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DIGITAL EDUCATION DEPLOYMENT IN DEVELOPING COUNTRIES IN THE CONTEXT OF A NEW DIGITAL ECONOMY BASED SOCIETY

By

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Dissertation

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"Caritas et Scientia."
Saint Augustine

Abstract

Education is one of the most potent instruments for development as it contributes to reducing poverty and improving health, equality and peace. The introduction of new technologies in the teaching and learning processes boosts the acquisition of necessary 21st-century competencies required in a new Digital Economy. The deployment of Digital Education is especially relevant in developing countries as an equalizer factor for students at the early stages of schooling that can benefit from quality instruction, personalized tutoring, stem classroom experiences, gamification, advanced collaboration and improved assessments. The school closure originated during the Covid-19 pandemic lockout, caused a significant disruption in the education of 1.6 billion children worldwide and has destroyed 20 years of education gains as measured by the evolution of the Agenda 2030 SDG 4 metrics. However, on the other hand, the interruption of face-to-face teaching has accelerated the training of teachers on digital technologies and the adoption of improved learning experiences based on ICT. Despite significant advancements in measuring the evolution of digital economy and lifelong learning opportunities, there is a lack of knowledge on the actual deployment of Digital Education in developing countries; thus, this project has aimed to close this knowledge gap by researching the main factors affecting Digital Education implementation. Through a hybrid qualitative and quantitative methodology, a Digital Education Index for Developing Countries (DEIFDC) has been defined as a geometric mean of nine different variables (school net enrolment, persistence to the 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 by educational experts worldwide to assess Digital Education deployment in a developing country. After a detailed study in three different geographies, the application of the Digital Education Index for Developing Countries has shown unsatisfactory results in Kenya (0.576), India (0.596) and Peru (0.709) due to poor school infrastructure, limited teachers' capabilities and uncertain student skills. Therefore, significant reforms will need to be undertaken to ensure that children from developing countries can actively participate in a new digital society independently of their place of birth.

Keywords: digital education, developing countries, digital divide, education gap, digital economy, compound index.

Resumen

La educación es uno de los instrumentos más potentes para el desarrollo ya que contribuye a reducir la pobreza y mejorar la salud general de la población, la igualdad y la paz. La introducción de las nuevas tecnologías en los procesos de enseñanza y aprendizaje impulsa la adquisición de las competencias necesarias del siglo XXI demandadas en las nuevas profesiones de una nueva Economía Digital. El despliegue de la Educación Digital es especialmente relevante en los países en vías de desarrollo como un factor ecualizador para los estudiantes en las primeras etapas de la escolarización ya que pueden beneficiarse de una instrucción de calidad, un seguimiento personalizado, experiencias en el aula enriquecedoras, procesos de *gamificación*, colaboración avanzada entre pares y evaluaciones avanzadas. El cierre de las escuelas debido a las restricciones de confinamiento impuestas durante el desarrollo de la pandemia de Covid-19, causó una gran interrupción en los sistemas educativos de todo el mundo y afectó a la escolarización de 1.600 millones de niños desmantelando 20 años de progresos educativos, de acuerdo al seguimiento realizado por el Objetivo de Desarrollo Sostenible 4 definido por la Agenda 2030. Sin embargo, al mismo tiempo, la interrupción de las clases presenciales ha acelerado la formación de los docentes en tecnologías digitales y la adopción de mejores experiencias de aprendizaje basadas en las TIC. A pesar de los importantes avances en la medición de la evolución de la economía digital y las oportunidades de aprendizaje, existe una falta de conocimiento sobre el despliegue real de la Educación Digital en los países en vías de desarrollo, por lo que este proyecto tiene como objetivo cerrar esta brecha de conocimiento mediante la investigación de los principales factores que afectan su implementación. A

través de una metodología híbrida cualitativa y cuantitativa, se ha definido un Índice de Educación Digital para Países en Vías de Desarrollo (DEIFDC, por sus siglas en inglés) como una media geométrica de nueve variables diferentes (tasa neta de matrícula, persistencia hasta el último grado de primaria, habilidades de lectoescritura y matemática, prácticas de enseñanza digital, disponibilidad de recursos digitales, aprendizaje personal y adaptativo, acceso a la electricidad, cobertura de banda ancha y disponibilidad de sistemas de aprendizaje) que se han agrupado en tres palancas (preparación de los estudiantes, capacidades pedagógicas y desarrollo de infraestructura tecnológica) y se les ha asignado un peso diferente en función de la importancia percibida por expertos educativos para evaluar el despliegue de la educación digital de un país en vías de desarrollo. Después de un estudio detallado en tres geografías diferentes, la aplicación del índice ha mostrado resultados insatisfactorios en Kenia (0,576), India (0,596) y Perú (0,709) debido fundamentalmente a una infraestructura deficiente en las escuelas, destrezas limitadas de los docentes e insuficientes capacidades de los estudiantes. Es primordial por tanto garantizar el despliegue de educación digital en estos países para que niños de entornos vulnerables puedan participar activamente en una nueva sociedad digital independientemente de su lugar de nacimiento.

Palabras clave: educación digital, países en vías de desarrollo, brecha educativa, brecha digital, economía digital, índice compuesto.

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List of Acronyms

AISHE	All India Survey on Higher Education
BBNL	Bharat Broadband Network
BRICS	Brazil, Russia, India, China and South Africa
CBSE	Central Board of Secondary Education
COVID	Coronavirus Disease 2019
DEIFDC	Digital Education Index for Developing Countries
DESI	Digital Economy and Society Index
DIKSHA	Digital Infrastructure for Knowledge Sharing
DTH	Direct to Home
EDTECH	Education Technology
EGMA	Early Grade Mathematics Assessment
EU	European Union
GSAT	Geosynchronous Satellites
GDP	Gross Domestic Product
HDI	Human Development Index
I-DESI	International Digital Economy and Society Index
ICT	Information and Communications Technology
IOS	iPhone Operating System
ISTE	International Society for Technology in Education
IOT	Internet of Things
IWB	Internet Whiteboard

IT	Information Technology
JKUAT	Jomo Kenyatta University of Agriculture and Technology
K-12	Range of years of publicly supported primary and secondary school
KICD	Kenyan Institute of Curriculum Development
KNBS	Kenya National Bureau of Statistics
KNEC	Kenya National Examinations Council
KENET	Kenya Education Network
LMS	Learning Management Systems
MIT	Massachusetts Institute of Technology
MOE	Ministry of Education
MOOC	Massive Open Online Courses
NASMLA	National System for Monitoring Learning Achievement
NCERT	National Council of Educational Research and Training
NEMIS	National Education Management Information System
NESSP	National Education Sector Strategic Plan
NGO	Non-Governmental Organisation
NOFBI	National Fibre Optic Backbone Infrastructure
PISA	Programme for International Student Assessment
SDG	Sustainable Development Goals
SEGDI	Secretaría de Gobierno Digital
STEAM	Science, Technology, Engineering, Arts and Mathematics
UIS	Unesco Institute for Statistics

UN	United Nations
UNHCR	United Nations High Commissioner for Refugees
UNDP	United Nations Development Program
VLE	Virtual Learning Environment
WASH	Water, Sanitation and Hygiene
3D Printing	Creation of three-dimensional objects with computer based design

List of Publications

Status of publications based on the thesis ongoing research and conclusions as of September 2022:

International peer-reviewed journals

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

Social Sciences & Humanities Open 6.1 (2022): 100281.

https://doi.org/10.1016/j.ssaho.2022.100281.

"Digital Education Index for Developing Countries framework: evaluation of the deployment of Digital Education in Kenya"

African Journal of Science, Technology, Innovation and Development (under revision)

"Digital Education Index for Developing Countries framework: evaluation of the deployment of Digital Education in Peru"

Journal of Research on Technology in Education (under revision)

Communications presented in Congresses

“Aplicación en Perú del índice de Educación Digital para países en vías de desarrollo”.

VI International Conference of Development Studies (Barcelona, 2022)

Chapter 1: Introduction

The Universal Declaration of Human rights proclaimed by the United Nations General Assembly in 1948 established on its article 26 the right to free compulsory elementary education for everyone and technical and professional education generally and equally accessible (United Nations, 1948). Additionally, education is a precondition for the exercise of other human rights as additional economic, social and cultural rights such as the right to work or receive an equal pay encompasses the requirement of a minimum level of literacy and so it is directly related to education (Nowak, 2001). Moreover, many studies suggest the importance of education as one of the most potent instruments for development as it contributes to reducing poverty and improving health, equality and peace (Alvarado, 2019).

Based on the Incheon declaration (Ainscow, 2016), the launch of the 2030 Agenda for Sustainable Development brought the deserved attention to education and the need to ensure inclusive and equitable quality education and promote lifelong learning opportunities (United Nations, 2015). Education is a fundamental building block for all 17 SDGs as all of them rely on education to draw the path for sustainable growth, building social cohesion and stability, and promoting human rights and equality through its ten differentiated targets (Thomson, 2017). The importance of Digital Education is collected in target 4.4 that measures the increase in the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship. More specifically, indicator 4.4.2 is measuring the percentage of youth and adults who have achieved a minimum level of proficiency in digital literacy skills (Law et al., 2018).

The World Economic Forum in the Future of Jobs report defined a series of technical and soft skills crucial in a 21st society where evolution of artificial intelligence, machine learning, Internet of Things (IoT), robotics, 3D printing, genetic engineering, nanotechnology, quantum computing and virtual reality entail that 65% of children entering primary school will ultimately end up working in jobs that do not even exist today (Leopold et al., 2016).

Several authors have researched over the past years to establish the skills required in the 21st century, for example, Wats (2009) defines that the hard skills (including academic skills, experience and level of expertise) only account for 15% of a student success while the soft skills such as communication, critical thinking, problem solving, creativity, collaboration, negotiation, self-development, time management, cultural awareness, positive attitude and empathy contribute on 85% (Schulz, 2008; Voogt, 2012; Van Laar, 2017). Moreover, the competencies of Digital Literacy such as the use of computers and digital equipment, the ability to use online applications, find and qualify online information and make use of it in daily life are essential today for primary school children entering the labour market in ten years' time (Oberländer, 2020).

Most education systems are still relying on old education models based on the industrial revolution (Rivas, 2022), and students do not find in the education they receive the necessary training to acquire the skills that will allow them to face a future full of uncertainty and constant change (Higgins, 2013; World Economic Forum, 2017). This is why one of the main concerns is how to adapt the education systems to cope with the needs required by the society and how introduce the changes at early stages of education so the benefits encountered can be greater at a later stage (Heckman, 2017). This is the reason

why Digital education becomes a building block to live, work and contribute in a new knowledge society characterized by its rapid technological advancement (Chu, 2017; Bravo, 2021).

This adaptation is especially relevant for developing countries as they try to keep up the pace of digital progress of more advanced economies affected by different ways of social interaction, random consumer behaviors, new business models and novel e-government processes. The digital adoption affects developing countries growth expectations as it is directly related to productivity, access to capital and economies of scale. However, the risk of widening the digital divide between developed and emerging countries and within developing countries between cities and rural areas and educated and non-educated is a remarkable problem. In many cases technical advancement depends on ICT infrastructure and the level of digital literacy that developing countries are still planning at public and private sectors alike (Dahlman et al., 2016; Lazović et al., 2014; Pangrazio & Sefton-Green, 2021).

2020 was a year of profound changes at a social, economical and educational levels (Blake & Wadhwa, 2020). The Covid-19 pandemic accelerated the use of digital tools in social and productive interfaces due to the restrictions imposed by the confinements around the world. In the case of education, school closures disabled traditional face-to-face interactions and education systems tried to maintain the learning processes for 1.6 billion children in 195 countries through the usage of online learning platforms, educational applications, broadcasted lessons on internet channels, radio or television, social media messaging and hanged out printed materials (Daniel, 2020; Kang, 2021). However, the poorest households had no access to ICT equipment: laptops, tablets or mobile phones

(Tadesse & Muluye, 2020), lacked a proper internet connection (Cahyadi et al., 2021) and did not count with the minimum level of literacy to be able to cope with the pedagogical changes (Inan et al., 2021).

Purpose of the study

Several frameworks have been employed to determine the levels of digital transformation at a country level like the European Digital Economy and Society Index (DESI), that summarizes markers on Europe's digital implementation and measures the evolution of European Union countries, and the International Digital Economy and Society Index (I-DESI) that measures the digital economy performance of the 28 European Member States and the European Union as a whole in comparison with 17 non-EU countries, using a similar methodology to the DESI index (Bánhidi et al., 2020; Stavytskyy et al., 2019).

Moreover, recent research has established country comparisons on digital education implementation observing lifelong learning opportunities (Beblavy et al., 2019) and addressing the digital divide in education (Peña-López, 2010). However, there is a knowledge gap in the state of current digital education deployment on developing countries, thus this research aims to answer the following questions:

RQ1. What are the main metrics that affect the implementation of a Digital Education program in a developing country?

RQ2. What is the state of readiness of Digital Education so students acquire sufficient 21st-century skills?

RQ3. What are the main differences found on Digital Education deployment depending on the geography?

In developing the index, composite indicators guidelines and other indexes were used to establish the procedure stages: theoretical framework, data selection, imputation of missing data, multivariate analysis, robustness and sensitivity, back to the real data, links to other variables and presentation and visualization (Joint Research Centre European Commission, 2008).

For the purpose of this study, the focus was set on developing countries of three different regions: Latin America, Africa and Asia. The countries selected were Peru, Kenya and India based on their education level in terms of performance as it has been demonstrated by different evaluations reports (Agasisti & Zoido, 2019), the rural vs. urban distribution and how it affects access to quality education in complex contexts (Khan et al., 2019), the social differences among ethnics' groups that drive learning processes in languages different from the students' mother tongues (Mbiti, 2016).

Additionally, the ultimate goal of this research was to build and present a tool that might be used in the future for policy makers, Ministries of Education and international agencies working in developing countries to identify major areas of improvement in the deployment of Digital Education.

Research model and procedure

The research approach was mixed, since it combined a descriptive study based on the application of semi-structured interviews, a questionnaire to establish a weight for the digital education variables selected, the definition of a compound index as well as the

introduction of available data from international resources to apply and define an overall score.

