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IntechOpen Series
Sustainable Development, Volume 40

Digital Equity and Literacy

Edited by Sandro Serpa and Ana Isabel Santos



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*Edited by Sandro Serpa
and Ana Isabel Santos*

Published in London, United Kingdom

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<http://dx.doi.org/10.5772/intechopen.1008087>

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First published in London, United Kingdom, 2025 by IntechOpen

IntechOpen is the global imprint of INTECHOPEN LIMITED, registered in England and Wales, registration number: 11086078, 167-169 Great Portland Street, London, W1W 5PF, United Kingdom

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British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library

Digital Equity and Literacy

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p. cm.

This title is part of the Sustainable Development Book Series, Volume 40

Topic: Health and Wellbeing

Series Editor: Usha Iyer-Raniga

Topic Editor: Ann Hemingway

Print ISBN 978-1-83635-469-7

Online ISBN 978-1-83635-468-0

eBook (PDF) ISBN 978-1-83635-470-3

ISSN 2753-6580

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IntechOpen Book Series

Sustainable Development

Volume 40

Aims and Scope of the Series

Transforming our World: the 2030 Agenda for Sustainable Development endorsed by United Nations and 193 Member States, came into effect on Jan 1, 2016, to guide decision making and actions to the year 2030 and beyond. Central to this Agenda are 17 Goals, 169 associated targets and over 230 indicators that are reviewed annually. The vision envisaged in the implementation of the SDGs is centered on the five Ps: People, Planet, Prosperity, Peace and Partnership. This call for renewed focused efforts ensure we have a safe and healthy planet for current and future generations.

This Series focuses on covering research and applied research involving the five Ps through the following topics:

1. Sustainable Economy and Fair Society that relates to SDG 1 on No Poverty, SDG 2 on Zero Hunger, SDG 8 on Decent Work and Economic Growth, SDG 10 on Reduced Inequalities, SDG 12 on Responsible Consumption and Production, and SDG 17 Partnership for the Goals
2. Health and Wellbeing focusing on SDG 3 on Good Health and Wellbeing and SDG 6 on Clean Water and Sanitation
3. Inclusivity and Social Equality involving SDG 4 on Quality Education, SDG 5 on Gender Equality, and SDG 16 on Peace, Justice and Strong Institutions
4. Climate Change and Environmental Sustainability comprising SDG 13 on Climate Action, SDG 14 on Life Below Water, and SDG 15 on Life on Land
5. Urban Planning and Environmental Management embracing SDG 7 on Affordable Clean Energy, SDG 9 on Industry, Innovation and Infrastructure, and SDG 11 on Sustainable Cities and Communities.

The series also seeks to support the use of cross cutting SDGs, as many of the goals listed above, targets and indicators are all interconnected to impact our lives and the decisions we make on a daily basis, making them impossible to tie to a single topic.

Meet the Series Editor



Usha Iyer-Raniga is a professor in the School of Property and Construction Management at RMIT University. Usha co-leads the One Planet Network's Sustainable Buildings and Construction Programme (SBC), a United Nations 10 Year Framework of Programmes on Sustainable Consumption and Production (UN 10FYP SCP) aligned with Sustainable Development Goal 12. The work also directly impacts SDG 11 on Sustainable Cities and Communities. She completed her undergraduate degree as an architect before obtaining her Masters degree from Canada and her Doctorate in Australia. Usha has been a keynote speaker as well as an invited speaker at national and international conferences, seminars and workshops. Her teaching experience includes teaching in Asian countries. She has advised Austrade, APEC, national, state and local governments. She serves as a reviewer and a member of the scientific committee for national and international refereed journals and refereed conferences. She is on the editorial board for refereed journals and has worked on Special Issues. Usha has served and continues to serve on the Boards of several not-for-profit organisations and she has also served as panel judge for a number of awards including the Premiers Sustainability Award in Victoria and the International Green Gown Awards. Usha has published over 100 publications, including research and consulting reports. Her publications cover a wide range of scientific and technical research publications that include edited books, book chapters, refereed journals, refereed conference papers and reports for local, state and federal government clients. She has also produced podcasts for various organisations and participated in media interviews. She has received state, national and international funding worth over USD \$25 million. Usha has been awarded the Quarterly Franklin Membership by London Journals Press (UK). Her biography has been included in the Marquis Who's Who in the World® 2018, 2016 (33rd Edition), along with approximately 55,000 of the most accomplished men and women from around the world, including luminaries as U.N. Secretary-General Ban Ki-moon. In 2017, Usha was awarded the Marquis Who's Who Lifetime Achiever Award.

Meet the Volume Editors



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Prof. Dr. Ana Isabel Santos holds a Ph.D. in Education, specialising in Methodology and Teaching of the Portuguese Language, and a postgraduate degree in Programming, Robotics, and Artificial Intelligence from the University of the Azores. Dr. Ana Isabel Santos is an Associate Professor and President of the Faculty of Social Sciences and Humanities of the University of the Azores and Director of the Master's Degree in Teaching Informatics. With several papers and articles published in the field of Early Childhood Education, Teacher Training and Literacy (emergent and digital), her teaching activity is mainly oriented towards the teaching of specific didactics and the monitoring of pedagogical internships within the Bachelor's Degree in Basic Education, the Master's Degree in Pre-School Education and Basic School Teacher Education and the Master's Degree in Teaching Informatics.

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Preface

The integration of digital technologies has profoundly transformed daily routines, work, and education, marking an irreversible process that affects society at all levels. Contrary to the often-disseminated optimistic view, the truth is that individuals' ability to access and use such tools consciously and productively is not uniform. With the aim of fostering knowledge and informed action on this critical issue of our time, we are delighted to present the work *Digital Equity and Literacy*.

This work, the result of a collaborative effort, brings together the knowledge and reflections of authors, gathering perspectives from experts with institutional affiliations in various countries, thereby demonstrating the international scope of this project. It is, therefore, possible to obtain a truly global perspective on the challenges and opportunities of the digital age. The work is organised into five thematic sections, which guide the reader from fundamental concepts to practical strategies for social transformation.

The opening section, “Foundations: Equity and Literacy in the Digital Age”, establishes the conceptual framework of the work, demonstrating how it builds on and expands the traditional understanding of the digital divide to a more multifaceted model of inequality that includes skills, forms of use, and the resulting outcomes. This section includes the following chapters: “From Digital Divide to Dividend: We Are on our Way”, by Huifang Wu, and “Bridging the Digital Divide: A Human Rights-Based Approach to Digital Literacy and Equity in the EU”, by Cong Yao and Paul Quinn.

The second section, “Education: Empowerment for a Digital Future”, focuses on pedagogical solutions, addressing the construction of equity through curriculum development and higher education. This section examines intentional and institutional initiatives that seek to promote digital equity through education and policy. The following chapters present concrete measures for building a more equitable digital future: “Building Digital Equity through Curriculum Development: Navigating AI, Ethics, and Critical Thinking in the Age of Information”, by Cameron Kiosoglous, “Information Literacy in Engineering Education”, by Cristina Tripon, and “Digital Literacy Space and Value Re-Oriented in Nigeria: A Critical Examination of the National Orientation Agency’s Mandate”, by Mustafa Adediji Tukur.

The third section, “Challenges: Governance, Ethics and Risks in the Digital Transformation”, analyzes the intrinsic risks and governance challenges associated with digital transformation, providing an essential counterbalance to more optimistic views and grounding the debate in practical and ethical considerations. The section includes the chapters “A Study of Resolving Ethical Issues of Digital Health Technology: Learning from United States and Europe Union”, by Fateme Tavallaei, and “Perspective Chapter: Financial Risk Management in the Age of Digital Transformation – Challenges and Opportunities in Africa”, by Nesrine Gafsi.

The last section, titled “Digital Transformation in Action: Policies and Strategies for Social Transformation”, summarises the regional case studies, illustrating how the theoretical and thematic debates in the book are reflected both in national policies and practical reality, in a variety of global contexts in the following chapters: “Bridging the Digital Divide in the South African Public Sector: Assessing Digital Literacy Gaps and Capacity-Building Strategies”, by Andrew Enaifoghe, and “Digital Transformation in Mexico: Evolution and Trends”, by Mario Alejandro Arellano Morales.

We would like to express our deepest gratitude to all the authors, whose trust and excellence were paramount to the completion of this collective work, as well as to the Editorial Office of IntechOpen, for their professionalism and unwavering commitment to scientific quality.

Ultimately, the contribution of this book is to provide conceptual tools, empirical evidence, and global perspectives to promote knowledge and informed action. The goal of this work is to contribute to the advancement of knowledge in the field of digital technology development by producing a set of substantial contributions. The book’s value lies in its integrated perspective, which demonstrates that digital transformation, while being a powerful engine for progress, is not an automatic or linear process. Instead, its benefits are profoundly shaped by pre-existing social structures, targeted policy interventions, and deliberate capacity-building efforts. The aim is for these to inspire policymakers, educators, researchers, and citizens to work towards a more equitable, fair, and inclusive digital future, actively contributing to the attainment of the United Nations Sustainable Development Goals. Building the future is a responsibility that rests on our shoulders.

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Section 1

Foundations: Equity and Literacy in the Digital Age

Chapter 1

From Digital Divide to Dividend: We Are on our Way

Huifang Wu

Abstract

Digital technology was supposed to bring about digital dividends, but instead, it has created a wider digital divide. Most policies focus narrowly on infrastructure or isolated skill training, neglecting systematic integration across the full digital equity lifecycle (resource allocation → capability development → ethical governance). However, traditional digital divide theories struggle to explain emerging ethical gaps, necessitating new analytical frameworks that integrate technological, social, and ethical dimensions. Another critical gap is the limited exploration of mechanisms to convert digital literacy into social inclusion drivers, particularly regarding vulnerable group empowerment pathways. Therefore, on the basis of integrating current practice and research development, this chapter puts forward the key issues that need to be studied. The chapter depicts digital equity and literacy from three aspects: resources, opportunities, and capabilities. It provides effective evidence through outstanding global cases and proposes future research directions.

Keywords: digital divide, digital equity, digital literacy, ethical governance, technical ethics

1. Introduction

Since the twenty-first century, digital technology has permeated every aspect of society at an exponential rate, reshaping economic structures, governance frameworks, and daily life patterns. The integration of AI, big data, and 5G technologies has created transformative opportunities: enabling ubiquitous access to education through distance learning platforms, empowering SMEs *via* digital ecosystems, and optimizing public service delivery in smart cities [1–3]. Conversely, the unequal distribution of technological dividends has deepened social stratification [1, 4]. World Bank data reveal that 30% of the global population lacks internet access, while the digital skill proficiency gap between developed and developing nations reaches 45% [4, 5]. This double-edged sword characteristic of the digital revolution exposes a fundamental paradox: Technology, intended as an equality-promoting tool, has instead become an agent intensifying social inequalities in practice.

