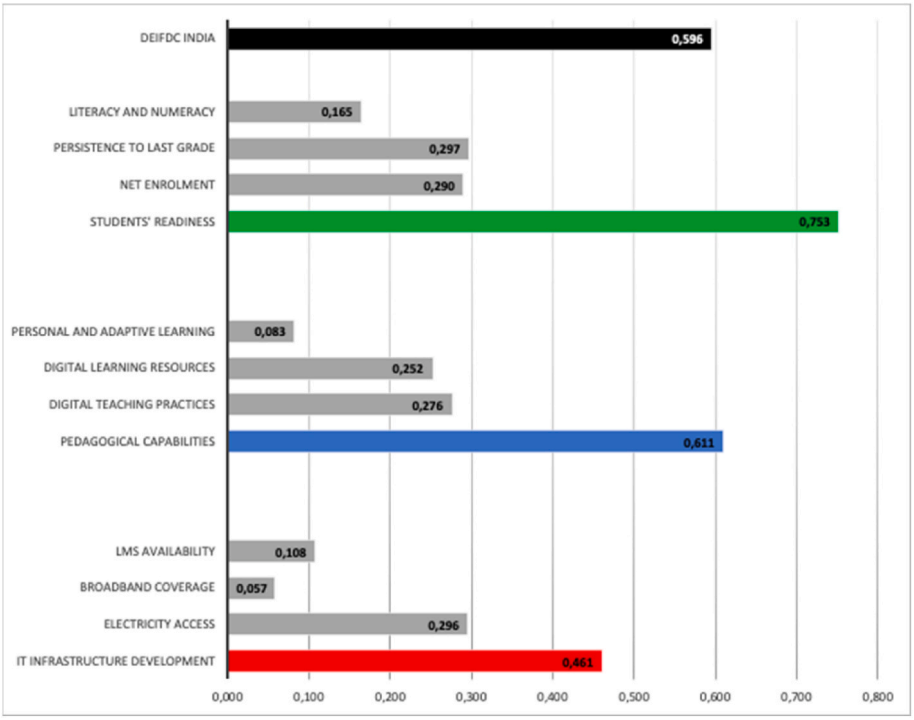

Fig. 4. DEIFDC Score result. Source: Author's elaboration with data from UIS Unesco Database, World Bank Data Development Indicators, Sheshagun Dashboard, National Learning Assessment and AISHE report. July 2020.

received the minimum organised pre-service or in-service training required for teaching according to the World Bank indicators. On the other hand, the multilingual platforms and applications run a vast number of resources available in the most common languages, mainly Hindi and English, and rely on the effort of local Institutions and teachers to produce, curate and share digital content in other official languages.

In terms of electronic devices penetration, the last data available from the Ministry of Education Dashboard shows that 30% of schools count on computers for pedagogical purposes. This low percentage, together with the low penetration of electronic devices among the Indian population, 24% of Indians own a smartphone, but only 11% of households possess any type of computer (desktop, laptops, notebooks or tablets), makes very relevant the need to improve in this variable so children can get exposure to digital devices (Kundu, 2020). This is also aligned with the National Digital Literacy Mission, which aims to empower at least one person per household with crucial digital literacy skills by 2020 (National Institute of Electronics and Information Technology, 2020).

According to the recent Pearson's Global Learner Survey (Choksi et al., 2020), 78 per cent of Indian learners believe that the use of technology supports their learning and makes it easier and more fun for them, highlighting the importance that ICT has in the Indian Education System. However, it has not been possible yet to provide proper digital infrastructure to each and every individual of the country (Gogoi et al., 2021), thus the inequality that arises with the DEIFDC application.

The development of School Infrastructure (L_3) is poor mainly due to the great digital divide between rural and urban environments along the country (Chacko, 2020). The Indian Government has been rolling out several programs to provide both power points and internet access to schools together with other initiatives to upgrade schools' infrastructure with toilets (95%) and drinking water (89.97%). The Bharat Broadband Network (BBNL) is expected to bring fibre to 250,000 Gram Panchayats covering more than 600,000 villages (Ministry of Electronics and Information Technology, 2021) and thus to provide an internet connection to rural schools; nevertheless, the rollout has been delayed, and it is currently on their second phase of deployment. Even though electricity reaches 74% of Indian Primary schools, only 19% of schools count with Internet Access. This is why Diksha, one of the major LMS initiatives of the Ministry of Education, is capable of working both with and without an internet connection, and great importance has been given to digitally enhanced textbooks, so blended learning is available (Ministry of Human Resource Development, 2020b,c). Even though there is no data available on the deployment of the Operation Digital Board program, during 2020, 72% of teachers were using the Digital Education platforms that the Government has made available (World Bank, 2020c) and were able to maintain the learning process during the school closure originated in the lockdown which demonstrates a high value in terms of platforms' penetration.

5. Conclusion, limitations and future research

During 2020 a significant increase in the usage of digital resources and learning platforms was observed due to the Covid-19 school closure as a response from Governments not to interrupt learning with the use of distance education. However, Digital Education must develop to become a tool to strengthen education systems by providing knowledge dissemination, quality and effective learning and development of competencies to achieve universal literacy to live and work in a technology-driven world.

Through RQ1, we analysed the different variables that affect the implementation of Digital Education deployment and defined a framework to measure and compare among developing countries. As a result, the proposed Digital Education Index for Developing Countries (DEIFDC) is a geometric mean of nine different variables (school net enrolment, persistence to last grade, literacy and numeracy skills, digitally teaching practices, digital learning resources, personal and adaptive learning, electricity access, broadband coverage and LMS availability) that have been grouped into three levers (students' readiness, pedagogical capabilities and IT infrastructure development) and assigned a different weight based on the perceived importance to assess Digital Education deployment.

The specific application to India was analysed through RQ2; based on desk research, we studied the Indian context from a social and educational perspective focusing on the digital education programs that have been developed. The results show Insufficient Deployment of Digital Education due to poor school infrastructure, lack of pedagogical capabilities and main challenges on students' readiness. The results show there is still great room for improvement to ensure that all variables affecting the DEIFDC are planned and developed in the correct coordinated manner and that the future of Indian children is not jeopardised. Moreover, even with impressive results in terms of digital penetration and GDP digital quota, significant efforts need to be undertaken to ensure Indian society is fully able to cope with the demands of digitalisation in all sectors that will bring the advancements lifted by the economy.

Proposed further research to deep dive into the Indian Digital Education system evolution and its future impact will need to explore both the evolution of DEIFDC at different periods of time, its possible application in higher education (secondary, technical and university) and different social and geographical disaggregation levels, the evolution of the digital workforce competencies and Digital GDP growth, as well as the comparison with other countries of similar economic development, given we overcome limitations encountered like the availability of annual data to monitor the proposed variables at a sufficient disaggregation level.

CRediT authorship contribution statement

Ana Victoria Delgado Martín: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft. **José María Larrú Ramos:** Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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