Phase	Methodology	Description
I	Theoretical and contextual frameworks	Overview of supporting literature: professional journals, expert think-pieces, case studies, interviews, systematic reviews, comparative studies and policy statements.
II	Qualitative study	Semi-structured interviews with recognized experts in Digital Education to define drivers and variables
III	Quantitative study	Detailed survey to educational experts world-wide, including senior public officials from international organizations, NGOs leaders working on developing countries and EdTech executives to support weighting of variables
IV	Index definition	Definition of the index as 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
V	Global application	Application and evaluation of the results obtained in three different geographies

Table 1: Research model and procedure.

Qualitative study

The qualitative study was designed to complement desk research information obtained through literature analysis, information from international organizations and educational congresses participations. The conversations provided valuable insights into the opportunities and challenges related to Digital Education across developing countries.

The interview design is based on the methodological approach of qualitative interviewing as a flexible and powerful tool to capture the voices and the ways people make meaning of their experiences (Guion et al., 2001; Klimova et al., 2021; Kvale, 2012; Rabionet, 2011).

The research was conducted between January and April of 2021 after most educational systems were recovering from the pandemic crisis and students were back to school. The respondents were chosen based on their expertise on Digital Education based on three different profiles: academia, international educational institutions, and NGOs active in developing countries.

The data was collected through online semi-structured interviews where the participants were invited to discuss their insights on the relevance of Digital Education deployment for developing countries. To solve the problems of availability and travel constraints, the online interview was the most appropriate technique as the time difference between the geographies disclosed a more flexible spectrum of possibilities for interviewing (e.g. weekends or evenings).

The interview consisted of the following stages:

1. Introduction

2. Clarification on the research context

3. Semi-structured questions and answers

4. Conclusions and suggestions

The interview was designed to create a natural environment for conversation, with the researcher encouraging more detailed responses. Moreover, to inspire their contribution, the participants of the study were asked the following open-ended questions:

A. What would be the main factors affecting Digital Education deployment? Is there any difference between developing countries and more developed economies?

B. What would be your top recommendations for governments at a national level in developing countries regarding Digital Education?

C. What level of relevance has Digital Education in each level of education? Primary vs. Secondary schools in developing countries?

D. How did you think the Covid-19 pandemic affected digital education deployment? Are the changes to stay?

E. What are the top solutions/app/platforms that you recommend for developing countries? Should they be based on basic literacy and numeracy or work on computational thinking, stem, mathematics, etc.?

F. What relevance will have Digital Education in the preparation with 21st century skills of a future work force in developing countries?

G. What are the key roles of different agents and institutions in the development of Digital Education in developing countries?

H. Is there any other aspect regarding Digital Education deployment in developing countries you would like to discuss?

All these questions were presented to the participants in a verbal format at the beginning of the interview: to facilitate the transcription of all the answers provided, each question was asked by the researcher and then there was sufficient time for the interviewee to express his opinion or relate the discussion to previous questions already responded. All

participants were free to express their opinion independently of the organization they were working for but determined to show the experience acquired before, during and after the pandemic crisis for research purposes.

The interviews were conducted in the language most convenient to the participant, mainly English and Spanish. They lasted between 60 and 90 minutes and were transcribed during the interview to facilitate the subsequent analysis. All participants agreed on their participation on an anonymous basis so no personal information about the interviewees was ever collected, therefore data is presented without any personal identification.

Given the variety of responses obtained, the results have been grouped into clusters to facilitate the analysis:

Cluster	**Topic**
I	Relevance of Digital Education in a new Digital Economy driven society
II	Main variables affecting deployment in developing countries
III	Covid-19 pandemic crisis as a turning point in digital education

Table 2: Clusters' selection on qualitative study.

In the first cluster, interviewees highlighted the importance of deploying Digital Education as a response to socioeconomical changes derived from the 4th industrial revolution:

"The main factor is not pedagogical; the Digital Education is a socio-political concern, and it is necessary to reach consciousness on the importance of Digital Education for the future of the society. Even for advanced economies, we cannot even assume it is already implemented as it is not reaching everyone. And if there is not consciousness at a

political level then the necessary investment to ensure adequate deployment is not reached".

"Digital education is a requirement to prepare the worker of the future, but it is not the only one. Digital education is relevant for students as learners, for example, as a communication and collaboration channel, it is relevant for the present, it has a huge potential today".

The interviewees also pointed out the need to achieve universal Digital Education and think of different models that can reach all:

"It is fundamental that advancements in educational technology reach the poorest of the poorest, independently of the issues of accessibility and affordability; in the current status quo we are translating the way teachers and students access digital education in the same manner as the students in developed countries consume educational resources, and this model for certain countries in Africa with poor and expensive internet connections does not work".

Additionally, there were specific concerns about the complexity of the implementation process at a country level that derive in the assignment of specific budgets needed to deploy Digital Education:

"For me, there is no question about if Digital Education is necessary, the main difficulty is to understand all the previous steps to reach the ultimate goal that is having schools using the best of technology in the teaching and learning processes. We need to train teachers and equip schools with devices and internet access and these steps are for all the countries. The difference comes on the number of resources available to make it happen."

They also pointed out the need for a common ground before starting any Digital Education deployment:

"First of all, the Governments needs to be clear on what Digital Education is and what they are trying to achieve with their implementation. It is necessary to have a reference framework to be able to link learning and teaching with technology. In Europe we have a more advanced or internalized approach because we part from existing frameworks. Once the framework has been defined, there is a common language to plan lines of work, progress, skills, dependencies, types of technology, etc. This is very important because depending on the reality of the country, it will be necessary to establish a roadmap to define investments. In countries with social inequality, having a framework allows differentiated roadmaps depending on the region so that not everyone advances at the same speed of implementation"

In the second cluster interviewees focused on the main variables affecting Digital Education deployment and shared a common vision on the role of teachers as enablers of successful rollouts:

"The main factors affecting Digital Education deployment are (1) digital infrastructure, to ensure children count with the adequate devices and connectivity - this variable really makes a difference in developing countries as it requires a huge investment – (2) teachers' capacity, in the sense of teachers pedagogical skills (not only IT skills), (3) digital resources, during the pandemic crisis some countries really had an issue getting digital resources (4) the integration of Digital Education on the existing curriculum".

"We must give the school a lot of autonomy, a Digital Education project is bottom up, we need to give the teachers recognition as they cannot be replaced"

Furthermore, they pointed out that children need to have a minimum level of literacy and numeracy to start using technology in the classroom:

"[…] you have to develop some skills prior to start using digital. In secondary school it is essential as you have to work by projects and digital helps out a lot. Digital Education is also an autonomy enhancer to develop different skills"

The interviewees also expressed their opinion with the regards to the type of software as an opportunity for using open-source resources:

"It is important that the software and resources are free and open source that are sustainable, easy to scale, with low level of demand for administrators and a simple learning curve. Education should not depend on market constraints"

"Education has to be universal so the State cannot commit to a payment but they can get products already existing with white labels. Governments have to focus to give it scale".

Furthermore, the interviewees emphasize the importance of all variables working together for a successful implementation:

"The most important thing is coordination, we work very isolated, we have to work as a team and not repeat efforts, to spend resources better. Teachers must be empowered a lot and Governments have to guarantee access and universality. All on the same side...."

In the third cluster interviewees critically analyzed the effect that the school closure originated during the Covid-19 pandemic as an enabler for the future of Digital Education:

"Covid displayed the existing divide, some countries were somehow prepared but most of them had to catch up, the differences between rural and urban development were also important, that's why they used combined strategies exploiting radio, television, youtube, whatsapp… the teachers all of a sudden became digital teachers and discovered innovative ways to approach their students with a mixed of online and mobile technologies"

Other important aspect they considered was the participation of different actors and the role they have to play as part of a Digital Education deployment:

"*The Covid-19 pandemic obliged the interoperability of various actors and moving forward they all need to participate to ensure successful implementations: Governments, by setting up the vision and the policies, Universities, to support teachers and continuous improvement, private sectors and NGOs, and parents and their communities so they can have an active role engaging with schools*"

Parents were identified as a key figure during the pandemic crisis although by now they have moved to the background:

"The role of parents also evolved and they became more important engaging students with digital content".

Additionally, the negative effects on the learning process and the divide between the effectiveness of different responses to the school closure were also pointed out:

"The big problem has been the break in the educational process, in many countries there has been no teaching for many months. Many countries have tried to deploy digital education resources but with the infrastructure, networks and human capital that each country had. From other point of view, it has meant the settlement of diverse educational

platforms but the platforms have become one-way mailboxes instead of being used as collaborative work tools."

Also, the pandemic originated a major disruption in the education process that accelerated much more than what had been possible in the last years:

"The pandemic was an accelerator of incorporation, but many things are going to be lost; for example, the involvement of families. The acceleration in the use of technologies moved 3 times faster."

Regarding the main variables affecting deployment after the Covid-19 crisis in development countries, different subjects like the training of teachers or the development after the pandemic arose: *"The training of teachers is fundamental but also additional aspects that have been arising lately like the availability of quality educational resources that can be used on safe environments."*

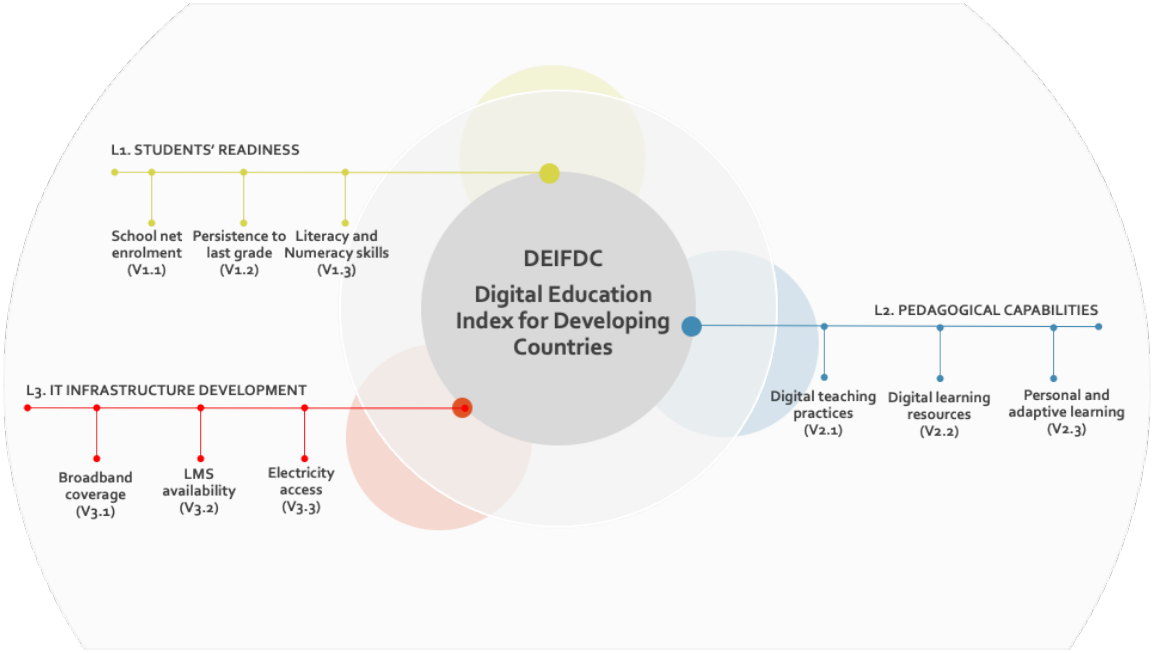
"After Covid-19, we will still have development, Digital Education will be used but collectively in the school,"

Quantitative study

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 qualitative study and 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).

Figure 1: DEIFDC Schema



Source: Author's elaboration.

As exposed in figure 1, after the first part of the research has concluded, the main levers chosen to assess Digital Education deployment in developing countries are: Students' Readiness ($\boldsymbol{L_1}$), Pedagogical Capabilities ($\boldsymbol{L_2}$) and IT Infrastructure Development ($\boldsymbol{L_3}$). 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

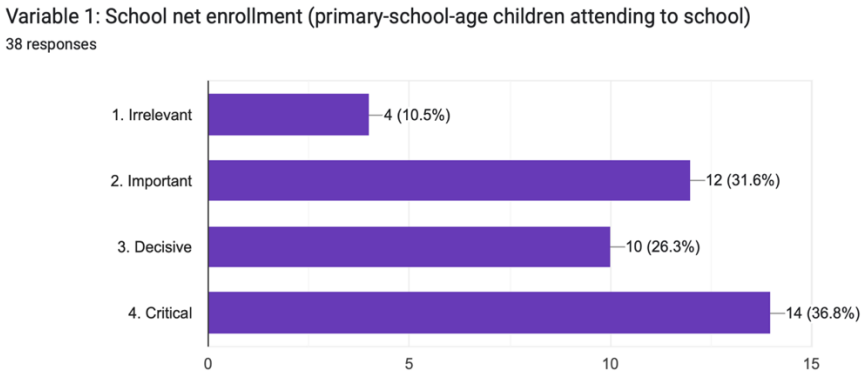
EdTech executives. The survey has served to gain their insight on the importance they assign to the variables on a 1-4 scale (see table 3):

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

Table 3: Variables' metric distribution.