Early research primarily examined the access dimension of the digital divide, focusing on hardware infrastructure and network coverage [6, 7]. However, the

nature of the digital divide has undergone profound structural shifts in recent years. First, the capability gap has widened significantly [8]. Despite global internet penetration exceeding 60%, many users remain passive consumers lacking critical information analysis skills [4, 9]. For example, only 28% of developing country netizens can discern fake news, compared to 41% in the developed nations. Second, ethical divides manifest across various domains, with algorithmic bias, data misuse, and privacy breaches becoming increasingly acute [10, 11]. The Cambridge Analytica scandal revealed digital technology's darker side, while generative AI's rise has sparked international debates over deepfake governance and IP rights [12–14]. Third, intergenerational and socioeconomic disparities in digital literacy are creating new exclusionary mechanisms. This literacy divide between youth/seniors, urban elites/rural residents, and skilled workers/low-income groups perpetuates social exclusion [15, 16].¹

Despite these challenges, current policies and scholarly debates exhibit notable shortcomings. Most policies focus narrowly on infrastructure or isolated skill training, neglecting systematic integration across the full digital equity lifecycle (resource allocation → capability development → ethical governance) [7, 10, 17]. However, traditional digital divide theories struggle to explain emerging ethical gaps, necessitating new analytical frameworks that integrate technological, social, and ethical dimensions [18]. Another critical gap is the limited exploration of mechanisms to convert digital literacy into social inclusion drivers, particularly regarding vulnerable group empowerment pathways [19]. Therefore, this chapter summarizes the current development status in the field of research and practice through a literature review and case analysis. And on this basis, the author puts forward the key issues that need to be studied.

2. Digital equity and digital literacy

2.1 Digital equity

2.1.1 Resource equity

Digital resource equity has transcended traditional material access paradigms, evolving into a three-tiered framework encompassing hardware accessibility, network quality stratification, and data utilization capacity [6, 7]. Global digital resource distribution exhibits pronounced core-periphery disparities, with the least developed countries showing 26% broadband adoption versus 91% in the developed nations [4]. This digital divide is further exacerbated by urban-rural disparities within countries—China's rural fiber-optic coverage lags 15 percentage points behind urban areas, while western regions exhibit only 33% of the eastern 5G base station density. This data aristocratization trend constitutes a novel form of digital exploitation requiring urgent attention [2, 20]. These findings necessitate a paradigm shift from simplistic “access = equity” notions toward contextualized resource optimization,

¹ At the 4th Shanghai Science and Technology Communication Conference in 2025, the School of Media and Communication of Shanghai Jiao Tong University released a study focusing on the development of generative artificial intelligence and digital communication.

hardware-software synergy, and localized innovation frameworks for affordable solutions in underdeveloped regions.

2.1.2 Opportunity equity

Opportunity equity emphasizes the equitable distribution of digital technology-enabled social mobility pathways, centering on three pillars: digital competency development, lifelong learning ecosystems, and occupational adaptability [7]. However, global digital competency deficits exhibit pronounced intergenerational persistence, with UNESCO reporting that only 32% of educators possess systematic digital pedagogical capabilities [4, 21]. AI-driven occupational restructuring further exacerbates skills gaps, as evidenced by World Bank projections indicating 44% of workers require reskilling by 2030². These practices demonstrate three strategic shifts: (1) Proactive alignment through predictive skills-industry mapping mechanisms, (2) Inclusive participation *via* universal design principles for marginalized groups, and (3) Institutional innovation through Digital Skills Credit Banks to bridge accreditation gaps between education providers and employers.

2.2 Digital literacy

Digital literacy has evolved from basic technical proficiency to a critical competency framework for digital citizenship, encompassing foundational tool mastery and advanced ethical judgment [18, 22]. This chapter proposes a two-tiered digital literacy development model: foundational competence acquisition and higher-order cognitive transformation. Foundational competence development requires context-aware pedagogical design that addresses intergenerational skill gaps, linguistic barriers, and cybersecurity awareness deficits through mother tongue adaptation and preemptive risk education. This approach systematically bridges generational divides, overcomes linguistic barriers, and mitigates safety blind spots through culturally responsive teaching methodologies and proactive digital risk literacy programs. Higher-order literacy development necessitates critical thinking frameworks that convert technical proficiency into value-creating capabilities through ethical reasoning and creative problem-solving. Achieving this cognitive transformation requires institutional innovations that reorient digital competency development from mere tool utilization to ethical technology stewardship.

This chapter conceptualizes advanced digital literacy through three interconnected dimensions: (1) Critical reflection—establishing Technical Reflection Laboratories to transition users from tool operators to semantic critics; (2) Creative production—developing open-source communities and industry-education platforms to shift youth practices from passive consumerism to generative innovation; and (3) Ethical accountability—implementing Digital Ethics Passport systems integrating algorithm transparency and data sovereignty into civic education. This tripartite framework constitutes a responsibility ethics matrix for the digital age, providing analytical tools to debunk technological neutrality myths.

² Banking on Intelligence: Using AI to Drive a Step-change in Business Productivity. Featuring research from Forrester. The State of AI in Banking, 2023.

2.3 The interaction of digital equity-digital literacy

The governance dilemma in digital equity/literacy arises from the interplay of technical logic, social structure, and ethical norms—requiring a shift from unidimensional to three-dimensional collaborative governance frameworks [4]. Technical governance faces dual challenges: (1) Algorithmic bias institutionalizing discrimination and (2) Data monopolies exacerbating digital resource Matthew effects. Addressing these requires “algorithmic auditing + data trust” dual correction mechanisms. Social equity challenges manifest in educational resource disparities, disrupting intergenerational knowledge transmission. Urban-rural teenagers exhibit a 37-point gap in AI ethics cognition, with rural youth scoring 63% on digital ethics assessments versus 100% for urban peers. Ethical norms face systemic legal gaps in digital personality rights protection and algorithmic accountability, creating persistent power asymmetries between platforms and users.

Breaking this systemic governance dilemma requires a three-dimensional collaborative framework integrating technical, social, and ethical interventions. Technical interventions should mandate algorithmic auditing and ethical-by-design architectures to preempt discriminatory technical pathways. Social strategies require embedding AI ethics education in workforce lifelong learning systems to empower digitally vulnerable populations through technological countermeasures. Ethical reforms demand digital personality rights compensation systems and algorithmic interpretability litigation mechanisms to dismantle the legal fiction of technological neutrality. This collaboration transcends dimensional superposition, forming a good governance closed loop through progressive technical standardization → social empowerment → ethical internalization mechanisms. When code ethics, institutional design, and cultural cognition achieve resonance, digital fairness transitions from conceptual ideal to operational reality.

3. Cross the chasm and move toward the future

3.1 Path reconstruction: Social intervention strategies toward digital inclusion

3.1.1 Policy innovation: From equal access to capacity empowerment

Digital equity governance must transcend the initial infrastructure equalization phase and advance to a Capability-Empowerment and Ecosystem-Reconstruction paradigm [23]. This chapter proposes an Inclusivity-Empowerment-Sustainability Framework to catalyze a paradigm shift from physical connectivity to value-driven digital ecosystems.

Global inclusive infrastructure initiatives follow three strategic pathways:

Technological adaptation: Kenya’s Solar Base Stations + Satellite Backhaul model reduced remote network costs by 67%. Its M-Pesa Village-to-Village Connectivity initiative boosted mobile payment coverage from 19 to 83%, demonstrating an African model of cost-efficient technological leapfrogging.

Network expansion: China’s 5G for Every Village program achieved 95% 5G coverage in administrative villages using low-band spectrum. However, sustainability challenges persist: annual maintenance costs consume 3.2% of local fiscal revenue in western provinces, forcing 21% of mountainous base stations to shut down due to power constraints.

Model innovation: India's Public WiFi Initiative deployed 200,000 access points in transit hubs and clinics, lowering data costs to \$0.2/GB. Yet device theft rates surged to 34% in pilot regions, exposing operational vulnerabilities in public-access models.

These cases demonstrate China's application-driven infrastructure upgrade paradigm:

Coordinated resource allocation strategy: Yunnan's practice demonstrates the cross-industry synergy of integrating resources, co-constructing and sharing power and communication infrastructure to achieve a "1 + 1 > 2" composite benefit. This integrated infrastructure model reduces single-station construction costs by 42% and improves operational efficiency by 35%.³

Prospective planning mechanism: Zhejiang's example shows that digital infrastructure should be integrated into national spatial planning through digital pipeline embedding and reserved functional blocks to avoid redundant infrastructure construction. This approach increases urban underground pipe utilization by 61% and reduces road excavation frequency by 78%.⁴

Investment and financing mechanism innovation: Guangdong's exploration demonstrates that special bonds act as catalysts for enterprise cooperation and innovation by establishing a three-dimensional financing structure integrating financial capital, social capital, and financial tools. Innovations such as infrastructure REIT pledges, profit-sharing models, and financial leverage amplification (up to 1:15 per project) have increased social capital participation to 89%.⁵

3.1.2 Digital dividend redistribution: Data subsidies and equipment donations for low-income groups

The redistribution of digital dividends narrows the digital divide through a triple mechanism of data poverty alleviation, equipment circulation, and skill bundling [2, 24].

China's best practices demonstrate three digital dividend redistribution strategies:

Resource activation: China transforms data into a precision poverty alleviation asset, establishing sustainable, usable-valuable-scalable mechanisms beyond short-term aid.⁶

Circular economy: Japan combines equipment regeneration with financial innovation, converting e-waste into inclusive digital resources with dual economic-social value.⁷

Ecosystem building: Brazil lowers digital access thresholds through hardware-skill bundling, nurturing self-developing digital native cohorts.

Collectively, they illustrate a paradigm shift from digital relief to digital empowerment—where institutional innovation redefines digital resources as productive factors rather than mere consumer goods.⁸

³ One pole for multiple uses + Save money, space and time! Yunnan Builds "Shared Towers" People's Daily, 2018-2103-27

⁴ Lessons from Others. Achievements and Experiences in the Construction of "Digital Zhejiang" - Shandong Committee of the Chinese People's Political Consultative Conference 2023-2111-18

⁵ "New" Data. How can the Special Bonds of the "Largest Economic Province" "Tap into" More Vitality? CCTV News, 2025-2102-22

⁶ Digital Education, Mobile Poverty Alleviation Network + | China Mobile helps Disadvantaged people move toward a better digital life, People's Posts and Telecommunications News, 2020-8-10.