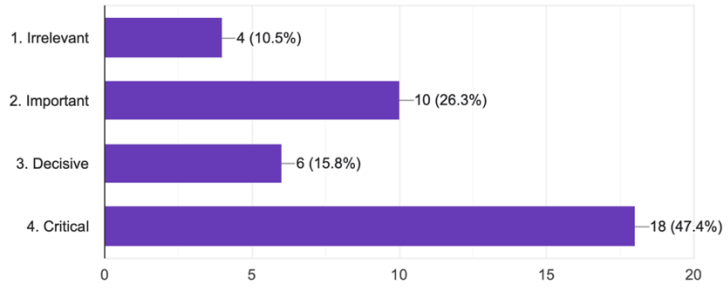
As suggested by the central limit theorem (Kwak et al., 2017) the objective was to count at least with thirty responses, however the responses received were thirty-eight; and divided according to the following distribution:

Figure 2: Detailed survey overview results (variables 1-9)



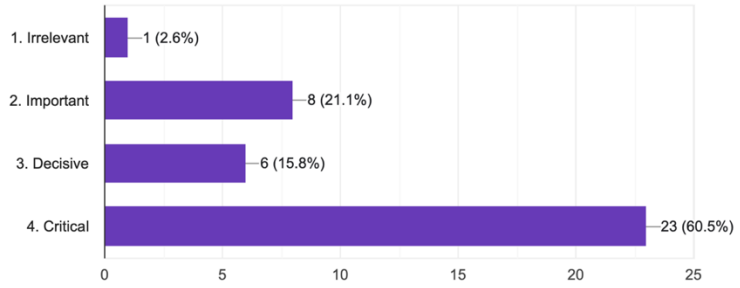
Variable 2: Persistence to last grade (persistence to last grade of primary)

38 responses



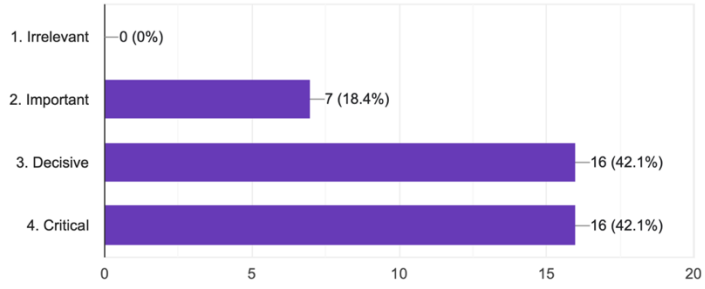
Variable 3: Literacy and numeracy skills (children achieving a minimum proficiency level in reading and mathematics)

38 responses



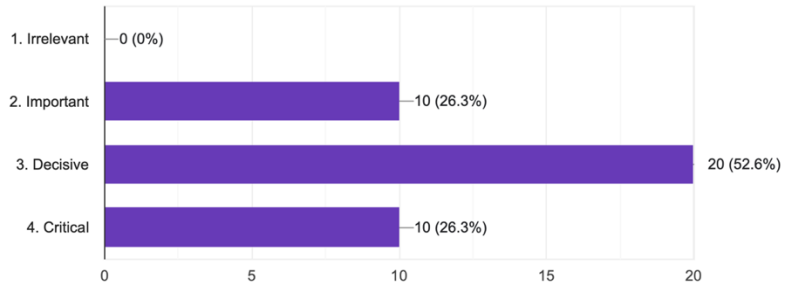
Variable 4: Digitally teaching practices (teachers who have received the minimum organised teacher training pre-service or in-service capable of introducing Digital Education in the classroom)

38 responses



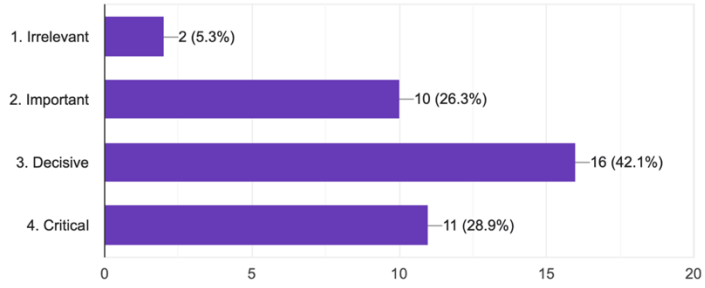
Variable 5: Digital learning resources (availability of digital learning resources for students in their mother tongue)

38 responses



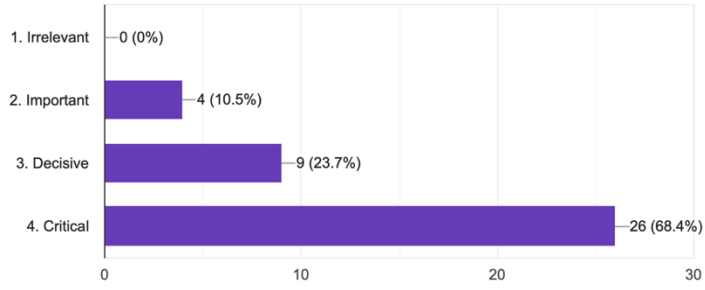
Variable 6: Personal and adaptive learning (students with access to electronic devices and personalized practice)

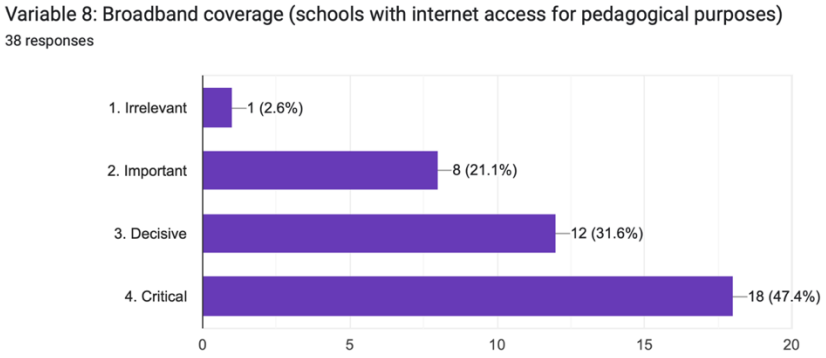
38 responses

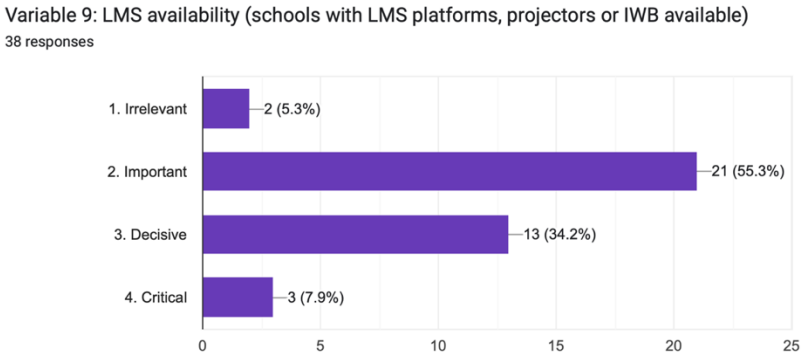


Variable 7: Electricity access (schools with electricity access)

38 responses







Source: Author's elaboration from results obtained through Google Forms.

To establish the variable weights, the following equations were established, where $\boldsymbol{GM}(\boldsymbol{V}_{\mathbf{i,j}})$ is the geometric mean of all the responses obtained and $\boldsymbol{W}_{\mathbf{i,j}}$ is the calculated weight for each variable:

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

Where n is the number of responses obtained and $A_{i,j}^{k}$ are the responses obtained for the variable $\boldsymbol{V}_{\mathbf{i,j}}$

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

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

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

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

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

Depending on the DEIFDC score, the developing countries understudy will be grouped according to one of the categories defined in table 4:

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 4: DEIFDC Score Distribution.

Table 5 summarises all levers and their assigned variables and weights:

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**	

Lever/ Variable	Name	Description	Weight
$V_{2.1}$	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%

Table 5: DEIFDC Weight variables Summary.

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

Students' readiness

The first lever (L_1) groups the variables that help us determine if students are ready to be digitally exposed, mainly:

One of the main challenges to apply Digital Education in developing countries is the fact that enrolment ($\boldsymbol{V_{1.1}}$ 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 ($\boldsymbol{V_{1.2}}$ 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 ($\boldsymbol{V_{1.3}}$ 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.

Pedagogical capabilities

The second lever (L_2) groups the variables that help us determine if Digital Education has been integrated into the learning process, mainly:

The variable with the most significant importance is the training of teachers ($\boldsymbol{V_{2.1}}$ 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, 2016).

The second variable in terms of importance is the availability of suitable content ($\boldsymbol{V_{2.2}}$ 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 (Reed, 2019), contexts without an Internet connection or specific devices different from laptops like tablets or mobile phones.

The penetration of electronic devices per student ($\boldsymbol{V_{2.3}}$ 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 et al., 2016), gaming and certification.

IT Infrastructure Deployment

The third lever (L_3) groups the variables that help us determine if the infrastructure deployed meets Digital Education demands. 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 ($\boldsymbol{V_{3.1}}$ 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 ($\boldsymbol{V_{3.2}}$ 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 ($\boldsymbol{V_{3.3}}$ 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, 2012).

The rest of the dissertation is structured as follows; the first chapter showed the qualitative and quantitative analysis carried out to determine the relevance of Digital Education in developing countries and the variables that drive a successful implementation; the second, third and fourth chapters review the Indian, Kenyan and Peruvian context 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, contributions, encountered limitations and lines of upcoming research.

Chapter 2: DEIFDC framework: Evaluation of digital education deployment in India in the midst of the Covid-19 pandemic

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.

Keywords: digital education, compound index, developing countries, digital economy

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, 2020). 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 (World Economic Forum, 2020; Internet Society, 2017).

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 (Oberländer 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 (Unicef, 2020; Ministry of Human Resource Development, 2020; Unesco, 2022).

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, 2020). Most Governments used Digital Education as a backup response to ensure learning continuity at all levels of education (Selim, 2020; Lennox et al., 2021; Unesco, 2021). However, the current digital divide (World Bank, 2020) 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 two-thirds of children aged 3 to 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, 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.

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; Bayne et al., 2021). 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, 2020).

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, 2014). 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, 2018). 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, 2016), 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, 2021).

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 1,400 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 of Home Affairs, 2020). 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 Database, 2019). At the same time, India ranks 131 in the Human Development Index with an HDI 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, 2020).

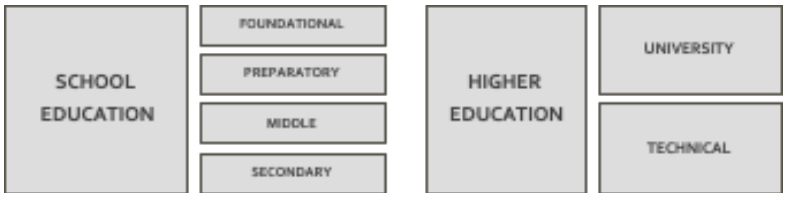
The Indian Government has established different measures "to build back better" while keeping on reducing inequality (World Bank, 2018). In this aspect, the impact of Digital Education will be analysed in a profound manner at early stages of schooling. As the conformation of a digital high productive 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, 2021). 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.

Figure 3: Indian Education System



Source: Author's elaboration with data from the National Policy on Education (Ministry of Human Resource Development, 2020)

Figure 4: Indian Education System, School Education

Source: Author's elaboration with data from the National Policy on Education (Ministry of Human Resource Development, 2020)

In July 2020, a new National Policy on Education was approved (Ministry of Human Resource Development, 2020) 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 (figures 3, 4), 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, 2105). 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 5^{th} with rates of 79.3% and 56.5% for 6^{th} and 8^{th} grade. The role of the teachers is also considered a critical factor in the transformation process, giving importance to 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 4,450 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, organisations 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 4,024 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, 2021). 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 3,886 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, 2021), reaching 1,163.41 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, 2020) 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 Electronics, 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, 2019). 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, 2020) 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).

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.

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, 2020).

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.

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 (figure 5). 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, 2021). 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, 2020).

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, organisation, 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, 2010). 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 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

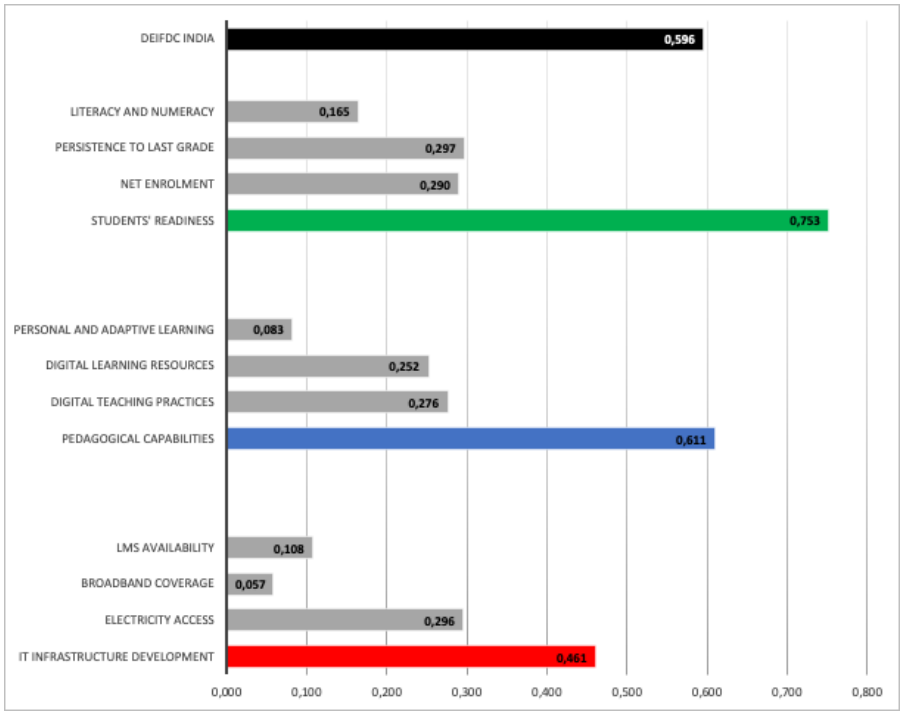
very relevant the need to improve in this variable so children can get exposure to digital devices (Kundu, 2020). This is also aligned with the National Digital Literacy Mission, which aims to empower at least one person per household with crucial digital literacy skills by 2020 (National Institute of 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 ($\boldsymbol{L_3}$) 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, 2020). 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, 2020) 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.

Figure 5: DEIFDC Score result for India



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.

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.

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Chapter 3: Digital Education Index for Developing Countries framework: evaluation of the deployment of Digital Education in Kenya

Abstract

Despite major efforts on introducing Digital Education in public schools since the launch of the DigiSchool program in 2016, the application of the Digital Education Index for Developing Countries (DEIFDC), with a value of 0.576, demonstrates insufficient deployment in all main levers largely due to poor broadband infrastructure, lack of trained teachers and poor literacy and numeracy performance of Kenyan students at early stages of education. With impressive results on mobile penetration and advancements in the banking industry, Kenya has become an ICT hub for all the African region, with inspiring results in the usage of digitalised services for public and private sectors alike. Although with significantly less research and investment, the experience acquired has also favoured the Education sector that has launched mobile applications and education platforms whose use has exploded during the Covid-19 pandemic and has facilitated the continuity of teaching and learning after the school closure in 2020. However, significant social, geographic, and cultural differences arise in the study and bring down the overall performance of Digital Education deployment. The Ministry of Education has promoted major reforms in the Education System like the new Competency-Based Curriculum; however, additional development is required to ensure school children acquire the necessary 21st-century skills and their future, independently of their birth condition, is not jeopardised.