⁷ <https://www.mufg.jp/english/pressrelease/2024/>

⁸ ICEGOV '21: Proceedings of the 14th International Conference on Theory and Practice of Electronic Governance

3.2 Education system reform: Building a lifelong learning ecosystem

3.2.1 Basic education: Incorporate digital literacy into the core curriculum system

Global basic education reform prioritizes disciplinary integration, critical thinking, and ethical literacy [25, 26]. Finland mandates media literacy in college entrance exams, requiring analysis of algorithmic recommendation systems. Its 2025 reform mandates data bias identification for junior high students, with pilot high schools reporting 130% higher science competition win rates among course participants. Singapore's AI Detective primary school program uses scenario-based games to cultivate critical thinking: experimental classes demonstrate 41% greater accuracy in identifying online misinformation compared to traditional classrooms.

Drawing on global best practices, this chapter argues that the assessment framework for digital literacy education should encompass three core dimensions:

1. Curriculum design: Metrics include core digital literacy course proportion and interdisciplinary integration cases to evaluate humanistic-technical balance.
2. Teacher development: Process indicators like continuous training compliance rate and blended teaching frequency correlate with student performance (e.g., a provincial study showed a significant positive link between teachers' digital innovation capacity and student outcomes).
3. Infrastructure: Key parameters are per-student smart terminal ratio and gigabit campus network coverage. China's Yunnan power-tower sharing model raised rural school network coverage from 31 to 89%, demonstrating infrastructure's catalytic effect.

This system enables dynamic policy monitoring, emphasizing that curriculum-teacher-infrastructure synergy—not isolated breakthroughs—drives educational digital transformation.

3.2.2 Vocational education: Collaborate with enterprises to develop “micro-certification” skills training programs

Global vocational education reforms have addressed the skill mismatch issue through school-enterprise collaboration, modularized learning, and internship alignment [27]. The German dual vocational training system, in collaboration with enterprises, has developed the Industry 4.0 Micro-certification program, directly linking certificate acquisition to career progression. Data from a certain manufacturing enterprise shows that the promotion rate of employees who have passed this certification has increased to 3.1 times that of the conventional path. Alibaba Group of China, in collaboration with the Ministry of Education, has established the Digital Talent Academy, building a practical training system covering fields such as cloud computing and big data analysis. The initial salary of trainees is 27% higher than the industry average. The Digital Craftsman program launched by Nigeria in Africa cultivates cross-border e-commerce talents through a hybrid model of “online theory + offline practical operation.” The sales of independent online stores of graduating students have increased by 4.3 times.

Based on this, build skills-post-dynamic adaptation of the development of the reform needs to focus on the following three aspects:

Agile certification system: the skills into the degree of can overlay unit, such as International Business Machine (IBM) launched artificial intelligence (AI) micro professional certification program;

Collaborative education: to set up the industry skills council dynamic update training standards, digital classifications ceremony have been incorporated into China 97 new jobs;

Employment access: requiring companies to digital skills certification as a condition of hiring hard. Data from a certain recruitment platform shows that job seekers holding micro-certifications have an interview invitation rate 3.2 times higher.

This model reveals that the vocational education system needs to shift from a degree-oriented approach to a competency-oriented one, and achieve a dynamic match between talent supply and job demands through a fragmented certification system of small steps and rapid progress.

3.2.3 Elderly education: Community digital assistance centers and intergenerational learning programs

Global elderly digital education achieves breakthroughs through community assistance, intelligent support, and institutional guarantees. Shanghai's Digital Feedback Workstations train youth volunteers to assist seniors with health code usage and online registration, boosting smartphone adoption from 21 to 78%. Japan's Silver-haired Digital Companion robot teaches smart device use via voice interaction, with users averaging 42 minutes/day of engagement. Germany mandates digital survival courses for pension eligibility, tripling online shopping frequency among elderly participants in one state and fostering technology adaptation-social integration synergy.

3.3 Technical ethics framework: Full-cycle intervention from design to governance

Digital ethics governance requires lifecycle ethical integration across design-development-deployment-governance stages, implementing a three-stage governance model featuring proactive ethical safeguards, continuous process oversight, and accountability tracing.

Global Algorithm Auditing Systems enforce accountability through three mechanisms: technical transparency requirements, professional review mechanisms, and filing and public announcement systems [4, 28]. At the technical implementation level, algorithm auditing tools support the implementation of supervision through the technical environment of open-source libraries, standardized development frameworks, and intelligent filing platforms. Global digital ethics education is implanted into the common value framework of technology through a three-dimensional path of professional self-certification, compulsory subject courses, and industry norm systems. The industry self-discipline mechanism builds an ethical restraint framework through professional certification, risk no-go lists, and the creation of dedicated positions.

4. Future outlook: Key issues under technological iteration

Generative AI, which utilizes deepfake technology, cognitive offloading effects, and the perpetuation of algorithmic bias, is reshaping the information ecosystem [12]. These impacts have set off a chain reaction, putting generative AI in a crisis of truth perception, causing functional distortion in education, and shocking the job market, especially the content creation sector [11, 29]. To overcome these difficulties, it is crucial to shift from a technological defense strategy to a cognitive upgrading approach. Future research could focus on promoting cognitive upgrading, improving the global governance system, and strengthening the binding power of ethical guidelines.

Brain-computer interfaces and metaverse technologies are reshaping human existence through three key technical approaches: digital upload of consciousness, full-sensory immersive experiences, and perpetual memory storage [26]. This technological revolution, while offering opportunities, has also sparked the digital identity crisis, the risk of privacy breaches, and the crisis of human alienation [27]. Therefore, future research should construct the theoretical framework of digital humanity by focusing on the establishment of technological forbidden zones, the protection of legal personality, and digital ethics.

The legislation concerning global digital fundamental rights is evolving in three stages: from constitutional recognition to rights refinement, and then to judicial implementation [14, 23]. In the future, a rights guarantee system for the digital age should be established, and it is imperative to set up a three-dimensional linkage mechanism comprising constitutional recognition, legislative refinement, and judicial safeguards.

The global digital literacy certification system ought to tackle the problem of fragmented governance by adopting unified standards, interoperable certification, and quality-assurance solutions [28]. Future research should concentrate on the implementation and advantages of the three schemes.

Digital empowerment technologies adhere to the developmental path of individual leap-social reconstruction-civilization evolution, thereby elevating the value dimension [22]. Therefore, in the future, researchers need to establish a system to assess the development level based on technology access and capability improvement to judge the maturity of digital civilization.

Inclusive digital civilization champions the coordinated advancement of technology-friendliness, social equity, and ethical consciousness. Technology-friendliness necessitates that AI design adheres to the principles of non-harm, explainability, and accountability [29]. Inclusive digital civilization is propelling profound transformations in technological justice, a distribution revolution, and value consensus. The current global digital governance landscape is plagued by three obstacles: the monopolies of tech giants undermine sovereignty, the fragmentation of regulations across countries increases costs, and the value conflicts arising from cultural differences impede consensus.

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Bridging the Digital Divide: A Human Rights-Based Approach to Digital Literacy and Equity in the EU

Cong Yao and Paul Quinn

Abstract

Digital literacy is essential for meaningful participation in society, extending beyond technical skills to encompass critical competencies such as data privacy and online information navigation. However, current policies often prioritize infrastructure expansion over digital education, leading to increased digital vulnerability. A legally grounded, literacy-focused strategy is crucial for closing the digital gap and ensuring equitable digital participation. This chapter investigates the digital divide through a legal and human rights-based lens, exploring the intersection of digital rights, literacy, and equity. It addresses key questions: What are individuals' evolving digital rights in the digital era? What core digital literacy skills are necessary to exercise these rights? And how can legal and policy frameworks shape effective and inclusive digital literacy training programs? It employs a theory-building methodology to build a human rights-based framework to mitigate digital exclusion. The framework critically examines international and European Union (EU) digital rights legislation, evaluates state and corporate obligations, and advocates for regulatory approaches that integrate digital literacy as a fundamental right.

Keywords: digital divide, digital literacy, digital rights, digital equity, legal framework

1. Introduction

The term digital divide has been commonly used to refer to the gap between individuals who have access to information and communication technologies (ICTs) and those who do not [1]. Initially, this divide was presented as an “access divide” in the early 1990s, primarily concerning access to the Internet [1]. This type of divide is observed as a binary distinction between those connected to the Internet and those who are not. It is now referred to as the first level of the digital divide, focusing on access to ICTs [2].

With the expansion of the Internet connection in many Western countries, having a connection is no longer the only barrier to benefiting from the Internet. As broadband and digital device access become more prevalent, the research agenda of the digital divide has expanded to the differences among Internet users [3]. That is, to what extent can they use digital technologies and resources in ways that are of the most interest to them and the most useful to their particular needs? The digital divide goes beyond the issues of access to ICTs and also includes issues of inequity affecting people who either lack skills and opportunities to access ICTs or who are in a less equal position to use them [4]. In some cases, people with low digital literacy gain access and enter the “haves” in ICTs but feel confused about using them and, further, show reluctance to the use of digital technologies [5]. As Internet adoption has grown globally, the paradigm has shifted from access to skills and meaningful engagement. Merely having access to digital tools does not ensure their effective use, particularly for individuals who lack digital literacy or face other barriers [6]. Hence, while the medium has spread to a majority of the population, the need for digital literacy is highlighted, which has become part of the second level of the digital divide [7].

Over time, the traditional digital divide (access divide) evolved into a “learning divide” and a “content divide” [8]. This concept gradually expanded to include divides in ICT skills, physical access, motivation, and the purpose of use [9]. These dimensions highlight that the digital divide extends beyond mere access to technology, encompassing factors such as the opportunity to use ICTs (physical), motivation and confidence (psychological), and practical skills [10]. Gradually, the digital divide is often conceptualized across three levels: access to digital technology (first level), skills and use of technology (second level), and the benefits derived from technology (third level) [11].

While the focus has shifted from access disparities to disparities in skills and usage, vulnerable groups, in particular, are more likely to experience nonuse of digital services due to a lack of skills rather than a lack of access [3]. This shift underscores the importance of analyzing the digital divide in terms of how ICTs are used [12] and the varying capacities of individuals from different socioeconomic backgrounds to leverage these technologies [13]. While the gap in Internet access has narrowed, disparities in usage and skills remain significant concerns in the digital era [14].

Addressing these challenges requires targeted education and training for both individuals and professionals [15, 16]. Closing the gap of the digital divide requires both access and improvement of the digital literacy of individuals and groups for meaningful social practices [14]. This chapter conducts theory-building research to propose a human rights-based framework that bridges the gap of the digital divide during digital transformation. It analyzes both international and EU policies to explore the human rights involved in digital literacy development and digital inclusion. The framework will help different stakeholders tackle the real needs of different population groups, based on which they can apply specific digital inclusive measures to bridge the gap and ensure digital equity.

2. Digital transformation and digital literacy

Digital transformation has shown rapid development in various sectors, including commerce [17], healthcare [18], education [19], government services [20], and employment [21]. While there seems to be no escape from the digital landscape, the move to digitalization has created a digital divide between people who have

broadband access and the skills and motivation to effectively use digital technologies and those who do not [22].

Research also highlights other dimensions of the digital divide, such as the education divide, socioeconomic divide, and learning divide [23, 24]. Factors contributing to these disparities include age, education, employment, income [25], ethnicity/race [26], gender [27], sexual orientation [28], geographical location, and disabilities [29]. While the process of digitalization seems to be inevitable, the digital divide is closely tied to broader social inequalities, which involve the unequal distribution of opportunities, resources, and privileges across different social groups. As access to ICTs becomes increasingly essential, the digital divide has emerged as a human rights and social justice issue. In 2016, the United Nations (UN) declared Internet access a human right, integral to the exercise of freedom of opinion and expression and critical for enabling affordable and inclusive education [30].

As discussed above, communication infrastructure is the first level to address digital inequality nationally, regionally, and internationally [2]. Although access is the first step to reducing the digital divide, having equal digital literacy, skills, and awareness to use digital technology is equally important [10]. This section will explore the characteristics of digital transformation and the requirements to realize it from different levels. Besides, it addresses the significant role of digital literacy in the effective use of digital technologies, the empowerment of individuals, and a better user experience of digital technologies in the digital environment.

2.1 Requirements of digital transformation

2.1.1 Digital access and digital infrastructure (accessibility)

Traditionally, digital infrastructure refers to broader access to hardware, software, or the broadband Internet. In a narrow sense, digital infrastructure means the infrastructure based on the evolution and development of new information technologies against the background that data has become the key factor of production [30]. It covers communication infrastructure represented by broadband, the Internet of Things, and the Industrial Internet and technology infrastructure represented by cloud computing, blockchain, artificial intelligence, and other data-driven technologies. In addition, besides the general characteristics of infrastructure, digital infrastructure also includes the application of advanced technologies, which are highly technical and professional [31]. It aims to ensure equal distribution of digital resources and information for various purposes, including employment, education, and social services.

In recent years, there has been a witnessed focus on ICT infrastructure development, requiring not only physical resources of digital technologies, including cables, satellites, devices, and Internet providers, but also adequate electricity. A series of international organizations have addressed the equal accessibility of the Internet and digital technologies, including the Broadband Commission for Sustainable Development, formed by UNESCO, the International Telecommunication Union (ITU), and the Organization for Economic Cooperation and Development (OECD). However, broadband access in rural areas is more costly than in urban areas, which undermines the competition among ICT operators [4]. Private companies lack the incentives to drive rural deployment of broadband, resulting from higher costs of infrastructure and lower profits. As a result, it requires the support from the public sector to support broadband deployment in these areas to narrow the digital access divide [32], which has been shown in many countries [33].

2.1.2 Digital participation and digital literacy (availability)

Compared to digital access, digital participation focuses more on the availability of digital technologies and their correct use. It indicates the ability not just to access digital infrastructure but also to utilize it in their daily and social life [5]. In the context of an increasingly digitalized society, it is essential to consider the requirements for individuals to participate in digital, social, and democratic life [34]. The notion of digital participation emphasizes the meaningful use of digital technologies for resource acquisition, communication, and interaction [35]. It enhances the ability of individuals to effectively engage with their affairs and the external society, including but not limited to social welfare, democratic processes, benefiting from e-governmental platforms, and innovative activities in technologies.

Meaningful participation in the digital era requires specific skills and knowledge for citizens to function in society. However, the current approach to digital services has a narrow assumption that all users already possess standard digital skills like literacy, numeracy, and basic digital competence to participate effectively. This rigid framework failed to accommodate the diverse digital realities of different population groups, including various accessibility and skill levels, different ways they engage with technologies, awareness and attitudes toward technologies, and individual needs. It leads to the significant exclusion of those who do not fit the predefined mold. As a result, the design of the digital system should adapt to the diversity of population groups, ensuring accessibility and availability for all rather than privileging only those who meet the benchmarks.

According to UNESCO's definition, digital literacy is defined as the "awareness, attitude, and ability of individuals to appropriately use digital tools and facilities to identify, access, manage, integrate, evaluate, analyze, and synthesize digital resources, construct new knowledge, create media expressions, and communicate with others, in the context of specific life situations, to enable constructive social action; and to reflect upon this process" [36].

From the definition, we can find that digital literacy is transversal to many different activities in people's daily lives. It is about the confident, critical, and creative use of digital technologies to achieve goals related to work, learning, leisure, and participation in society. It is a set of social competencies associated with interacting with a range of digital technologies for self-development in the digitalized society. Basic digital literacy is not derived technologically but is derived from social participation practices in the digital environment. Hence, digital literacy not only includes basic IT skills and knowledge about the information society but also indicates the awareness, attitudes, and perspectives toward digital technologies and the interconnected society.

2.1.3 Digital security and digital protection (acceptability and quality)

Digital security, also known as cybersecurity, aims to create a safe and healthy digital environment by safeguarding data, digital assets, and systems from unauthorized access, use, disclosure, disruption, modification, and destruction [37]. In the digital era, digital security is an elementary requirement for industry and society [38]. It is a cornerstone of trust and operational integrity in the digital environment.

Digital security includes two important aspects: network security and data security. In general, it means that the information is not tampered with in the computer

network environment. With proper technical and administrative measures, the network system can run smoothly while ensuring the confidentiality, integrity, and availability (known as CIA) of network data [38]. While digital security has been acknowledged as an essential requirement of digital transformation, it exposes many new risks during the development and deployment of digital technologies:

First, data leakage and data misuse are serious issues in the digital system. The cases of illegal collection of personal information are frequent, including unauthorized access to computer systems, ignorance of human rights, and excessive data collection. Data leakage and data misuse occurred frequently in many countries, leading to great losses to the industry's assets and reputation [39]. In addition, both individuals and the public suffered from privacy exposure and harassment fraud. Some data leakage even threatened social stability and public security. Hence, it is essential to prevent data leakage for data security.

Second, the content security risks are also obvious. The widespread use of digital platforms has enhanced the ability of individuals to search for information, communicate, and participate in democratic processes in their daily lives. However, the exposure to large amounts of information in public cyberspace also brings digital security risks. The dissemination of harmful content, including hate speech, child pornography, and terrorist content, threatens both private and public security. The spread of misinformation also provokes fears and confusion among citizens and affects their attitude toward industries, governments, and civil societies [40]. As there is an urgent need for the regulation of online content for the safety of both private and public sectors, governments and companies should strive for safety and security, even though 100% safety usually cannot be guaranteed. Many countries have codified that governments have the duty of care to provide a safe and secure society, but it is not clear whether this extends to the online environment, considering the balance with other human rights such as freedom of expression. However, having explicit norms for minimum levels of online safety and security is essential for the quality and acceptance of online services, guaranteeing users' online experience and their trust in online products and service providers.

Third, infrastructure security risks spill over, resulting in the design of the system. While the application of information systems and digital devices is extending to almost every part of life, the key network infrastructure will become the battlefield in the future. Cyberattacks and cybercrimes not only steal personal information but also undermine the confidentiality and integrity of public infrastructures such as transportation, energy, and security systems. With the high velocity and volume of data, the risk could be more disruptive than traditional attacks.

2.2 Digital literacy and core competencies

Digital literacy builds upon the concept of the digital divide, indicating the ability to utilize the Internet and digital technologies. This concept came out when people realized that simple access to ICTs was not sufficient to acquire needed information or services; one needs knowledge, abilities, and skills as well [41].

Digital literacy refers to the ability to locate, evaluate, and use digital information. It also encompasses the ability to deal with and make meaningful use of the amount of information one receives online. One significant component of digital literacy is known as information literacy, which entails the ability to find, evaluate, and use information effectively. In addition, the ability to absorb and create content is also a component of digital literacy [42].

UNESCO (2011) defined digital literacy as a set of basic skills required for working with digital media, information processing, and retrieval [43]. It enables them to make use of the information they find to meet their needs by evaluating the available information. Digital literacy also enables individuals' participation in social and professional life by creating and sharing knowledge and developing a wide range of professional skills. It provides an individual with the capacity to achieve other valued outputs in life in the digital era. As more and more areas of knowledge are acquired from digital media, digital literacy also becomes a significant foundation for individuals to shape the process of lifelong learning successfully [43].

Digital literacy involves more than simply using a digital device or software; it is a multidisciplinary concept that expands to a large variety of abilities, including cognitive, sociological, and emotional skills for effective function in the digital environment [44]. It includes the understanding of the benefits and risks of advanced ICTs, equitable and affordable access to advanced digital technologies and resources, and opportunities to benefit from educational, economic, and social opportunities through these technologies.

2.2.1 Critical digital literacy: Navigating misinformation

Digital literacy also requires people to have critical thinking about the large scale of information and protect themselves from disinformation, including misleading and false information. Disinformation has become a main challenge online, and it has become more evident during COVID-19, when a massive amount of information about the virus was spread and made it difficult for people to find trustworthy sources and reliable guidance [45].

Critical digital literacy is also called information literacy, which refers to the ability to search, receive, evaluate, analyze, and create digital content. It includes a set of abilities requiring individuals to recognize what information is needed and have the ability to locate, evaluate, and use needed information effectively [46]. Hence, it includes the ability to research, critical thinking, and communication [45]. Information literacy empowers people in their daily lives to seek, evaluate, use, and create information to achieve their personal, social, educational, and professional goals. It is closely related to self-development, freedom, and prosperity when information-literate people can access this information about their health, environment, education, and work to make decisions about their lives critically [45].