Keywords: digital education, developing countries, digital economy, social impact

Introduction

Education is a human right (United Nations, 1948; Lee, 2013) 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, 2020). Based on the Incheon Declaration (Ainscow, 2016), adopted at the World Education Forum in 2015, the Agenda 2030 for Sustainable Development Resolution approved by the United Nations General Assembly included the specific development goal number 4 (Boeren, 2019) to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Digital Education appears in six out of the ten SDG4 targets (United Nations General Assembly, 2015), especially target 4.4, which is described as substantially increasing the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship.

Before the pandemic crisis, in low and middle-income countries, 258 million children were out of school, and 53% did not reach a minimum literacy and numeracy level (Rogers et al., 2020); moreover, in sub-Saharan Africa, the learning poverty rate was as high as 88% (Unesco, 2017). The school closure originated by the Covid-19 pandemic aggravated the global learning crisis, with 1.6 billion students losing access to their classrooms (Unesco, 2020), and it has been estimated that as many as 9.7 million children will never return to school (Wagner et al., 2020). National Governments worldwide have

tried to promote learning continuity through the usage of online platforms, radio and television; however, the deployment in developing countries was scarce and reliant on families' resources.

In Kenya, the Ministry of Education responded to the Covid-19 lockdown by promoting the usage of digital platforms and media resources (Uwezo, 2020) to be able to keep up with the lessons during the school closure, especially at higher stages of education (Ngari et al., 2020). However, only 25% of the 17 million Kenyan students could follow up with digital learning due to lack of electricity access (Ministry of Energy, 2019), availability of digital devices (Ndung'u, 2019), internet fares expenditure (Al-Samarrai et al., 2020) and lack of personalised content for rural contexts and slow learners (Mariara et al., 2020; Wepukhulu, 2019).

Kenya emerged as an African ICT hub on innovative technologies after the implementation of mobile transfers services in 2007, and new mobile products continuously emerge. Most bills from public and private institutions ranging from electricity, water, insurance, travel and tax contributions, are paid via mobile phone platforms (Githinji et al., 2014). Following its National Broadband Strategy, Kenya has made tremendous strides in promoting the uptake of ICT services in all industries by ensuring high-speed and reliable broadband networks, local content and regulatory frameworks. For example, mobile cellular subscriptions constantly increase and are above 114 per 100 users. Nevertheless, the digital divide must be addressed if all Kenyans are to participate actively in the knowledge economy. For example, in some parts of the country, people still have to walk more than 2 kilometres to access mobile cellular signals, especially from Turkana to Mandera. In addition, access to Internet services is still a mirage

in many parts of Kenya, as fibre optic cables only cover 17% of the land (Ministry of Information, Communications and Technology, 2018). Even with impressive results in terms of mobile penetration, significant efforts need to be undertaken to ensure Kenyan society is fully able to cope with the demands of digitalisation in all sectors that will bring the advancements lifted by the economy (World Bank, 2018).

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 and make use of it in their daily life (Internet Society, 2017). Additionally, Digital Education is preparing children for advanced STEM education, increasing the number of children who will later deploy a career in programming, data analysis, cybersecurity or cloud management. 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 (Dede, 2010) as its progress is decisive in the conformation of a future workforce.

More developed economies have defined digital education indexes to measure the ability of a country to upscale its workforce (Beblavý et al., 2019), focusing on the application of Digital Education on lifelong learning opportunities. At the same time, systematic research has been developed in order to provide trend analysis and country comparisons of their digital performance (Foley et al., 2018). However, there is a lack of information on the deployment of Digital Education at the early stages of schooling; hence the purpose of this research is to contribute to closing this knowledge gap by defining a

framework with related educational variables required in developing countries' schools to provide the necessary conditions that enable the acquisition of Digital Age skills.

Thus, the following research questions were formulated: *RQ1*. What are the main metrics that affect the implementation of a Digital Education program in a developing country? RQ2. What is the state of readiness of Digital Education in Kenya, so students acquire sufficient 21st-century skills?

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 the 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 provided by educational experts. In the application of the DEIFDC for the Kenyan case, an overall score of 0.576 situates Kenya in the countries with insufficient deployment, and therefore, significant reforms need to be undertaken to plan the introduction of Digital Education in schools properly.

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 Kenyan 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.

Theoretical framework

Digital Technologies have been progressively introduced in most Education Systems, even if traditional textbooks and chalk and board lessons were also used. Nowadays, and due to the workarounds originated due to the school closures during the Covid-19 pandemic (Arora et al., 2020), many education world leaders agree that technology is no longer a supplementary tool (Gianini, 2020) and that it should be fully integrated into all Education Systems. In 2021 most schools in developing countries were still closed due to restrictions imposed by the pandemic that started in 2020 (Selim, 2020; Lennox et al., 2021). As a result, 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 continuity (Unesco, 2020). Moreover, in vulnerable environments, the current digital divide (World Bank, 2020) has made evident that those with less technical resources have greater challenges to follow up with online lessons as more than two-thirds of children aged 3 to 17 years lack internet access at home (Unicef, 2020).

For the purpose of this research, we have reviewed the index construction based on the potential use of Digital Education tools to improve learning practice in low and middle income countries (Trucano, 2017).

On the one hand, individual learning tools are principally based on the usage of educational resources on computers, tablets or mobile phones to speed up the learning

process by giving each student access to different content available on the internet or previously downloaded and made available offline. This way of working is singular for three reasons:

1) Knowledge boundaries: Digital Education extends the boundaries of knowledge of the traditional textbooks, especially if the children can connect to the internet and explore further than what is written in the books just with a device. This process can be thought to be similar to having access to an infinite library where thousands of books are available, and children are capable of conducting their own research (Mitra, 2014).

2) Adaptive learning: Digital Education enables learning personalisation and the ability of the educational resources to adapt to the current capacities, abilities, achievements and misconceptions depending on the student's level (Luckin et al., 2016).

3) Evaluation and assessment: Digital Education facilitates evaluation and assessment as different types of tests and questionnaires can be applied to verify students' levels at different stages of the learning process. At the same time, it simplifies the individual certification or warranty of proficiency in particular subjects or matters than can be used to access higher education or specialised jobs (Beblavý et al., 2019).

On the other hand, collective learning digital tools bring a new way of working with soft skills that allow teachers to introduce complementary forms of interaction among students. It changes the way of interaction in a classroom from a teacher-centred approach to a student-centred approach (Ruhl, 2018). 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, 2016). Among others, they enable:

1) Teamwork and collaboration: The students can be grouped in smaller clusters to develop different subjects, research together or complete tasks that involve thinking out of the ordinary (Scheuer et al., 2010).

2) Peer evaluation: The software deployed on tablets or computers allows the students to assess the work of their peers and help them create a cooperative environment where everyone learns from both producing and reviewing the work of others (Gueldenzoph et al., 2002).

3) Gamification: It helps to motivate the students with the creation of avatars and game-related content that can be used to study a specific matter deeply. The children will get higher scores depending on how they dominate the subjects and how they perform compared to others (Freitas, 2011).

Digital Education is critical as it prepares children to acquire the digital competencies indispensable in a 21st-century workforce, like digital literacy and computational thinking (World Economic Forum, 2020). 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 (Unesco, 2015): learn to know, learn to do, learn to live and learn to be. On the other hand, the ISTE framework proposes the following standards 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, maths, 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.

It has also been considered that providing the required basics to schools in terms of technological resources like electricity, internet connectivity, and learning digital resources is insufficient. Therefore, it is even more relevant that educators (Béteille et al., 2018) are prepared to teach and learn based on new innovative methodologies (Light, 2016) and able to translate this knowledge to students.

International experiences show that Digital Education is related to increased levels of school attendance, decrease in dropout rates, creation of content, improvements in educational management and teachers' training (Marcone, 2010). However, in Kenya recent research has shown that providing internet access in schools served to increase students' participation in digital education programmes but did not help on improving basic

metrics like school attendance (Okyere, 2020). The current effects of Digital Education will be part of future evaluations of basic competencies and how Digital Technologies are enhancing the effectiveness of learning (Qureshi et al., 2021).

As crucial as Digital Education has been revealed during the pandemic crisis (Monirujjaman et al., 2021). Empirical findings (Riviello, 2020; Olszewski et al., 2020) demonstrate it should not be considered as a backup instrument to respond 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).

Globally, it has been demonstrated that there is a 9% increase in hourly earnings for one extra year of schooling (Psacharopoulos et al., 2018), but universal education should be accompanied by universal digital literacy. Moreover, in developing countries, Digital Education is even more relevant because it can not only improve the teaching and learning processes but also introduce the approach necessary for producing a technologically proficient workforce (Kalolo, 2018) that might change in the next 10-15 years the composition of the labour market (Kask, 2021).

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).

The recent pandemic crisis had shown that only those with jobs adapted to the

current digital economy could introduce massively home working. Furthermore, lower-income economies had a lower share of jobs that could be done at home (Dingel et al., 2020). Likewise, 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.

Research context

The Republic of Kenya is one of the most developed East African countries bordering Ethiopia, Somalia, South Sudan, Tanzania, Uganda and the Indian Ocean. Kenya is the 48th largest country in the world and the 27th most inhabited country, with a population of 53.77 million people (United Nations, 2020). Most of the population lives in rural areas; 27.8 % of the urban population is mainly distributed between the capital city of Nairobi, the coastal city of Mombasa and Kisumu City, the inland port of Lake Victoria and around 56% of this urban population live in informal settlements or slums. In addition, 43% of the Kenyan population are children, and one in four children under the age of 5 are stunted, with the highest rates of stunting in rural and remote areas (Masibo et al., 2012).

Kenya is divided into 47 counties that establish an administrative division for management and election (Ministry of Devolution and Planning, 2016); however, the diverse ethnic groups (Kikuyu, Luhya, Kalenjin, Luo, Kamba, Somalis, Kisii, Mijikenda, Meru, Maasai and Turkana among others) extend their influence independently of the

administrative borders. Although English and Kiswahili are the official languages, the ethnic groups use their mother tongue within their communities while they tend to be multilingual, mainly in the major cities. In addition, skirmishes often occur among diverse ethnic groups due to land assignation for agriculture and farming, political conflicts and availability of natural resources (Veit, 2019).

After gaining independence from the British empire in 1963, Kenya has undergone significant reforms, especially during the establishment of the new 2010 constitution that marked the beginning of modern democracy. The long-term Vision 2030 (Ministry of Planning and National Development, 2007) aims to develop the major areas of concern: economic improvement, universal healthcare, affordable housing and food security (World Bank, 2021). Climate change (Kenya Food Security Steering Group, 2012) is also a key concern due to Kenya's varied landscape of plateaus and high mountains that create great contrasts in humidity and temperature, affecting the primary sector production and the nutrition stability of a high percentage of the population (Mohajan, 2014).

Kenya is one of the countries with the highest number of refugees and asylum seekers due to the conflicts of neighbouring Somalia, South Sudan and Democratic Republic of Congo. The two major camps are in Dadaab and Kakuma, although there is also a minority residing in urban areas (Hyndman et al., 1998).

Kenya's GDP has steadily grown at 5.4 per cent over the last years based on agriculture, fishing, mining, manufacturing, energy, tourism and services (International Monetary Fund, 2018). GDP growth contributed to reducing extreme poverty from 46.8 per cent in 2003 to 36.5 per cent in 2016. Still, Kenya ranks 143 in the Human Development

Index with an HDI of 0.601 (United Nations Development Program, 2020), which places the country in the medium human development category. In addition, 38.7 per cent of the population are multidimensionally poor, while an additional 34.9 per cent are classified as vulnerable to multidimensional poverty. Moreover, the effects on the economy of the Covid-19 pandemic (contraction of domestic demand, exports decline, and tourism dropping out) have widened the goal of eradicating extreme poverty by 2030 (International Bank for Reconstruction and Development, 2020).

Kenya has the potential of becoming an example for the rest of the African countries in terms of social development, sustainable economic growth and improved services infrastructure. In this scenery, counting on a youthful skilled workforce is indispensable to lead the necessary change (World Bank, 2021); and it is within this context that the importance of digital education at the early stages of schooling has been analysed.

Education in colonial times was reserved for a small, privileged group which gave access to only 31% of Africans to secondary school (Eshiwani, 1993). However, since gaining independence, the Kenyan government has appointed several education commissions to introduce access to basic education, eliminate social and gender inequalities, provide further opportunities for post-secondary education and update curriculum content (Lelei et al., 2012).

Under the Kenyan Constitution, articles 43(f) and 53(1) provide the right to free and compulsory education managed through the national and county governments. At the national level, four central state departments (Early Learning and Basic Education, Vocational Education, University and Skills Development) develop standards, policies,

curriculum guidelines, examinations and access to universities, whereas the county governments oversee pre-primary schools, vocational training and home craft centres (Ministry of Education, 2019).

Before the Covid-19 pandemic broke out, there were 496,801 teachers in Kenya (Ministry of Education, 2019), 92,359 teachers in pre-primary learning centres, 287,532 teachers in primary schools and 116,910 teachers in secondary schools, with public schools accounting for 90% of the teachers. On enrolment, there were 2.7 million learners in pre-primary centres, 10.1 million pupils in primary schools and 3.26 million in secondary education. One of the main achievements in public schools has been the reduction in the students per teacher ratios, with 39 pupils per teacher in primary schools and 29 in secondary schools (Koc et al., 2015).

The student per textbook ratio in primary schools has also improved to reach 0.96 books per student due to the centralised procurement and distribution of Mathematics, English and Kiswahili books by the central government (Ministry of Education, 2019).

Current education reforms are based on the 2018-2022 National Education Sector Strategic Plan (NESSP), which establishes an all-inclusive plan to enhance access and equity, provide quality and competency-based education, strengthen management, governance and accountability and improve relevance and capacities for science, technology and innovation (Ministry of Education, 2018).

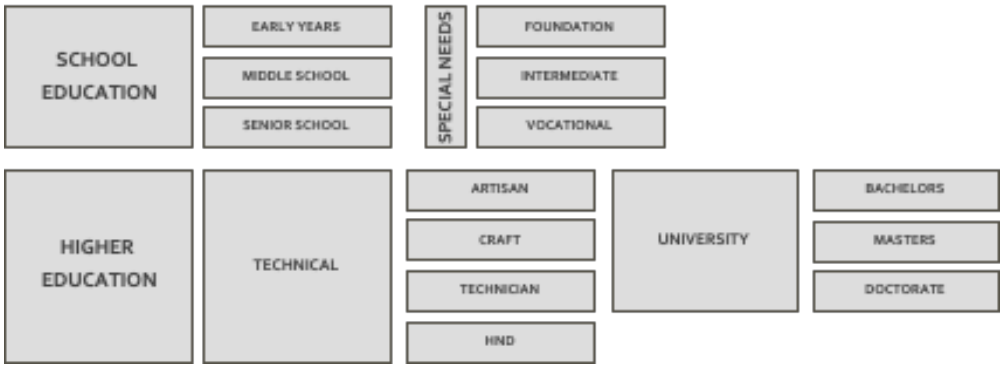
Figure 6 summarises the renovated Kenyan Education System routes to create a high-quality, competent workforce for sustainable economic, social and environmental development (Technical and Vocational Education and Training Authority, 2018). The

Ministry of Education, Science and Technology tries to guarantee a strong link between skills learnt and the needs of the labour market by producing graduates with superior employability through education provided in National Polytechnics, Technical Training Institutes, Vocational Training Centres and Technical Trainer Colleges.

As we can see in figure 7, at a school level, the old 8-4-4 summative examination-oriented system has been replaced by a 2-3-6-3 competency-based system where the emphasis is on communication and collaboration, critical thinking and problem solving, creativity and citizenship through the adoption of new methodologies that change the teachers and learners' mindset: learning to learn, self-efficacy and digital literacy (Kenya Institute of Curriculum Development, 2017). This new formative assessment has continuous feedback measurement, hands-on experience, and interactive learning to prepare children with relevant competencies to prosper in a rapidly changing world.

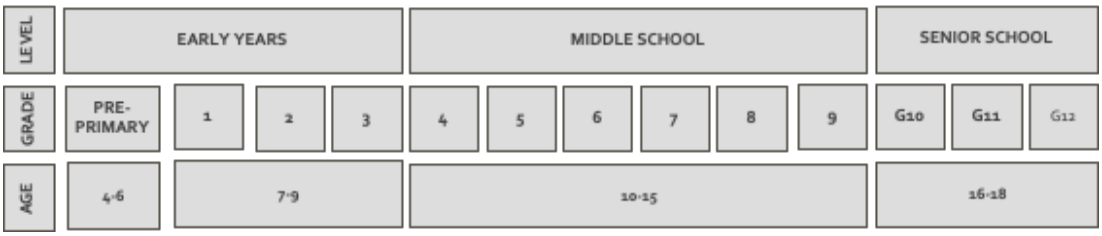
As of the end of 2019, all pre-primary and primary schools had migrated to the new Competency-Based Curriculum, although the Covid-19 pandemic closure has slowed down the implementation and evaluation process of the new program.

Figure 6: Kenyan Education System



Source: Author's elaboration with data from the National Education Sector Strategic Plan (Ministry of Education, 2018)

Figure 7: Kenyan School Education



Source: Author's elaboration with data from the National Education Sector Strategic Plan (Ministry of Education, 2018)

As part of their Vision 2030 program, the Kenyan Government launched the Digital Literacy Program in 2013, intending to enable teachers and students in public primary schools to incorporate digital technology into the learning process (Ministry of Information, Communications and Technology, 2021). The program publicly known as DigiSchool has been developed based on three priorities:

1. Infrastructure and technology: It ensures the schools are provided with all necessary facilities to introduce Digital Education within the classrooms, mainly a stable power connection (solar power or the national grid), internet connectivity, storage and servers, devices for teachers and students and digital content. An initial assessment ensures the classrooms are e-ready with adequate free of dust desks, secured storage cabinets and charging points. The DigiSchool components (teacher laptop, student tablet, projector, content servers and router) have been assembled locally in a consortium created by the Jomo Kenyatta University of Agriculture and Technology (JKUAT) and the Ministry of Industrialization and Enterprise Development (MoI&ED) (Ministry of Information, Communications and Technology, 2021).

2. Teacher capacity: A specific training program has been rolled out to ensure at least three teachers per primary school have the necessary digital skills to enhance the students' learning process. As of November 2021, 80,980 teachers have completed the training module (Teachers Service Commission, 2021)

3. Digital Content: The Kenya Institute of Curriculum Development (KICD) has been in charge of developing a content creation framework to ensure it can be consumed independently of the platform. The Digital Learning Program devices are preloaded with Kiswahili, English, Mathematics, Science and Social Sciences resources available in text, audio and video formats. In addition, the Kenya Education Cloud portal contains Open Educational Resources for all grades of Primary and Secondary Education as well as online materials for teacher training on ICT integration, competency-based curriculum and health and financial literacy content. These resources are also preloaded in the teachers' laptops

deployed in public schools and are available without the need for an internet connection (Kenya Institute of Curriculum Development, 2018).

There are also several private and NGO digital education programs that have been operating at a country or regional level in public and private schools (Atambo, 2020), providing an experimentation ground to introduce the mobile innovations already succeeding in the banking industry:

- M-shule: A knowledge-building platform that relies on SMS to reach the 80% of the Kenyan population that does not have smartphones or access to the internet. The students get personalised training and micro-courses in a self-paced, interactive and personalised manner using artificial intelligence to evaluate performance and assess progress through quizzes and tests (Ojino et al., 2018).

- e-Limu: With 500,000 users in 2019, e-Limu is one of the most awarded online platforms in Africa and is widely used in East Africa. It offers digital education resources in a gamified manner to improve learning outcomes and out of school support. In addition, the content is adapted to the local context with videos, images, animations and local stories to improve reading and writing in for early years (Masago et al., 2020).

- Kytabu: It deploys a mobile-based information management system for learning institutions and a mobile-first learning management system with digital content for students specially created for the African context. It is based on the fact that 87% per cent of schools administrators and 68% per cent of students have access to a smartphone on a daily basis, whereas the access to desktop or laptop computers is limited to 30% and 6%, respectively. The Kytabu digital ecosystem includes several applications like Super School for school management purposes, Kibanda for teachers' training and Somanasi with learning content

for students in textbooks, audiobooks, assessments and courses for rent on an hourly, daily or weekly basis (Wepukhulu, 2019).

- iMlango: It is a public and private collaboration programme that provides high-speed satellite broadband connectivity to schools, maths and literacy digital content, ICT training for teachers and electronic attendance monitoring with conditional payments to ensure families send their daughters to school. It aims to improve maths and literacy skills by integrating technology into the learning processes at the same time as they help children that do not regularly attend school due to environmental, economic and social issues. iMlango is currently working with 180,000 students (including 70,000 marginalised girls) in 240 schools in the counties of Kajiado, Kilifi, Makueni and Uasin Gishu (Ndiku et al., 2016).

- Ubongo: It delivers African educational entertainment through radio, tv and multimedia platforms. It provides children with an amusing and interactive way to understand maths, science and literacy principles and also promotes team and collaboration skills and citizenship behaviours through original stories and songs. In addition, children can interact with the characters through short assessments on their mobile phones. It is available in English and Kiswahili, reaching around 6 million households every week (Watson et al., 2021).

Data Analysis

The existing data suitable for constructing the DEIFDC was obtained from reputable available national and international sources through desk research. Data sources include global databases like the Unesco UIS Database and the World Development

Indicators from the World Bank, as well as local Kenyan sources provided by the Ministry of Education on their biannual basic education statistical booklets based on the information collected through the National Education Management Information System (NEMIS) platform. The Kenya National Examinations Council (KNEC) provides monitoring data on examinations and national assessments like the Early Grade Mathematics Assessment (EGMA) and the National System for Monitoring Learning Achievement (NASMLA). Additionally, the Ministry of Energy and the Ministry of ICT, Innovation and Youth Affairs provide data on electrification and internet access in schools, respectively. The Kenya National Bureau of Statistics (KNBS) was also helpful to measure general education statistics information.

The use of international databases will be useful to build a base for comparison among other developing countries where the DEIFDC will be applied. However, we still encounter other limitations like the availability of annual data to determine future evolution and the monitorisation of SDG 4 targets at a sufficient disaggregation level that will allow deep dive into a particular social (gender, ethnic groups, special needs) or geographic (rural, urban, coastal, savannah) groups.

Results

The analysis and application of the DEIFDC came with relevant insights on the development of Digital Education in Kenya. Despite the efforts during the last five years, with an overall result of 0.576, Kenya is situated among the countries with Insufficient Digital Education deployment. The Kenyan Government introduced DigiSchool as part of

their Vision 2030 program to promote Digital Education in primary education. However, the Covid-19 pandemic, on the one hand, slowed down the deployment of devices in schools and the training of teachers to lead transformation. On the other hand, it boosted the availability of locally produced educational resources on digital platforms, mobile applications and radio and television broadcasts.

As we can see in figure 8, in terms of Students' Readiness, Kenya has considerable room for improvement, especially in literacy and numeracy skills. The net enrolment recorded in primary schools fluctuates around 79,96% and has been negatively affected by the Covid-19 pandemic. The Ministry of Education measures the percentage of students previously enrolled who return to school once the education system is fully operational. The persistence to the final grade is 93%, greatly supported by different Government programs like the School Meals Program, benefiting 2.5 million students (Langinger, 2011) and the Sanitary Towels Program reaching 3.7 million girls, which focuses on reducing absenteeism and dropout of girls between grades 6 and 8 (Austrian et al., 2021). However, the learning outcomes are inferior, and only 53.1% and 42.1% achieve the minimum proficiency level for literacy and numeracy, respectively. This information is gathered periodically by the Kenya National Examinations Council through the National Assessment System for Monitoring Learner Achievement (NASMLA), whose objective is to assess learners' acquisition of the knowledge, skills and attitudes stipulated in the national curriculum and provide insights into the factors that impact upon learner achievement intending to allow for appropriate interventions (Karogo et al., 2020). In this sense, the new Competency-Based Curriculum aims to reinforce skills acquisition through

improved pedagogy in order to allow for students' acquisition of critical subject-specific content and skills.

The development of pedagogical capabilities is also feeble, especially in terms of digital teaching practices. As part of the Digital Literacy Program, only 66 ICT champions and 80,980 teachers have been trained at the primary school level to integrate ICT into curriculum delivery, leaving 80% of teachers still with knowledge gaps in IT (Teacher Service Commission, 2019). Looking into the future, the Kenyan government has integrated ICT and computer usage subjects into the teachers' training curriculum at the college level. In terms of digital education resources, the Kenyan Institute of Curriculum Development (KICD) estimated that about 47 per cent of learners have been accessing the existing cloud platform with a 600% increase in content download since the school closure. A mapping of the free available resources is underway by the KICD to determine how the content created or approved by the government cover topics in the national curriculum considering the different official languages. Digital education resources are diverse and include online classes with discussion forums to videos, e-books, games, lesson plans, or lecture-style presentations. Regarding personal and adaptive learning, since its foundation, the Digital Literacy Program has focused on distributing digital devices in primary public schools with the mission to expose students to digital literacy in their initial years and promote personalised learning through the usage of the Learner Digital Device, already preloaded with content on Kiswahili, English, Mathematics, Science and Social Studies. The rollout has been very successful, and currently, 97% of schools have received all the equipment. Conversely, recent studies found that many schools were not using the devices because of lack of electricity and poor network coverage; additionally, teachers could not

operate the devices even after training, and digital resources did not correspond to the current syllabus content (Wanza et al., 2019).

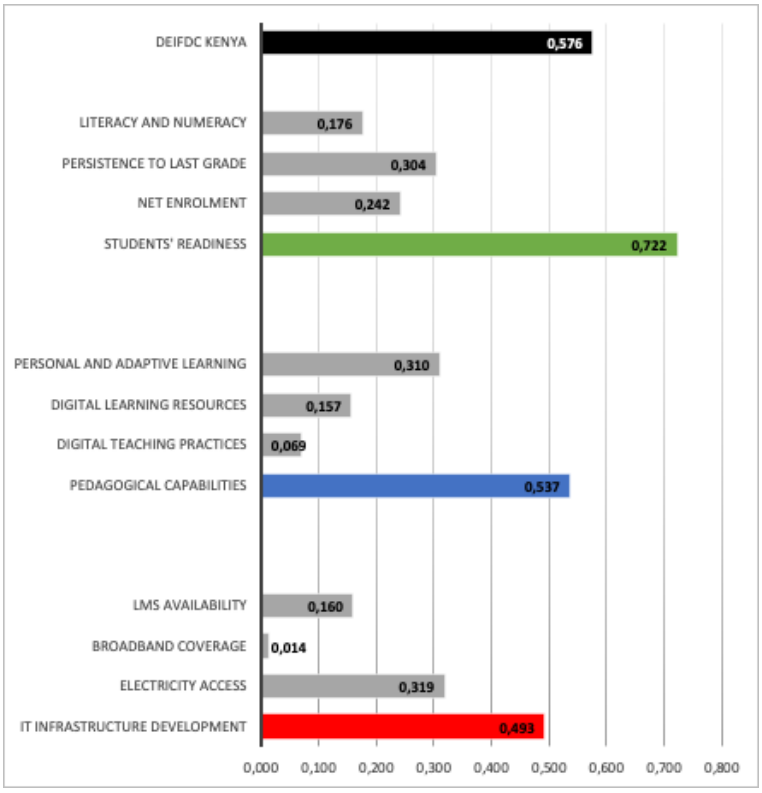
School infrastructure development is also impoverished, particularly in terms of internet access. Of the 22,259 schools targeted in the DigiSchool program connected to power, 83% of the schools have been connected to the power grid supply, and 17% rely on solar power. However, many schools in rural and semi-urban areas suffer constant power fluctuation, especially in remote counties such as Turkana, Samburu, West Pokot and Northern Kenya (Ngaril et al., 2020).