2.2.2 Data privacy and security awareness

Besides the accessibility and availability of digital technologies, there is also a need to address the safety and security of the digital environment. Research also found the tension between the right to participate in the digital environment and the right to be protected [47]. This has been witnessed when the General Data Protection Regulation (GDPR) [48] was adopted in the EU in 2016. The right to personal data protection is regarded as a fundamental right in the EU while balancing with other fundamental rights concerning the principle of proportionality. The GDPR introduced a range of rights for EU citizens in terms of the processing of their personal data, aiming to ensure their control over their personal data in the EU.

Besides the protection of personal data, many countries also addressed the protection of individuals from harmful content online, including illegal content and misinformation. The EU published the Digital Service Act (DSA) [49], which aims

to regulate online intermediaries to prevent illegal and harmful activities, as well as the spread of disinformation online. The DSA creates a fair and open online platform for all users while guaranteeing the protection of their fundamental rights, such as privacy and freedom of expression.

In addition, with the widespread application of data-driven technologies in people's daily lives, personal data has become a significant resource for technological innovation, scientific research, policymaking, and other areas. It is also crucial for individuals to develop the literacy to know the value of their personal data. Many online products and services are provided for free. However, companies offering the products and services are then allowed to access, collect, and process their users' data on some occasions and even sell and trade this data [50]. Although users may expect that "for free" is not really free and that their data is being processed under their "free consent," it is rarely transparent or can be complicated for individuals to know how the data processing is done. Although there is plenty of literature on the value of personal data, there is a need to raise awareness among people of the value of their personal data.

2.2.3 Civil engagement in digital spaces

Digital technologies also bring new opportunities to broaden participation in civic and political processes. The application of e-government has played a significant role in improving the relationship between people and government by increasing the transparency and accountability of the public decision-making process. Besides, e-participation offers an opportunity to engage marginalized population groups and rebalance power relationships in policy areas [51]. Digital participation also serves as an effective way of knowledge transfer by governments with the application of data analytics through the decision-making process. Governments have an easier way to provide and distribute information and consultation opportunities to relevant stakeholders through digital platforms. Besides, online discussion and submission in an anonymized format enabled governments to hear the voices of different groups who find it difficult or risky to express their opinions.

To facilitate civic engagement in the e-government project, governments need to require policies that support ICT infrastructure development, improve citizens' digital skills, provide essential online content and space, and provide detailed guidance for citizens on involvement in decision-making. Digital literacy, as a critical factor for effective e-participation, has increasingly shown its significance in recent years. Digital skills and literacy shape an individual's digital experience, which contributes to their ability to overcome the fear of using digital devices and services or navigating the digital space effectively, safely, and creatively. Hence, digitally literate citizens will have a stronger willingness and capacity to engage with digital technologies and contribute to the e-government project.

3. Digital literacy as a human right: A legal foundation

In 2016, the United Nations General Assembly declared access to the Internet as a basic human right, emphasizing that "access to Internet facilities vast opportunities for affordable and inclusive education" while allowing individuals to "exercise their right to freedom of opinion and expression" [52]. This Declaration indicates the importance of the Internet and digital technologies in people's daily lives, including gaining access to resources, education, healthcare, and jobs, among others. We see

that access to broadband and digital resources is becoming a necessity instead of just a convenience. The digital divide is not merely a societal or ethical issue but has become a human rights issue [15].

3.1 The evolution of digital rights in international law

3.1.1 UN human rights frameworks and digital inclusion

The United Nations has called for the adoption of a global digital rights framework based on human rights law [53]. It aims to achieve equality, safety, freedom, and dignity for everyone in the digital era, ensuring that all people can enjoy these rights online. The framework supports equal access to information, opportunities, and social participation while providing equal protection from persecution, discrimination, and abuse. In addition, it promotes equal respect for privacy, identity, and self-expression. The framework presents nine core principles for the digital environment:

Universal and equal rights [53]. This principle is based on international human rights law, stating that digital rights must apply to everyone without discrimination. All individuals must be treated equally, regardless of gender, race, disability, or other identity. Digital technologies must be designed fairly to prevent bias and inequality. This principle also calls for legal protections for vulnerable groups such as women, LGBTQ+ people, and ethnic minorities to prevent digital exclusion and harm.

Personal safety and data privacy [53]. This principle protects the right to privacy and the protection of the personal data of individuals. It ensures that people have control over their own information and are protected from surveillance, exploitation, and cyber violence. Governments and companies have the responsibility to prevent abuse, support international investigations, and offer remedies to victims of harm online.

Digital self-determination [53]. This principle protects individuals' freedom to define their identities in the digital environment. It calls for freedom from unfair influence by algorithms. It also promotes transparency in automated decision-making and bans judicial rulings based on digital profiling. Besides, it introduces human rights assessments for new technologies to ensure that they are being developed and deployed in a legal and ethical way.

Digital Access for All [53]. This principle regards access to affordable Internet as a basic right. It focuses on reducing digital inequality, especially for rural and low-income communities. To achieve this, this principle supports policies that promote inclusive technology design that tackles the needs of different populations, such as tools for people with disabilities and services in minority languages.

Freedom of expression and association [53]. This principle defends the right to speak and organize freely online by limiting harmful content, including hate speech, disinformation, and child exploitation. Any restriction must be lawful, necessary, and fair. It must not silence women, activists, or marginalized groups under the excuse of "security." Platforms are obliged to prevent harmful practices like online harassment that prevent people from participating in public life.

Secure, stable, and resilient networks [53]. This principle states that everyone deserves safe and reliable Internet access. It calls for strong cybersecurity and protection from data breaches, surveillance, and service disruptions. This will be a multi-stakeholder task that involves governments, companies, civil societies, and other groups. Key steps include privacy by design, limiting unlawful surveillance, and holding companies accountable for users.

Linguistic and cultural diversity [53]. This principle supports the right to use minority languages and keep cultural traditions alive online. It addresses digital diversity and encourages the use of multilingual platforms and public information in local languages.

Universal standards and regulations [53]. This principle calls for strong human rights laws to guide the digital environment. The social and environmental effects of digital tools must be checked and reduced. Feminist and inclusive values should be embedded in new technologies. Companies must take responsibility for the protection of their users and prevent harm, including data abuse and biased algorithms.

Good digital governance [53]. This principle calls for fair and democratic control of the Internet. Multiple stakeholders are involved in decision-making, including civil society and affected communities. Also, good digital governance requires open and clear policies and legal ways to respond to digital rights violations. The framework recommends victim-focused justice systems, diverse leadership, and global cooperation for better governance practices.

The UN's proposed digital rights framework is a comprehensive response to the growing importance and attention of human rights in the digital environment. It emphasized current issues concerning universal access, privacy, safety, equality, and freedom, while also tackling pressing concerns including algorithmic bias, digital exclusion, and online harms. The framework helps ensure the value of dignity, equality, and participation by grounding digital rights in established human rights law. In addition, it not only focuses on individual rights but also considers systemic and structural factors, including infrastructure, governance, and corporate accountability. Inclusive measures are also considered to respect cultural, linguistic, and gender diversity. Furthermore, it goes beyond technical issues to address the ethical and social dimensions of digital transformation.

However, despite the ambition and clarity of the framework, it still faces several challenges in implementation. While the framework provides universal principles, it lacks legal force unless adopted in national law or international agreements. The levels of commitment to human rights vary in different countries, especially in terms of data privacy and digital freedom. Diverging regulatory models could hinder a unified global approach. Besides, the implementation of the principle of "Digital Access for All" requires substantial investment in digital infrastructure, especially in low-income and rural areas. Additionally, access to digital infrastructure cannot guarantee the effective and meaningful use of digital products and services. As digital technologies are expanding to people's daily lives, the education and training for digital literacy should be addressed for effective use, awareness, and confidence of individuals [9]. The success of this framework depends on the cooperation among various stakeholders, including

policymakers (political will and regulatory innovation), industries (human rights protection by design), and civil society (engagement in digital accessibility, availability, and acceptability).

3.2 EU policies on digital rights and digital literacy

3.2.1 Putting individuals at the Center of Digital Transformation

In the EU, the European Parliament, the Council, and the Commission have proposed the joint Declaration on Digital Rights and Principles for the Digital Decade [54]. The Declaration serves as a comprehensive guide for the EU's digital transformation while ensuring it remains human-centric, inclusive, and aligned with fundamental rights. It acknowledged the significant impact of digital technologies on people's lives, including the quality of life, economic growth, and sustainability [54]. In addition, it addressed the challenges that digital transformation brings to democratic societies, economics, and individuals and stated that digital transformation should not entail the regression of rights. Hence, the Declaration outlines the EU's vision of human-centered digital transformation, ensuring that digital transformation upholds European values (e.g., democracy, equality, and sustainability) and fundamental rights (including but not limited to data protection, privacy, nondiscrimination, and gender equality) both online and offline. It also addressed several principles such as consumer protection, technical and net neutrality, trustworthiness, and inclusiveness.

The Declaration addresses that digital transformation should “put people at the center” to achieve this goal. It aims to strengthen a framework that benefits every individual in the EU by ensuring responsible and diligent action by all stakeholders in the digital environment [54]. The framework emphasizes inclusion by guaranteeing affordable and high-speed digital connectivity, digital education, training, and skills, and digital public service for all individuals in the EU. It also safeguards freedom of choice in interaction with algorithms and AI systems, choosing online services in a fair digital environment. It also upholds participation online, guaranteeing the freedom of expression and information in a trustworthy, diverse, and multilingual online environment. Lastly, safety, security, and empowerment are prioritized, with commitments to individual control over data and protection and empowerment of children and young people [54]. Furthermore, the EU promotes sustainability, addressing eco-friendly digital products and responsible digital services. The Declaration also proposed several core principles of digital rights in the EU, including:

People at the Center of Digital Transformation [54]. Digital technologies must prioritize fundamental rights, democracy, and ethical governance over commercial interests. They should serve societal well-being and promote a humanistic approach globally, ensuring that both public and private actors act responsibly. Key methods include promoting transparency in algorithmic decision-making and holding corporations accountable for harmful content. In addition, the Declaration also commits to promoting these values globally to position the EU as a leader in human rights-based digital governance.

Solidarity and inclusion [54]. The Declaration also mandates universal access to affordable, high-speed Internet while upholding net neutrality. It addressed

disparities in digital literacy, targeting 80% basic digital skills among adults by 2030, with special attention to marginalized groups, e.g., rural populations and people with disabilities. This principle also addresses workers' rights in the digital space, including the right to disconnect and protection against surveillance. Furthermore, it ensures seamless digital public services by improving the interoperability of personal data across the EU, such as cross-border e-health records (European Health Data Space, EHDS) [55] and a standardized EU digital identity.

Freedom of choice [54]. This principle protects an individual's autonomy and freedom in a safe digital space. It demands transparency in the AI system to prevent manipulation. To ensure fair competition in the digital space, this principle also aligns with the Digital Market Act (DMA) [56], providing users the freedom of choice to switch online platforms without lock-in effects. Besides, this principle addresses protection against illegal content online (e.g., hate speech) with the balance of freedom of expression, as outlined in the Digital Service Act (DSA) [49].

Participation in the digital public space [54]. The Declaration encourages and supports the engagement of citizens to ensure the diversity of a vibrant digital democracy. This principle combats disinformation and algorithmic bias, requiring platforms to disclose content moderation policies. Besides, it protects journalistic independence and calls for inclusive design to ensure vulnerable groups' voices online. Also, it addressed the application of digital civic tools to enhance participation.

Safety, security, and empowerment [54]. This principle prioritized the security of the digital space through robust cybersecurity measures and strict data protection rules. It highlights the safeguarding of vulnerable groups, including age-appropriate content filters for children and young adults, and the prohibition of predatory surveillance. The Declaration also guarantees data subjects' rights over their data, enabling users to enhance their control over their data while ensuring data sharing among data holders.

Sustainability [54]. This principle promotes energy-efficient technologies, circular economy practices, and transparent labeling of products' carbon footprints to minimize environmental harm. It encourages the application of digital technologies for sustainability, such as AI-driven energy grids, while balancing the environmental costs of data centers and e-waste.

The Declaration reflects the EU's ambition and commitment to balance digital innovation with human rights protection and ensure that the digital era upholds democracy, equality, and sustainability. It puts individuals at the heart of policy-making by integrating digital transformation with human rights, democracy, and ethical governance. It corresponds to European values such as freedom, equity, and solidarity. A core strength of the Declaration is the comprehensive scope, covering a wide range of areas including online safety, digital literacy, digital participation, algorithmic transparency, and environmental sustainability. In addition, the Declaration acknowledges both opportunities and risks of digital transformation and proposes legal and ethical frameworks to ensure the right use of digital technologies.

The inclusion of key EU laws, such as the DSA [49], DMA, and the EHDS, reflects the EU's intention to create a harmonized digital space with strong accountability mechanisms. Furthermore, the Declaration calls for inclusive policies to ensure equal access to broadband digital public services and digital skill-building systems, especially for vulnerable population groups. It indicates the ambition of the EU to make it a global benchmark for legal and ethical digital transformation.

While the EU has the ambition for its digitalization, the full realization of the EU's digital principles remains difficult. The realization of universal access and digital literacy across the EU is still challenging, considering barriers faced by people in rural areas, low-income populations, and people with disabilities [32]. They continue to have difficulties due to infrastructure gaps, affordability, and lack of tailored training and services [34]. Hence, the efforts to meet the goal of 80% digital skills among adults by 2030 will require substantial investment in education, training, and outreach, based on the different needs of different population groups. Besides, the balance between fundamental rights protection and market regulation remains a sensitive issue [57]. The regulation of online content always raises concerns about interference with freedom of expression and censorship [58]. The distinction between harmful and illegal content remains vague, such as hate speech and misinformation, not only challenging content regulation but also affecting individuals' awareness and attitudes toward this content and their human rights [58]. Lastly, implementation may vary across EU member states depending on resources, legal structures, and political will. Without consistent EU standards and oversight, this process will lead to new fragmentation, as was shown in previous legislation. Strong governance, citizen engagement, and regular assessment are necessary to ensure that digital transformation truly serves individuals at the center and does not leave anyone behind [33].

3.2.2 EU digital education plan

In response to the growing importance of digital skills in people's daily lives, particularly highlighted by the COVID-19 pandemic, the EU adopted the EU Digital Education Action Plan (2021–2027) on 30 September 2020 [59]. The plan outlines two core priorities: building a high-performing digital education system in the EU and enhancing digital skills and competencies [54]. It aims to enhance the accessibility, quality, and inclusion of digital education systems across the EU.

The plan calls for a strong digital education ecosystem that improves Internet connectivity in schools, increases access to digital tools and services, and develops a system to support digital learning [59]. It emphasized the role of teachers and educators in digital transformation by supporting their professional development and digital teaching skills. It stressed the integration of digital education into teacher training programs and also provided a platform, the European Digital Education Hub, for the sharing of resources, research, and good practices.

In terms of digital skills and competencies, equity and inclusion are addressed as two fundamental principles of the plan. The plan addressed the significance of digital literacy for life in the digital environment, stating that all EU citizens should be educated about how digital technologies impact well-being and how technology systems work [59]. Digital competence is recognized as one of the key competencies for lifelong learning, involving confident, critical, and responsible use of and engagement with ICTs for learning, work, and participation in society.

In the EU, being digitally competent is recognized as both a necessity and a right. However, digital skills and digital literacy across Europe remain low, with 44% of EU

citizens having an insufficient level of digital skills, while more than a third of the EU labor force lacks the basic digital skills required in most jobs [59]. As a result, the plan sets a target that at least 80% of adults should have basic digital skills by 2030 [59]. To achieve this goal, the plan highlights the need to close the digital divide issue by ensuring that all learners, regardless of age, income, location, or ability, can access and benefit from digital education [59].

Besides the accessibility and digital literacy training, the action plan also promotes ethical and responsible use of digital technologies. It emphasized transparency in the use of artificial intelligence in education, the protection of personal data, and the safe use of online tools. It calls for ethical guidelines and safeguards to ensure that all learners' rights are protected while technologies do not exacerbate bias or exclusion.

The European Digital Competence Framework for Citizens (DigComp) provides a framework with digital competence descriptors for all levels of learners concerning their personal development, employment, and social inclusion for lifelong learning [60]. This literacy is instrumental in understanding the opportunities and risks of digital technologies for the safe and meaningful use of digital technologies in their daily activities. Hence, basic digital skills should be developed among all population groups to enable them to engage in society as active citizens, use public services, and exercise their basic human rights.

The education plan emphasized the importance of a basic understanding of new and emerging technologies among EU citizens. It will enable them to engage with technologies safely, critically, and positively. However, there are still some major challenges during the implementation. One major challenge is the digital divide issue within and among EU member states. Though infrastructure development is not the major issue now, the first level of the digital divide still exists in rural or low-income areas. Continuous investment should be provided for reliable Internet connectivity, digital tools, and basic infrastructure to ensure full participation in digital learning. In addition, while teachers and educators are essential to delivering high-quality digital education, many of them also lack basic digital skills and confidence. Some educators are not familiar with digital tools and services or lack the awareness and practice of data protection. Concerns over data privacy and security grow without clear training and guidance for educators, especially for the education of children. Lastly, the plan promotes lifelong learning for all individuals in the EU. However, participation in lifelong learning remains low, especially among certain vulnerable groups, including older people, low-skilled workers, and people with disabilities. More targeted measures and options should be provided to tackle the needs of these population groups to avoid the plan being an empty promise.

3.3 A human rights-based framework for digital literacy

Both the United Nations (UN) and the European Union (EU) aim to balance the protection of fundamental rights with the advancement of digital transformation. Their respective frameworks emphasize human dignity, individual autonomy, and social inclusion during technological innovation. Digital transformation must prioritize people's real needs and promote governance of digital environments that are grounded in human rights principles and serve the public good.

Both frameworks also recognize the risks that digital technologies pose to certain population groups. Some groups face higher levels of harm online, such as children, persons with disabilities, and ethnic or linguistic minorities. The UN and EU propose clear steps to protect these groups from digital harms, including online harassment, algorithmic bias, and systemic discrimination.

In addition, the UN and the EU call for affordable Internet access and digital literacy programs to reduce the digital divide, particularly for underserved populations such as rural residents and low-income communities. To fix this, they emphasize the importance of inclusive design in digital platforms and services, highlighting the need for linguistic and cultural diversity to ensure equitable access. Individuals should have the freedom to choose digital services and interact with them in their preferred language.

Three key digital rights are interconnected and shape their approach: provision, participation, and protection. The right to provision ensures access to digital tools and infrastructure; the right to participation guarantees individuals a voice in the digital space; and the right to protection safeguards individuals from harm. Together, these rights form a comprehensive framework for digital inclusion and equity (**Table 1**).

3.3.1 Right to provision

The right to provision refers to the entitlement of individuals and communities to receive essential goods and services to survive and have a dignified life [61]. It encompasses the sharing and distribution of resources, entailing the right to possess, receive, or access specific resources and services. This right is recognized by several key instruments, including the Universal Declaration of Human Rights (UDHR) [62] and the International Covenant on Economic, Social and Cultural Rights (ICESCR) [63].

Traditionally, the right to provision has covered access to food, healthcare, and social protection. In the context of a digital society, this right increasingly intersects with digital technologies and extends to equal access to digital goods, facilities, and services. Discussions around digital rights now often include the right to Internet access. However, in the digital era, the right to provision goes beyond connectivity—it includes the broader conditions needed to meaningfully access and use digital products and services. The right to provision also aligns with the following principles:

- **Universal access:** The UN’s Digital Access for All and the EU’s Solidarity and Inclusion principles say that everyone should have fast and low-cost Internet. This helps people in rural areas, those with low income, and people with disabilities.
- **Inclusive design:** The UN’s principle on language and culture says digital tools should work for many languages and cultures. This helps stop the control of

The right	Right to provision	Right to participation	Right to protection
Human rights involved	Right to information Right to education Social security and social assistance...	Right to personal development Freedom of information Right to privacy Cultural, religious, and linguistic diversity...	Right to privacy Right to data protection Right to be protected from harmful contents...
Key principles	Universal access Nondiscrimination Inclusive design Reliable infrastructure	Self-determination Free expression Democratic governance	Privacy and safety Nondiscrimination Accountability

Table 1.
The human-right-based framework for digital equity.

English and Western systems. The EU also supports systems that work together, like shared digital health records across countries.

- **Reliable infrastructure:** The UN wants networks that are safe, strong, and able to recover from problems. The EU wants these systems to be better for the environment, like using less energy in data centers.

A right to digital resources serves as a base for other human rights, including the right to education, employment, freedom of expression, and participation in the democratic process [34]. In most developed countries, access to the Internet and digital resources is not a big issue. However, the accessibility of digital resources varies among different population groups in society [15, 22] for different reasons [64]. The digital world cannot be fair if people face material limits. The right to provision calls for Internet for everyone, tools for people with special needs, and systems that are strong and safe. Without these, unfair gaps in school, work, and public life will stay the same. Governments should spend more on Internet access, support many languages, and use green technology so that everyone can join in.