Concerning internet connection, Kenya is one of the most connected countries on the eastern coast of Africa, with four submarine cables that offer connectivity to the rest of the world via redundant routing. Inland, the 6,000 kilometres of the National Fibre Optic Backbone Infrastructure (NOFBI) across all the 47 counties provide a robust infrastructure; however, this infrastructure does not provide broadband internet connectivity to all the schools. The National Broadband Strategy 2018-2023 (Republic of Kenya, 2017) aims to provide by 2030 a 1Gbps connection to 100% of schools; however, as of mid-2020, only 4% of primary schools counted with an internet connection. This rollout has been mainly promoted by the Kenya Education Network (KENET) initiative (Mwangi et al., 2013) that has built a private and public consortium to provide high-speed connectivity and cloud services to education and research and government institutions affiliated with the education sector including hospitals. In August 2020, the government earmarked $140 million in partnership with the United Nations Children's Fund to reach 1,000 schools as a pilot project before the massive rollout (Paul, 2020). This investment is extraordinary given that schools are still lacking other appropriate classroom structures and have inadequate WASH

infrastructure: nearly 50% of schools have no handwashing facilities and poorly maintained toilets (Alexander et al., 2016).

On March 15th, 2020, Kenya's Ministry of Education (MoE) indefinitely closed primary and secondary schools to mitigate the impact of Covid-19, thus interrupting the studies of 13,36 million students. At that point, most Digital Education programs were experiencing little success, mainly due to low levels of computer literacy; however, to ensure students remained engaged during the closing period, the Ministry of Education and the Kenyan Institute of Curriculum Development (KICD) developed remote learning systems and educational resources supported through several channels: Radio broadcasting, Education Television Channel, Education YouTube Channel and the Kenya Educational Cloud. As a result, it has been estimated that about 60% of primary and secondary school students have been accessing remote and online distance learning platforms and maintained increased exposure to learning infrastructure. However, there is no equitable access to learning solutions as internet costs in rural and underserved areas are prohibitive for many students; for example, only 12.1%, 2.1% and 4.4% of households in Turkana County have access to radio, TVs and internet respectively (Global Partnership for Education, 2020).

Figure 8: DEIFDC Kenya's results



Source: Author's elaboration with data from World Development Indicators and World Data Reports (World Bank), UIS Unesco Database, National Assessment System for Monitoring Learner Achievement (NASMLA) from the Kenyan National Examinations Council (KNEC), Kenyan Ministry of Information, Communications and Technology, Kenya National Bureau of Statistics and Digital Literacy Program Updates.

Conclusion, limitations and future research

Education is the key to reducing poverty, ensuring global sustainability, eradicating diseases and fostering peace. To ensure that digitalisation advancements do not broaden

the existing educational divide, developing countries must introduce Digital Education at the early stages of schooling as a means to prepare students with the skills required in a 21st-century workforce.

In this research, through RQ1, we analysed the different metrics that affect the implementation of a Digital Education program and defined the Digital Education Index for Developing Countries framework to measure and compare the degree of Digital Education deployment in different developing countries. The methodology used selected nine different variables (school net enrolment, persistence to the 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 were grouped in three levers (Students' Readiness, Pedagogical Capabilities and IT Infrastructure Development) and weighted thanks to a quantitative study launched to educational experts worldwide.

The specific application to Kenya was analysed through RQ2, where we studied the Kenyan context from a social and educational perspective focusing on the applications and digital education programs that have been developed. Although a major increase in the usage of educational resources and learning platforms was observed due to the Covid-19 school closure, in the application of the DEIFDC for the Kenyan case, the results show Insufficient Deployment of Digital Education mainly due to poor internet connectivity, lack of trained personnel and main challenges on students' learning performance. The DigiSchool program, part of the 2030 Vision agenda of the Kenyan government, aims to introduce Digital Education in all public schools; however, according to the latest Class 7 Monitoring Learner Achievement, 44.3% of teachers had not yet adopted the use of ICT in

teaching their subjects, and no effect has been recorded on the improvement of basic skills. At the same time, important differences are still present for the most vulnerable population, especially children attending schools in rural areas, refugee camps and slums.

Proposed further research will deep dive into the Kenyan Digital Education system evolution, and its future impact will need to explore both the evolution of DEIFDC in subsequent years, its possible application in higher education (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 variables at a sufficient disaggregation level.

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Chapter 4: Digital Education Index for Developing Countries framework: evaluation of the deployment of Digital Education in Peru

Abstract

Digital Education is a key factor to bring developing countries up to speed so they are able to compete under the new rules of the Digital Economy. The Covid-19 pandemic crisis has made more evident the need to implement a global educational strategy where all children can be prepared to learn in a digital environment independently of their country and birth condition. In this research, a Digital Education Index for Developing Countries (DEIFDC) has been defined and applied for the Peruvian case. The construction of the index is based on relevant variables organized in three levers to determine Peru's capacity to better prepare current primary school children to acquire the competences needed in a 21st century workforce. The results show good development on pedagogical capabilities and students' readiness but only adequate maturity on the development of schools' infrastructure. Peru's slow digital development, in comparison to other countries in the region, is distressing the availability of high-skilled labour, digital GDP growth and digital services productivity; hence major efforts will need to be undertaken to guarantee Peruvians upgrade to a digital prepared society.

Keywords: digital education, developing countries, digital economy, digital index, social impact

Introduction

Education is a human right and one of the strongest instruments for development as it contributes to reduce poverty and improve health, equality and peace (United Nations, 1948). For individuals and societies, education promotes employment, poverty reduction, economic growth and social cohesion (World Bank, 2020).

The importance of Education has been reflected in the Agenda 2030 for Sustainable Development adopted by the United Nations General Assembly, where the specific development goal number 4 has been dedicated 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).

2020 was a year of profound changes at social, economic and educational levels due to the Covid-19 pandemic (Unesco, 2020). 1,5 billion children and youngsters were displaced out of school with diverse consequences in terms of their learning progress, nutrition support and subsequent enrolment continuity. Specifically, in Latin America and the Caribbean more than 165 million children have lost an average of 158 school days during 2020 hindering in-person instruction (Petri et al. 2021). In vulnerable environments, the current digital divide made evident that those with less technical resources were unable to keep up with their standard learning process (Unicef et al., 2020) and have lost at least one year of educational development.

However, as important as Digital Education has demonstrated to be during the pandemic crisis, it should not be considered as a backup instrument to respond in case of

school closure but as a means to prepare children at early stages of education to acquire the competences that will be needed in a new Digital Economy (Riviello, 2020). In this sense, Digital Education prepares children for the Industry 4.0 revolution (Kask et al., 2021) as well as it enhances their learning experience by introducing innovative, collaborative tools and new social experiences (Luckin et al., 2012); moreover, it prepares children for advanced STEM education, increasing the number of children who will develop a career in programming, data analysis, cybersecurity or cloud management.

In developing countries, Digital Education is even more relevant because it can improve the teaching and learning processes and introduce the basis necessary for producing a technologically proficient workforce that might transform in the next 10-15 years the composition of the labour market (Kalolo, 2018). In Latin America, the expansion of education has been very significant in recent decades, but the degree of inequality remains relevant, as the creation of human capital is still dependent on the socio-economic origin of the families and education is not contributing as an equaliser factor, especially in Peru where the GDP growth has been very relevant in the last twenty years (Figueroa, 2008). Additionally, in the scenery of developing countries, globally, it has been calculated that there is a 9% increase in hourly earnings for one extra year of schooling (Psacharopoulos et al., 2018).

The recent pandemic crisis had shown that only those with jobs adopted to the current digital economy could introduce massively home working; in Latin America, 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, increasing overall

economic vulnerability and worsening inequality in lower-income households (López-Calva, 2020).

In a new Digital Economy, developing countries must aim to become not only countries of manufacturing outsourcing but also move into high skilled services with customer call centres, data entry facilities and higher-skilled professional jobs ranging from engineering to artificial intelligence (Lieberman, 2004). It is therefore relevant for developing economies, not only to ensure economic growth but also to build a more resilient and inclusive economy, focusing on how Digital Education is preparing future adults of the next generation to acquire the required Digital Competences to enter the labour market prepared with sufficient ICT skills.

More developed economies are focusing on the learning process at schools and on lifelong learning opportunities at university or on how to upscale the current workforce (Beblavý et al., 2019). At the same time, systematic research has been developed in order to provide trend analysis and country comparisons of their digital performance (Foley et al., 2018).

However, there is lack of information on the overall deployment and evolution of Digital Education in developing countries and this research tries to contribute to close this knowledge gap. Inspired by the mentioned studies and to determine the state of readiness of a particular country in terms of Digital Education acquisition at early stages of schooling, a Digital Education Index for Developing Countries (DEIFDC) has been defined. For this characterization, three specific levers relevant at low levels of education have been considered, mainly for primary schools where the impact has demonstrated to be higher (Heckman, 2007). The selection and weighting of levers and variables 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.

In order to apply the DEIFDC to the specific Peru case, detailed research of the education system has been conducted, as well as a revision of the different policies and programs that have been undertaken on Digital Education in Peru in the past 20 years that are directly impacting the variables that compose the index. In this sense, the DEIFDC will assess the current deployment of Digital Education in the midst of the Covid-19 pandemic, but it will not measure the social, political or cultural implications that might be affecting the index construction.

Theoretical framework

In the context of a new Digital Era, Digital Education is considered as a key factor to link schooling and the future of a Digital Society. Investments in education are critical for developing the human capital that will end extreme poverty (United Nations Development Program, 2019) and priority should be given to the lower levels of education in countries that have not yet achieved universal primary education (Psacharopoulos et al., 2018). Although there are several definitions for Digital Education that can be applied depending on the stage and purpose of education, i.e., early childhood, K-12, professional, university and life-long learning, for the purpose of this research, Digital Education has been defined as the process of teaching and learning in schools that is facilitated by Digital Technologies.

Digital Technologies have been progressively introduced in most Education systems, even if traditional textbooks and chalk and board were also used. Nowadays, and due to the workarounds originated due to the school closures during the pandemic, many education world leaders agree that technology is no longer a supplementary tool and that it should be fully integrated into all Education Systems (Gianini, 2020).

Digital Education is striking as it prepares children to acquire the digital competencies needed in a 21st century workforce like digital literacy and computational thinking (World Economic Forum, 2020). Nevertheless, 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 children to acquire a series of soft skills that have been described in several frameworks, such as the four C's (Ruhl, 2015): critical thinking, creativity, communication and collaboration, the ABCs, adapt, be resilient and communicate (Wilson-Body, 2020) or the four Pillars of Education: learn to know, learn to do, learn to live and learn to be (Unesco, 2015).

Recent studies (Ganimian et al., 2020) suggest four different ways to realise the potential of education technology to accelerate student learning and focus on potential uses of technology that play to its comparative advantages: scaling up quality instruction, facilitating differentiated instruction, expanding opportunities to practice and increasing learner engagement through videos and games.

For the purpose of this research and focusing on primary schools, Digital Education has been approached into two different areas depending on their potential use, individual and collective education technologies as they will help the children to develop the required 21st-century competences.

Individual learning tools are mainly based on the usage of educational resources on computers, tablets or mobile phones to speed up the learning process by giving each student access to different content available from the Internet or previously downloaded and made available offline. This way of working is differential for three reasons:

a. Knowledge boundaries: It extends the boundaries of knowledge of the traditional textbooks, especially if the children are able to connect to the internet and explore further than what it is written in the books just with a device, this process can be thought to be similar to have access to an infinite library where thousands of books are available, and children are capable of conducting their own research (Mitra, 2014).

b. Adaptive learning: It introduces the concept of learning personalization 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).

c. Evaluation and assessment: It facilitates evaluation and assessment as different types of tests and questionnaires can be applied to verify students' levels at different stages of the learning process, at the same time as it simplifies the individual certification or warranty of proficiency in certain subjects or matters than can be used to access higher education or specialized jobs (Beblavý et al., 2019).

The collective learning digital tools bring a new way of working soft skills that allow teachers to introduce complementary forms of interaction among students. It changes the way of interaction in a classroom from a teacher-centred approach to a student-centred approach (Ruhl, 2018). These tools can be interactive white-boards (IWB) (Lopez, 2010) 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, 2016):

a. Teamwork and collaboration: The students can be grouped in smaller clusters to develop different subjects, research together or complete tasks that involved thinking out of the ordinary (Scheuer et al., 2010).

b. Peer evaluation: The software deployed in tablets or computers allows the students to assess their peers' work and help them create a collaborative environment where everyone learns from both producing and revising the work of others.

c. Gamification: It helps to motivate the students with the creation of avatars and game-related content that can be used to deeply study a specific matter; the children will get higher scores depending on how they dominate the subjects (Freitas, 2011).

Research context

Peru is located in South America, bordering Bolivia, Chile, Ecuador, Colombia, Brasil and the South Pacific Ocean. It has a vast diversity, both cultural and geographical, that are often linked, drawing significant national differences between the coastal areas, the Amazonian regions and the Andean mountains. Although Spanish is the most common official language, there are other 47 indigenous languages, mainly Quechua and Aymara, that conform an important diversity in terms of cultural differences (Ministerio de Educación de la República del Perú, 2013).

Peru's economy has been one of the most prominent performers in Latin America in the last 25 years averaging 5.3 per cent growth since 2001, besides, its economy is one

of the largest in Latin America and the Caribbean. However, there are great differences between the coastline regions and the Andean and Amazonian ones; for example, the Lima area accounts for one-third of Peru's population and one half of its GDP (World Bank Group, 2017).

Peru ranks 82 in the Human Development Index with an HDI of 0,759 considered within the high group of Human Development (UNDP, 2019). However, the indicators of Peru in social and infrastructure metrics show that Peru is lagging behind its structural peers in almost all indicators such as electricity, sanitation, water, access to mobile phones and internet users, paved roads, stunting, secondary school degrees, social insurance and pensions (World Bank Group, 2017). This particularly affects 7.6 million indigenous people, around a quarter of Peru's 32 million population, where the higher poverty ratios are found. The higher poverty incidence among indigenous people is often driven by the fact that they live in rural areas rather than by their ethnicity (World Bank Group, 2017).