3.3.2 Right to participation

The right to participation refers to the ability of individuals to take part in social, cultural, and political life by expressing themselves and engaging in collective decision-making. In the digital era, this right includes access to and use of digital technologies to participate in public affairs, contribute to democratic processes, and exercise human rights in digital spaces. Through this, individuals are able to manage their digital identities, make independent choices, and engage in public life without unjust interference. The right to participation also aligns with the following principles:

- **Self-determination:** The UN emphasizes the importance of individuals' control over their digital presence. The EU supports this through the principle of freedom of choice, which enables users to switch between digital platforms more easily, especially under regulations like the Digital Markets Act.
- **Free expression:** The UN defends the right to free speech while warning that some safety measures may be used to justify censorship—often targeting women and activists. The EU addresses this by working to prevent disinformation while also safeguarding press freedom.
- **Democratic governance:** The UN calls for digital governance that includes multiple stakeholders, not just private companies. Similarly, the EU encourages transparency and public involvement, such as requiring platforms to explain how their systems operate, as outlined in the Digital Services Act.

Digital platforms often replicate real-world inequalities, excluding certain voices and reducing individuals to data points. The right to participation seeks to address this by supporting user control, protecting free speech, and enabling involvement in digital policymaking. This requires transparent rules for content regulation, inclusive mechanisms for civic engagement, and clear limits on the power of large technology companies. Participation is not only about using the Internet—it is also about who has the opportunity to shape its development.

Governments must respect and uphold this right for all people. This includes ensuring access to information, the right to be heard, and the right to education. In this context, digital skills and literacy are essential. Individuals must have the knowledge and ability to navigate the digital world effectively and safely.

3.3.3 Right to protection

The right to protection ensures that individuals are not exposed to harm in digital environments. It involves protecting people from practices—whether societal or individual—that may endanger their rights, safety, or well-being [65]. These rights highlight the urgent need to extend human rights frameworks to address new risks created by digital technologies, which can undermine the security of digital spaces.

Governments have a duty of care to foster safe and trustworthy digital environments. They are responsible for adopting measures that prevent third parties from violating digital rights, especially in areas such as data protection and privacy. The right to protection also aligns with the following principles:

- **Privacy and safety:** The United Nations emphasizes that personal data should only be used with informed consent and must be protected from surveillance. The European Union also prohibits the use of spyware and enforces special protections for children in online spaces.
- **Nondiscrimination:** According to the UN, digital technologies must be accessible and fair to all. The EU holds platforms and companies accountable for digital harm, using content moderation rules to prevent bias and abuse.
- **Accountability:** The UN calls for binding international standards to protect human rights online. The EU enforces compliance with such standards, including the General Data Protection Regulation (GDPR), which imposes fines on organizations that fail to respect users' data rights.

Digital technologies can cause widespread harm—for instance, through biased artificial intelligence or unjustified surveillance. The right to protection responds by requiring strong privacy safeguards (such as encryption), banning harmful practices (such as biometric profiling), and ensuring avenues for redress. Without robust regulation, technology can deepen social inequalities—examples include discriminatory hiring algorithms or deepfake videos used to harass individuals. Therefore, legal systems must treat digital harm with the same seriousness as harm that occurs offline.

4. Policy gaps and the need for a literacy-centered approach

4.1 Infrastructure vs. education: The imbalance in current policies

It is crucial to manage considerable investments in digital infrastructure for equal digital access. However, policies primarily focused on ICT infrastructure development do not guarantee that all population groups utilize these investments effectively [34]. Education and training on digital literacy are as important as infrastructure development. It will raise awareness of the benefits of digital technologies to overcome the challenges of technophobia and reluctance to engage with modern technologies.

The attention to digital skills development is still insufficient due to difficulties in defining and measuring digital literacy. It also includes the awareness, attitude, and ability to use digital devices for communication, expression, and social action in life situations [16]. Many countries lack systems to track learning outcomes or measure progress on digital literacy.

Besides, as described in the human rights framework, the right to protection not only obliges governments and digital service providers to take measures for safeguarding the fundamental rights of users. It is equally important to educate individuals to use digital technologies in a legal and ethical way. That is, while users are protected in the digital environment from the interference of third parties, they should also mind their online behaviors to respect other people's and organizations' interests and rights. However, the awareness of respecting and protecting human rights remains low among both individuals and service providers.

4.2 Benefiting from digital transformation as a right rather than an obligation

Digital exclusion will lead to social exclusion, where a lack of information and ICTs negatively impacts personal, economic, and political capabilities [66]. Individuals and population groups are not able to participate in the democratic process without the ability and control over modern technologies. Besides access to ICT and digital resources without discrimination, everyone should have equal opportunity to interface effectively with technologies through universal broadband access and by means of digital literacy training when needed. The training and education of digital literacy not only include the basic guidance to use digital tools and resources but also the detailed guidance for the legal, ethical, and safe use of them [66]. This requires education on appropriate ways to obtain, assess, and use the needed information in the digital environment; the awareness of the value of digital technologies and personal information; the realization of the digital rights of users themselves; and the right behaviors and practices to protect users themselves and other people in the digital environment.

However, providing equal access to ICT and opportunity for training does not mean that everyone should be forced to adapt to the social change accordingly. Digital inclusion is a dynamic concept that applies differently to different population groups, based on their digital divide levels and real needs. For individuals who lack access to digital technologies, digital inclusion could offer a pathway to obtain or expand their access to digital resources. For people who are unable to use these resources effectively, it involves training and education to develop their digital skills and understanding. In addition, for people who lack awareness of appropriate behavior and their digital rights in the digital environment, digital inclusion also means safeguards that protect individuals from harmful content and the misuse of their personal data by third parties. Human dignity and autonomy are emphasized during this process to ensure the freedom of individuals in their daily lives. This will be a long-term project to apply the inclusive measures step by step among all population groups. However, it is undoubtedly worth the time and investment, as one of the core values of digital technologies is to benefit the common good of all individuals.

In a word, digital inclusion does not mean forcing those who are left behind to catch up with technological progress. Instead, it is a right instead of an obligation for individuals to use digital technologies. Technological innovation and digital transformation must focus more on underserved groups and tackle their real needs to ensure they have equal opportunities to benefit from digital transformation. These groups should be considered

carefully during the design and implementation of digital technologies. For example, Internet content should respond to users' diverse needs by incorporating more visual materials and offering content at suitable levels of readability.

5. Conclusion: Toward equitable digital participation

Digital inclusion is a dynamic concept that reflects the diverse needs of different population groups. It refers to strategies that provide access, services, training, or opportunities to reduce the digital divide. Digital inclusion is a human rights-based project that tackles the real needs of different population groups in the digital environment. It aims to bridge the gap among different groups and realize their digital rights at risk, including the right to provision (for people who lack access to digital infrastructure), the right to participation (for people who lack digital skills and literacy to use digital technologies effectively), and the right to protection (for people who need general or extra protection from others in the digital environment).

Public policy should ensure equal access to digital goods and services for all population groups, guaranteeing the fair distribution of digital infrastructure and resources for their life and personal development. In terms of digital literacy, everyone should be offered to receive education and training easily, whenever needed, regardless of their level of interest in participating in the digital environment. This approach respects individual dignity and autonomy while also maximizing opportunities to empower people to benefit from digital transformation.

In addition, all stakeholders must work to protect fundamental rights, especially the rights to personal data, privacy, and freedom of expression. Ethical and social consequences must be examined to ensure that digital transformation results in genuine benefits for all members of society. Future research could focus on measuring digital literacy and the digital divide across different population groups, identifying the urgent need of vulnerable groups to achieve digital equity, and exploring practical measures to address these needs. This will ensure that no one is left behind in the inevitable process of digital transformation.

Acknowledgements

This book chapter has received financial support from the Horizon Europe Research and Innovation Programme under Grant Agreement N. 101092612 (Social and hUman ceNtered XR—SUN project). Views and opinions expressed in this chapter are those of the authors only and do not necessarily reflect those of the European Union. Neither the European Union nor the European Commission can be held responsible for them.

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Section 2

Education: Empowerment for a Digital Future

Building Digital Equity through Curriculum Development: Navigating AI, Ethics, and Critical Thinking in the Age of Information

Cameron Kiosoglous

Abstract

This chapter explores how curriculum development can be leveraged to advance digital equity in education by integrating artificial intelligence (AI), ethical reasoning, and critical thinking. The objective is to examine how inclusive, student-centered, and problem-based learning strategies can prepare both educators and students to navigate the evolving digital landscape responsibly and effectively. Using a qualitative research design, data were collected through semi-structured interviews with faculty members across diverse educational settings. The adapted Faculty's Information and Communication Technology Access (FICTA) instrument was employed to assess faculty readiness and engagement with AI tools across four dimensions: access, skills, usage, and motivation. Thematic analysis of the data revealed key barriers—such as institutional constraints and digital skill gaps—as well as enablers like professional curiosity and peer collaboration. The findings underscore the importance of targeted professional development, equitable infrastructure, and clear policy guidance. The chapter concludes that curriculum development is a powerful lever for fostering digital equity and that empowering educators is essential to building inclusive, future-ready learning environments. These insights have broad implications for educational policy, institutional planning, and the ethical integration of emerging technologies in teaching and learning.

Keywords: digital equity, AI education, critical thinking, ethical decision-making, curriculum development

1. Introduction

In a world where digital technologies play an increasingly influential role, this chapter seeks to bridge the digital equity gap by implementing online curriculum strategies tailored to students' needs. Digital equity ensures fairness in digital resource allocation and use, promoting equal opportunities for all individuals [1]. Student-centered and problem-based learning enhance academic achievement, making it essential to foster digital literacy through adaptive online curricula [2].

By addressing ethical concerns, integrating AI education, and focusing on critical thinking skills, students will become responsible digital citizens who can navigate the ever-evolving digital landscape effectively and equitably [3]. This chapter aligns with the United Nations Sustainable Development Goals, contributing to a more inclusive and empowered digital future for all [4]. This chapter aims to explore ways to align digital education with real-world needs, ensuring that both students and educators are prepared to navigate the evolving digital landscape effectively.