The main economic sectors in Peru are services, construction and mining. It is a wealthy country in terms of natural resources such as gold, silver and copper that drive substantial foreign investments; however, according to the World Bank, the lack of investments in innovation and more productive digital technologies is constraining growth: low productivity, slow technology adoption, lack of export diversification that are all closely related, describing an equilibrium of weak labour demand for productive, well-paid jobs. In this aspect, the impact of Digital Education will be profoundly analysed at early stages of schooling and the conformation of a digital high productive and high waged labour.

The key areas prioritised for action to ensure sustainable development are closely interrelated with the raising of human capital (World Bank, 2017) and also involve the improvement of connecting infrastructure and public services, government coordination, law enforcement and reduction of environmental risks, among others.

According to the INEI, in 2018 there were 567,347 teachers, 113,069 schools and 8,815,800 students in the Peruvian Education System organized following the procedures of the General Education Law (Ministerio de Educación de la República del Perú, 2003).

The education system has been structured in stages, levels, modalities, cycles and programs, these terms will be explicitly referred within the Peruvian context:

- The stages are the progressive periods in which the educational system is structured according to each student's learning needs.
- The levels are the periods within the educational stages.
- The modalities are educational alternatives organised according to the specific characteristics of students
- The cycles are developed based on learning achievements.
- The programs are sets of educational actions developed to meet specific demands

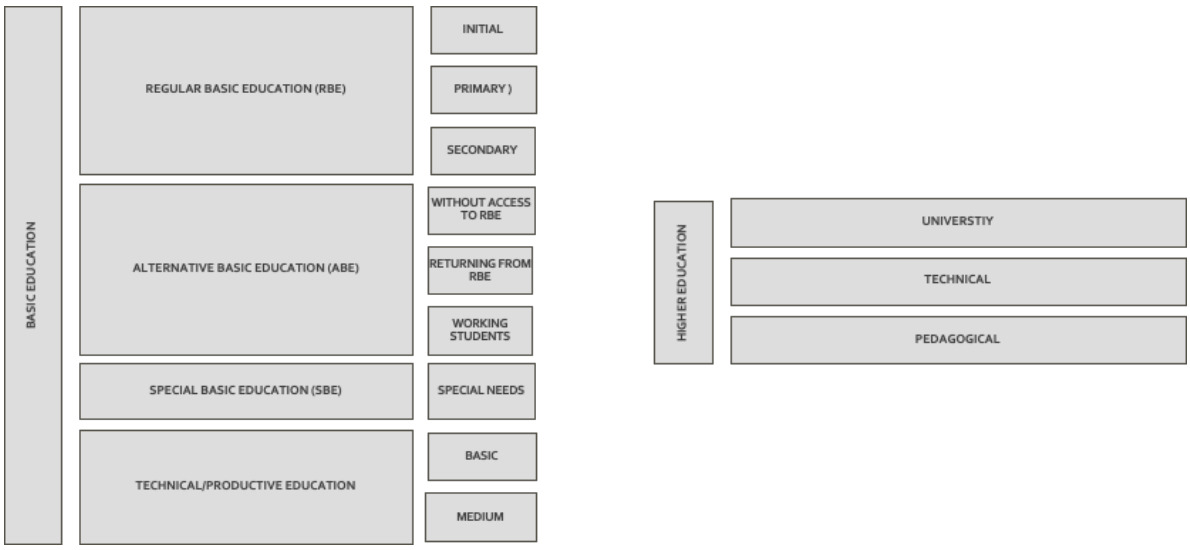
As we can see in figure 9, the Peruvian Educational System comprises the following two stages:

a. Basic Education, as a means to acquire fundamental competencies, promote the students' integral development and the development of capacities, knowledge, attitudes, and values to act and live in society adequately. It also attends from an inclusive point of view, children

and adults with special educational needs or learning difficulties.

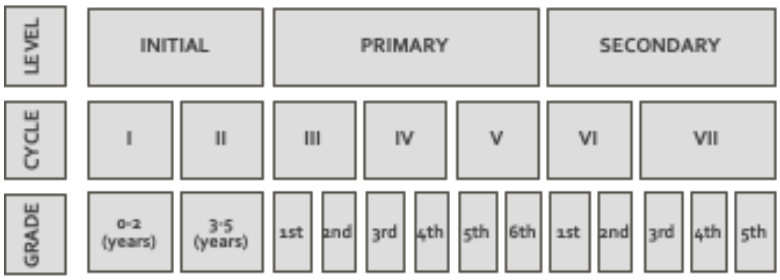
b. Higher Education, which is focused on specialisation and the acquisition of specific competences like high-level professional skills in accordance with the la-bour skills demanded by society.

Figure 9: Peruvian Education System



.Source: Author's elaboration with data from the General Education Law (Ministerio de Educación de la República del Perú, 2003)

Figure 10: Peruvian Basic Regular Education



Source: Author's elaboration with data from the Basic Education Curriculum (2016)

As we can see in figure 10, Regular Basic Education is divided into seven cycles that correspond to the central and more extended educational modality in Peru. It takes care of children and adolescents that adequately go through the educational process according to their physical and cognitive evolution.

For this study's purpose, only the schools within the Regular Basic Education have been considered leaving potential further research for the deployment of Digital Education in Alternative Basic Education, Special Basic Education, Technical Education and Higher Education. Additionally, special attention has been paid to the cycles that belong to primary education bearing in mind the importance of the last year of initial education compulsory in Peru to the first cycle of secondary education where the main competences acquired during Primary years are evaluated.

It is worth pointing out that the general education law considers as the main objectives of Basic Education not only the learning processes in the traditional fields of science, humanities, culture, art, physical education and sports, but also those that will allow the students to make good use and enjoyment of new technologies.

The Basic Education Curriculum (Ministerio de Education de la República del Perú, 2016) defines 29 general competences that children must have achieved by the end of the 6th grade. Specially dedicated to Digital Education are:

a. Competence 22: Design and build technological solutions to solve problems, justifying the scope of the technological problem and its alternative solutions based on scientific knowledge.

b. Competence 28: Proved capabilities in virtual ICT environments; it contemplates the creation of digital materials such as videos, presentations, designs, documents and the proficient usage of applications, the internet and social networks to integrate all its acquired knowledge.

The Peruvian government has progressively introduced ICT at different stages of education since 1996. Even if the first programs were deployed at a shallow scale, there has indeed been relevant knowledge acquired during the last 25 years, and that has positioned Peru as one of the countries with better digital response during the Covid-19 pandemic (Unesco, 2020). The main programs ordered by initiation date are:

a. Infoescuela (1996-2001): Teachers were trained in the Logo programming language and to use LEGO kits. The program was evaluated by MIT (Linares, 2016) and supported by Seymour Papert himself (Papert, 1993). Its deployment was remarkably reduced, and in 2001 there were only 360 active schools (Marcone, 2010).

b. Edured (1996-2001): It aimed to provide schools with an internet connection to improve the quality of learning and modernise high schools (Salas-Pilco et al., 2014). In 2001, there were 345 high schools implemented with internet access, but only 74 of them had the project in operation (Marcone, 2010).

c. Huascaran Project (2001-2007): This project tried to introduce ICT in Peruvian schools at a large scale compared to the previous projects that could be considered more like pilots. It developed a whole program that included not only the computer lab equipment and the internet access in the schools but also the training of teachers and the appointment of an ICT teacher specialist per school (Marcone, 2004). In 2001 there were 3,000 schools equipped, but most of them were urban schools as the rural schools required antennae to provide an internet connection.

d. One Laptop per Child (2007-2011): The OLPC implementation is one of the most well-known deployments of the program in the world and has been largely analysed. More than 800.000 XO laptops (Rivoir, 2016) were either handed over to students in rural areas or as a part of a Digital Lab in a second phase due to budget restrictions. The program had a formal evaluation using randomised control from the InterAmerican Development Bank, and it was found that even though there was no improvement noticed in literacy and numeracy competences, children and their families had a positive perception of the program and increased competence in the usage of ICT tools (Santiago A. et al., 2010). Also, it was found that it had impact on cognitive skills, although much effort had to be dedicated to teacher's qualification (Cristiá et al., 2012)

e. PeruEduca (2011-now): This project tries to create a community for teachers where they can access online MOOC training and certification and digital resources to use in their classrooms. It also allows them to publish in blogs and forums and create specialised groups.

f. Aprendo en Casa (2020-now): In 2020, during the Covid-19 crisis, all schools were closed for the whole school year, but there were several initiatives based on digital

capabilities already installed that ensured that up to 93% of the students could follow on with their learning (Semáforo Escuela, 2002). The project is aimed at Basic Education (Ministerio de Educación de la República del Perú, 2020), and it is very innovative as it is not only based on access to the internet but also broadcasted by television and radio. In the short term, it has been used during the pandemic crisis, but in the long term, it will try to reduce the educative gap between urban and rural zones in Peru.

g. Tablet distribution and virtual/presential hybrid approach (2020-2023): The plans of the current government in order to keep on responding to the pandemic crisis in Peru consist of ensuring quality infrastructure in schools, provide access to digital tools, distribute more than 1 million tablets (Ministerio de Educación de la República del Perú, 2020) and increase internet coverage in rural regions. There will be three ways to provide lectures, and it would be possible to combine virtual and presential lessons in schools and a complete virtual education model depending on the necessity and region. With an increase of 2.83% in the public budget allocated to Education (Ministerio de Economía y Finanzas de la República del Perú, 2020), it will be possible to prioritize essential literacy and numeracy, emotional aspects and digital competences (Fundación Santillana, 2020). The tablets acquired count with more than 35 applications and 3,000 educational resources that will be used by children in the last cycle of Primary Education and Secondary Education of rural areas and will be delivered to 90,000 teachers (Ministerio de Educación de la República del Perú, 2020). In a zone with internet coverage, the tablet will have a data chip to provide internet access for both children and teachers, and if there is no internet coverage, the content will be uploaded previously in the tablet so it can be available offline. Also, a solar charger will be provided to be used in those areas with no access to current

electricity. It has also been considered of great importance that the teachers in the program count with specific training on digital literacy and competences with preuploaded training resources in the tablets (Ministerio de Economía y Finanzas de la República del Perú, 2020).

Peru has been having an outstanding performance in terms of GDP growth, the best of the region during the last two decades (World Bank Group, 2017). This growth helped reduce poverty for each percentage point increase in GDP growth and poverty fell by 1.4 percentage points. Thus, from 2004 until 2015, 9.3 million Peruvians escaped poverty, moderate poverty fell by more than half, from 58 to 22 per cent, and extreme poverty fell from 16 to 4 per cent. In Peru's case, GDP growth has been based on natural resources and has attracted foreign investments in mining and enabled growth based on fast capital accumulation, although with few gains in productivity and negligible export diversification (World Bank Group, 2017). This GDP growth is based on the measurement of the monetary value of all final goods produced in an economy (Brynjolfsson et al., 2019), but it does not include digital offerings as free digital goods are consumed at no cost, which is relevant as it increases the gap related to the Digital Economy that has not been taken into account.

Overall, Peru has a very slow digital development and ranks below its regional peers on digitisation (BBVA, 2017; Sethi et al., 2020), largely because it falls short in infrastructure as it has low internet usage compared to other Latin American countries in terms of private and public sectors and personal use. Only 45% of Peruvians use the internet, but in urban areas, the rate is 54%, whereas, in rural areas, it is only 14%. Geographically, there is also a significant difference: over 63% of the population in Lima's province use the internet, whereas, in Cajamarca, Huancavelica and Amazonas, this rate is

around 20%. Young people and those with a medium-to-high education level use the internet most, having a considerable impact on qualified job opportunities and participation in the digital economy. The internet is mainly used for communicating, obtaining information, and entertainment, but the usage for interaction with the public sector, electronic banking, buy or sell product and services or training is residual. The evolution has been very positive with recent analysis in 2019 situating on 57,1% the percentage of the Peruvian population that uses the internet, an increase of 10 points in only two years (Instituto Nacional de Estadística e Informática, 2019).

76% of private companies use the internet, nevertheless, only around one-third of them have all their employees using it due to the internet connection speed. Companies in Peru are too slow in the adoption of new technologies. Only 7 per cent of firms have licensed technology from abroad, compared to 14 per cent in the Latin-American region as a whole. They also lag in the adoption of new digital technologies; for instance, less than 20 per cent of formal sector retail firms sell their products online, despite the significant opportunities to enhance their scale and productivity through online trade. This is among the lowest online shares for retail firms in Latin America as in Mexico, Colombia, and Chile, between 50 to 80 per cent of all sector retailers offer online sales (World Bank Group, 2017). There has been progress in government digitisation in Peru over recent years thanks to the effort of the SeGDi (Secretaría de Gobierno Digital) that is in charge of developing internet policies, national plans, standards, guidelines and strategies in e-government and IT matters. However, although it has developed several applications and web services, the government's online services and their perceived benefits still lag its peers in Latin America.

Data Analysis

The existing data suitable for constructing the DEIFDC was obtained from reputable available national and international sources through desk research. Data sources include global databases like the UIS Unesco Database and the World Development Indicators from the World Bank, as well as local Peruvian sources like Semáforo Escuela and standard PISA (Programme for International Student Assessment evaluations) results of 2018.

The use of international databases will be useful to build a base for comparison among other developing countries where the DEIFDC will be applied. However, we still encounter other limitations like the availability of annual data to determine future 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.

Results

The analysis and application of the DEIFDC came with relevant insights on the development of Digital Education in Peru. Overall, with a result of 0,711 is situated within the countries with Good Digital Education deployment.

In terms of Students' Readiness, the Peruvian context has considerable room for improvement. Even if net enrolment and persistence to the last grade of primary schools are reaching levels of high-income countries, 96.91% and 93.09%, respectively, the PISA evaluation levels are still deficient (42.46%), almost matching the levels of learning poverty, especially in mathematics (39.66%). This factor is very relevant because it

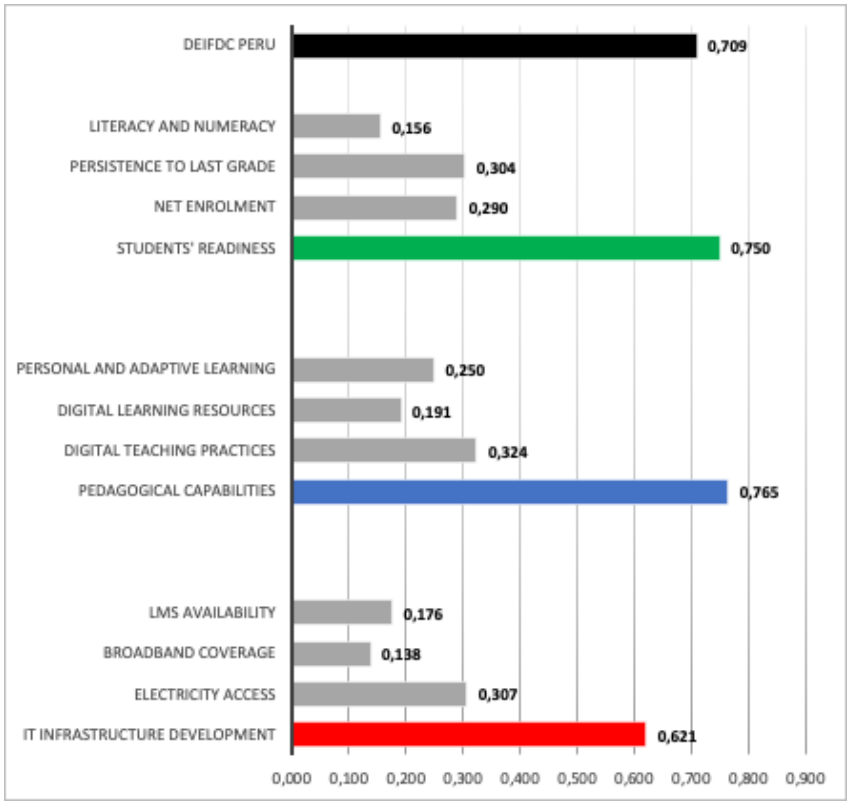
demonstrates that even if all efforts are made in a good direction, the instruments that are put in place also need to focus on the basic literacy and mathematics competencies. This lack of basic competences then translates into a subsequent variable resulting in only 31.70% of students applying on STEM superior education that will lead to scarce fulfilment of digital job positions. This lever brings an important point related to Digital Education and the fact that the introduction of ICT in the education systems does not help improve the learning process's efficiency, and it only aims to acquire complementary competences like research, organisation, problem-solving, collaboration, teamwork and project development (Marcone, 2010). Further research will need to determine the current effects of Digital Education on future evaluations of basic competences, so far increased levels of school attendance, decrease in dropout rates, students and teachers producing and sharing information, improvements in educational management and teachers' training have been demonstrated but impacts behind in the improvement of reading, writing and math skills are yet to be analysed (Cardim et al., 2021).

As we can see in figure 11, in terms of infrastructure, the Peruvian government has made plenty of effort to ensure schools count with electricity by standard means or with other renewable energy sources reaching almost 79.93% of the schools. However, only 40.77% of schools had an internet connection, making it challenging to introduce online learning individual and collective tools. Even though there is no data available on the deployment of LMS, IWB or projectors in schools, during 2020, at least 66.9% of teachers were using Aprendo en Casa, which is a very high penetration and demonstrates an outstanding response throughout the school closure originated during the school year. With a total of 0,634 the School Infrastructure Development is adequate, however, additional

effort needs to be made in terms of inter-net connection and usage of LMS, IWB and projectors to ensure the basic infrastructure is deployed both in rural and urban environments.

As we can see in figure 11, the pedagogical capabilities lever represents the highest score of the three levers that compose the DEIFDC. Teachers in Peru are receiving Digital Education instruction both in their initial capacitation programs and as part of their lifelong learning to enrich their curricula. In this sense, the PeruEduca portal is a centrepiece to ensure the acquisition of these abilities. The availability of digital learning resources has also boosted during the pandemic crisis when it was necessary to reach children in their homes; in this sense, it is essential to consider that most of these resources are online and mainly in Spanish, leaving behind those rural areas where the mother tongue is an indigenous language, and the internet connection is not a reality. In terms of penetration, the last data available from the UIS database regarding the number of schools with access to computers for pedagogical purposes was 78.31%, almost 80%. However, this data does not consider the latest distribution of tablets started by the Peruvian government (Ministerio de Educación de la República del Perú, 2020).

Figure 11: Peruvian DEIFDC Results



Source: Author's elaboration with data from World Development Indicators (World Bank), PISA 2018, UIS Unesco Database and Semáforo Escuela.

Conclusion, limitations and future research

Success in the Digital Age requires Digital Skills (Internet Society, 2017). As primary school children will enter the labour market in ten years' time, they will need to have acquired the basic competences of Digital Literacy: use of computers and digital equipment, ability to use online applications, find and qualify online information and make use of it in daily life. Building these skills is crucial for developing countries and should be included in the curricula and assessed in the same manner as other basic competences like reading, writing and mathematics.

In Peru, the composition of the labour market needs to upgrade to be able to respond to the demands of the new digital economy. The existing digital divide and the lack of infrastructure, especially in terms of internet connection in rural areas, is causing that developing countries lag behind in digital dividends. This situation makes them incapable of benefiting from the broader development benefits of using digital technologies (World Bank, 2016) that go beyond the traditional sectors that have been responsible for GDP growth in the last twenty years.

Several programs have tried to integrate Digital Education into the learning process by introducing different components in a linked way at different stages of education, and digital competences have been included as part of the Peruvian national curriculum. However, still plenty of effort needs to be put in place in terms of education policies to ensure all variables affecting the three different levers of the DEIFDC work in a coordinated manner.

In the application of the DEIFDC for the Peruvian case, the results show good results on Pedagogical Capabilities and Students' Readiness but only adequate IT Infrastructure Development. The Covid-19 response has been a major boost in terms of upgrading the usage of digital educational resources and digitally train the teachers in order to be able to keep up with the lessons during the school closure. However, important differences are still very relevant in terms of rural and geographical development, which greatly affect indigenous people, due to some factors such as their mother tongue but also due to the locations where their homes are based, normally rural, rather than by their ethnicity.

The current data available from several studies that follow up the state of digital readiness of the labour market in Peru show that currently, the country has tremendous room for improvement in terms of digitalisation of the personal, enterprise and government processes. As a result, the GDP growth will flatly grow during the following years if no adequate digital development takes place.

Proposed further research will need to explore both the evolution of DEIFDC at different periods of time, its disaggregation based on gender (male-female), social origin (indigenous children, disability status and conflict-affected) or detailed geo-graphic distribution (rural-urban, coastal-Andean-Amazonian), its possible application in higher education (secondary, technical and university) and its impact on the country's composition of the digital workforce, GDP growth, overseas attractiveness and index of digitalisation, as well as the comparison with other countries of similar economic development.

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Chapter 5: Conclusion: summary of contributions, results, and future research lines

In the 21st century, children of all age and condition should have been prepared during their compulsory years of education in the basic competencies required in a digital economy society powered by the fourth industrial revolution. The educational systems worldwide are gradually adopting Digital Education in schools, so their students are prepared to develop a set of technical and soft skills that enables them to employ themselves in jobs of the future. Naturally, the competencies required will vary depending on the business processes and the exposure to technology; nonetheless, digital literacy, understood as the sets of skills that enable users to find, evaluate, organise, create and communicate information, should be included as a set of fundamental skills, like literacy and numeracy and the dexterities that can help them manage and adapt to the uncertain type of work they will develop like communication, collaboration, critical thinking, resilience and problem-solving.

The Covid-19 pandemic showed that K-12 learners in vulnerable environments lacked reliable high-speed internet connections, devices, educational resources and trained teachers able to respond to the learning crisis adequately. In developing countries, the digital education divide was even more significant, and it showed that citizens had not adopted the ICT skills that are needed to work and live in a digital-driven economy that could give them better access to remote employment opportunities, job training or online services like telemedicine, public administration facilities and access to banking operations among others.

In more advanced economies, several indices are helping leaders to monitor the level of digital transformation at a social and economic level; nevertheless, there is not any tool to follow the degree of advancements of Digital Education deployment with the peculiarities that students at early stages of schooling have in developing countries. Hence, the Digital Education Index for Developing Countries (DEIFDC) might be used as an informative tool to guide the deployment process and help educational leaders worldwide to plan, implement and support the transformations required to guarantee availability, affordability, and adoption of digital learning by students, teachers and their communities.

Regarding RQ1 and RQ2, through its main levers (IT Infrastructure deployment, Students' readiness and Pedagogical capabilities) and associated nine variables (school net enrolment, persistence to the 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) the DEIFDC has been built as a compound index that permits the detailed measurement of all the interconnected layers that drive the success of a Digital Education programme.

Regarding RQ3, as we can see in figure 12, in the application for the three different geographies under study, Peru (0,709) obtained better results, followed by India (0,596) and Kenya (0,576), but in any case, an adequate level of Digital Education deployment was achieved. Although the results demonstrate some similarities related to the main levers to develop, the DEIFDC showed the main particularities that must be considered when planning for a Digital Education deployment for each and all students.

In terms of Students' Readiness, India (0,753), Kenya (0,722) and Peru (0,750) count with adequate scores of net enrolment and persistence to the final grade. This data

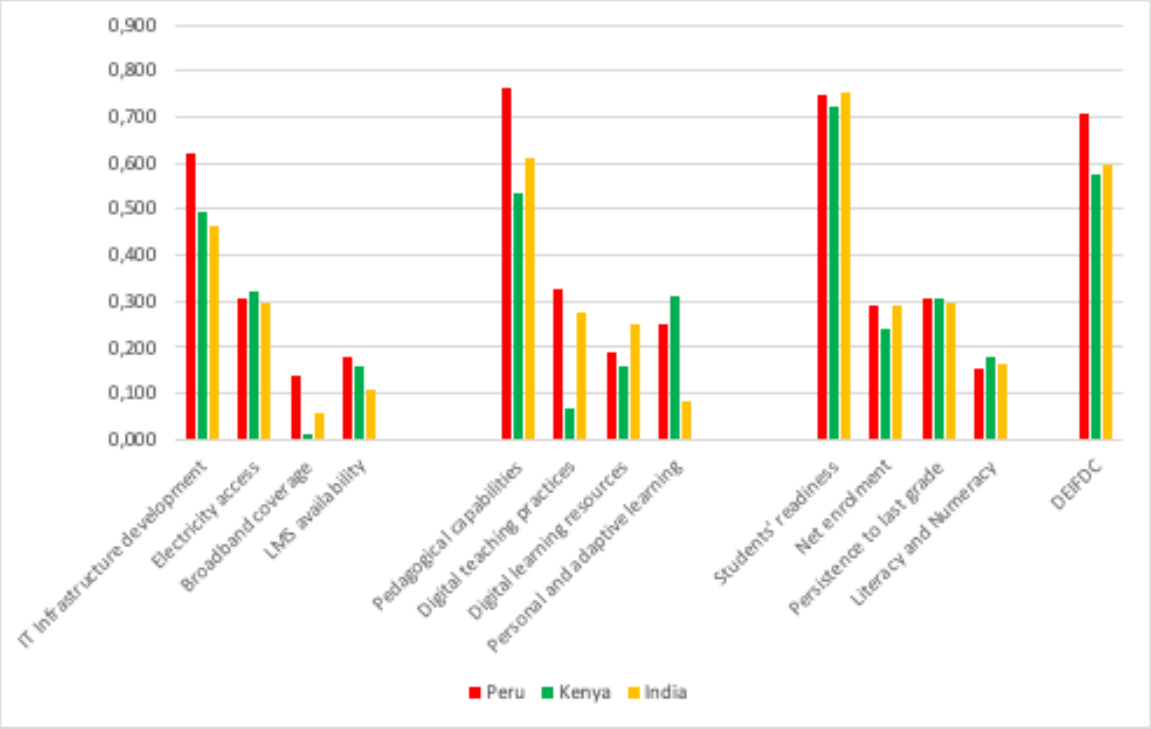
reflects the efforts done during the past years to achieve universal education in India, which have been supported by additional programs like the meals and sanitary pads program that have ensured boys and girls attend school and that their nutritional and hygienic needs are also met. However, the measurement of literacy and numeracy capacities is still shallow and moves in the parameters of learning poverty. This is particularly important for introducing Digital Education programs in school; as the children grow, they need to have developed the ability to read and write and interact with computer-based programs. One important aspect of Digital Education is that it can help learners with difficulties, through the introduction of artificial intelligence-powered tools, reach proficiency levels for their age.

Regarding Pedagogical Capabilities, the results of India (0,611), Kenya (0,537) and Peru (0,765) present the most significant variance of all levers mainly due to the effects that the Covid-19 pandemic had on the training of teachers on ICT skills and the availability of digital education resources in Peru to be able to cope with the learning process during the school closure. This effect has left Peru with sufficient initial exposure to be able to take advantage of Digital Education deployment moving forward. On the other hand, Kenya has a sufficient degree in terms of personal and adaptative learning, mainly due to the metrics published by the DigiSchool program that aims to provide every classroom with in-country-built computers for teachers and tablets for students preloaded with adaptative digital content.

The IT Infrastructure lever comes with the lowest metrics in all countries under study, India (0,461), Kenya (0,493) and Peru (0,621). Even if schools count on an electrical power supply either connected to the grid or through electric solar panels, the broadband

deployment that enables access to educational resources on the internet is very poor. In the case of India, Kenya and Peru, this has been partially solved by deploying learning management platforms with digital content previously uploaded that enables children to work on a local area network within their classrooms, simulating a real-life environment with open internet access. However, the full potential of digital education arises with children accessing open data and building complex projects by analysing and utilising the broad knowledge the internet has to offer.

Figure 12: DEIFDC Compound Results



Source: Author's elaboration from the DEIFDC case studies.

The main limitations of the research came from the availability of detailed data from international resources that would have enabled the application of the DEIFDC at different disaggregation levels, e.g., rural vs urban environments, sex adoption adjustments, ethnic alterations and geographic differences. However, the efforts done by local Governments and international organisations to collect SDG 4 advancements will make possible in the future a more comprehensive analysis. Moreover, the desk research could be completed with fieldwork in diverse schools, allowing different observation methods to contrast the metrics reported by the official channels.

The research carried out has shown that equity in terms of Digital Education deployment is a must-have condition for developing countries to ensure that every child can participate in a digital economy society as they enter the labour market and their future, independently of their place of birth, is not jeopardised.

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