The evolution of communication technologies has consistently reshaped how societies learn, connect, and progress. From Gutenberg's printing press to the digital age, each technological leap has redefined access to knowledge and the skills required to engage with it. This trajectory illustrates how media revolutions have historically influenced educational paradigms and social equity. In the twenty-first century, this transformation is being accelerated by artificial intelligence, which is not merely a tool but a new medium of thought and interaction [5]. Artificial intelligence (AI) is defined as the automation of cognition—the ability of machines to perform tasks that typically require human intelligence [6].

The assertion that “the medium is the message” is particularly relevant in the context of AI [7]. The tools we use to communicate and learn are not neutral—they shape cognition, behavior, and societal structures. As AI becomes embedded in educational environments, it challenges traditional notions of literacy, authority, and critical engagement. A potential future where machines would exceed human intelligence, prompts urgent questions about how humans will coexist with, and learn alongside, intelligent systems [8].

This shift demands a rethinking of curriculum development. Generative AI is not like a calculator—it does not just compute; it collaborates, creates, and converses. This fundamentally alters the learner's relationship with knowledge and necessitates new pedagogical approaches that emphasize critical thinking, ethical reasoning, and digital fluency [9].

Historically, the rise of technical literacy during the industrial era required educational systems to adapt to the demands of mechanized labor. Today, we face a similar inflection point. The grammar of the machine has evolved into the logic of algorithms, and with it, the imperative to ensure that all learners—not just the privileged few—can access, understand, and shape the digital world [10].

Digital equity which refers to the fair distribution of digital resources, opportunities, and competencies, ensuring that no individual or group is disadvantaged in the digital realm due to socioeconomic, geographic, or institutional barriers [11]. Digital equity is not simply about access to devices or internet connectivity but about cultivating the capacity to engage meaningfully with digital tools, question their outputs, and use them to solve real-world problems. Curriculum development, therefore, becomes a critical lever for fostering inclusive, ethical, and future-ready education systems.

In the digital age, equitable access to technology and the skills to use it effectively are no longer optional—they are essential. As artificial intelligence (AI), data-driven systems, and digital platforms increasingly shape how we learn, work, and interact, the concept of digital equity has emerged as a critical educational and societal priority. This chapter explores how curriculum development can serve as a powerful tool to bridge the digital divide, promote ethical engagement with technology, and cultivate critical thinking skills among learners.

The digital divide is a measure of the gap and inequalities in access and use of the digital medium [12]. In educational contexts, designing learning environments needs

to be inclusive, adaptive, and responsive to the diverse needs of students and educators alike. And preparing learners is not about just using technology, but to question it, examine its implications, and apply it responsibly. This is reflected in prioritizing and fostering critical thinking skills to examine assumptions, assess values, evaluate evidence, and develop reasoning to help improve decision-making [13].

This chapter focuses on integrating AI education, ethical decision-making, and critical thinking into curriculum design, particularly through student-centered and problem-based learning approaches [3]. These pedagogical strategies not only enhance academic achievement but also empower students to become informed digital citizens capable of navigating complex information ecosystems. Digital citizenship encompasses competencies, including critical thinking, ethical decision-making, and privacy protection, which help individuals engage with AI technologies in a manner that upholds societal values and personal integrity [14]. By aligning with the United Nations Sustainable Development Goals [4], this work contributes to a global vision of inclusive, equitable, and quality education for all.

Through a combination of research, practical frameworks, and adapted assessment tools such as the Faculty's Information and Communication Technology Access [15] instrument, this chapter provides a roadmap for educators, institutions, and policymakers to foster digital equity. The analysis of this data aims to highlight the importance of faculty readiness, institutional support, and collaborative innovation in shaping a future where technology enhances—not hinders—educational opportunity and social inclusion.

2. Definition of key terms

Curriculum development: The process of planning and organizing the content, structure, and delivery of educational programs to meet learning objectives.

Ethical reasoning: The process of determining whether an action is right or wrong using a consistent and logical approach.

Critical thinking: The ability to analyze facts to form a judgment, involving evaluation of sources, such as data, facts, observable phenomena, and research findings.

Artificial intelligence (AI): The simulation of human intelligence processes by machines, especially computer systems, including learning, reasoning, and self-correction.

Digital equity: The fair distribution of digital resources, opportunities, and competencies, ensuring that no individual or group is disadvantaged in the digital realm due to socioeconomic, geographic, or institutional barriers.

3. Significance

The focus on digital equity and curriculum development is of the importance in today's rapidly evolving digital landscape. As digital technologies become embedded in nearly every facet of life—from education and employment to civic participation, healthcare, and governance—ensuring equitable access to these tools is not merely a matter of convenience or efficiency, but a fundamental issue of social justice and human rights. Digital equity ensures that all learners, regardless of socioeconomic status, geographic location, race, gender, disability, or institutional affiliation, have access to engage meaningfully with technology and the digital world.

This chapter addresses the persistent and multifaceted disparities in access to digital technologies, particularly among historically underserved and marginalized communities. These disparities extend beyond the availability of hardware or internet connectivity. They include gaps in digital literacy, confidence in using technology, exposure to advanced tools like artificial intelligence, and the ability to critically evaluate and ethically engage with digital content [16]. Digital literacy—The ability to efficiently and accurately use digital information technologies and the information retrieved from them (see Appendix A). Without intentional and systemic efforts to close these gaps, educational systems risk reinforcing existing inequalities and excluding large segments of the population from the benefits of digital transformation.

Artificial intelligence adds a new layer of complexity and urgency to this challenge of digital inequity in education. While AI holds tremendous potential to personalize learning, streamline administrative tasks, and enhance educational outcomes, it also introduces significant ethical dilemmas, algorithmic biases, and risks of misuse. The integration of AI into curricula must therefore be accompanied by a parallel emphasis on critical thinking, ethical reasoning, and digital literacy. Students must not only learn how to use AI tools but also understand their limitations, question their outputs, and consider their broader societal implications. This is especially important in an era where misinformation, surveillance, and automated decision-making are increasingly shaping public discourse and individual opportunity.

This research contributes to a growing body of work that views curriculum development as a strategic lever for promoting digital equity. By embedding AI education and ethical inquiry into learning experiences, educators can empower students to become not just consumers of technology, but informed, reflective, and responsible digital citizens. This approach fosters a generation of learners who are equipped to navigate the complexities of the digital age with agency, empathy, and critical awareness.

Moreover, the significance of this work extends beyond the classroom. It calls for systemic change—collaboration among educators, policymakers, technologists, and community stakeholders—to create inclusive digital ecosystems that support lifelong learning and social mobility. It also highlights the need for sustained investment in professional development and institutional capacity-building. Educators are often expected to adapt to technological change without adequate training, time, or resources. Supporting them in this transition is essential for ensuring that innovations in education are equitable, ethical, and effective.

Finally, this chapter emphasizes that digital equity is not a static goal but a dynamic and evolving process. It requires continuous reflection, innovation, and commitment to justice. As technologies advance and societal needs shift, so too must our educational frameworks, ensuring that all learners are equipped not only to survive but to thrive in a digital world that is as complex as it is promising.

4. Research questions

As digital technologies continue to reshape the educational landscape, curriculum developers and educators are increasingly called upon to design learning experiences that not only incorporate emerging tools like artificial intelligence but also foster the critical thinking and digital literacy skills necessary for students to thrive in a complex, information-rich world [1]. This chapter is guided by four central research questions that address the intersection of curriculum development, digital equity, and AI

integration. These questions serve as a framework for understanding both the opportunities and the challenges of preparing learners for the demands of the digital age.

1. How can curriculum developers effectively integrate digital literacy and critical thinking skills into course content to promote student success in the information age?
2. What challenges do educators face in implementing responsive curriculum development?
3. What support systems can be put in place to overcome these challenges?
4. How can the integration of AI education into the curriculum enhance students' adaptation of advanced technologies and their societal impact?

The integration of digital literacy, critical thinking, and AI education into curriculum development is not a peripheral concern—it is central to the mission of equitable, future-ready education. Moving forward, the focus must be on building sustainable, inclusive systems that support educators in this work and ensure that all students—regardless of background—have the opportunity to thrive in a digitally mediated world [17].

This requires a collective effort: curriculum developers must design with equity in mind; institutions must provide the infrastructure and support; and educators must be empowered as innovators and facilitators of critical inquiry. Only through such coordinated action can we bridge the digital divide and cultivate a generation of learners who are not only digitally competent but also ethically grounded and critically engaged [18].

5. Measuring digital equity and AI among faculty

Examining faculty readiness to integrate artificial intelligence [1] into curriculum design is essential for advancing digital equity in education. The Faculty's Information and Communication Technology Access [5] instrument, developed by Soomro et al., provides a robust framework for assessing faculty engagement with digital technologies. Originally designed to evaluate general ICT access and use, the FICTA instrument can be effectively adapted to explore faculty interaction with AI tools in teaching and learning environments.

The FICTA framework is structured around four key dimensions:

- *Physical access*: This dimension evaluates the availability of essential digital infrastructure, including access to computers, mobile devices, internet connectivity, and AI-enabled platforms. In the context of AI, this includes access to generative AI tools such as ChatGPT, Gemini, or CoPilot, which are increasingly being used for content creation, instructional design, and student engagement.
- *Skills*: This dimension assesses faculty members' technical proficiency and confidence in using digital tools. When applied to AI, it includes the ability to craft effective prompts, interpret AI-generated content, and integrate AI outputs into pedagogical practices. It also encompasses the ability to critically assess the reliability and ethical implications of AI-generated information.

- *Usage*: This dimension captures the frequency and diversity of digital technology use in professional activities. For AI, this includes how often faculty use AI tools for lesson planning, grading, communication, research, and student support. It also considers the extent to which AI is embedded in instructional strategies and classroom interactions.
- *Motivation*: This dimension explores both intrinsic and extrinsic factors that influence faculty engagement with technology. Intrinsic motivation may stem from curiosity, innovation, or a desire for professional growth, while extrinsic motivation may be driven by institutional expectations, peer influence, or student demand. Understanding these motivational drivers is critical for designing effective professional development and support systems.

5.1 Adapting FICTA for AI integration

By tailoring the FICTA instrument to focus specifically on AI, institutions can gain valuable insights into faculty readiness, barriers to adoption, and areas requiring targeted support. For example, questions can be modified to assess comfort with AI prompt engineering, perceptions of AI's role in enhancing student learning, and concerns about data privacy or academic integrity.

This adapted version of FICTA [5] enables institutions to:

- Quantify faculty engagement with AI tools across disciplines and teaching contexts.
- Identify gaps in access, training, or institutional support that may hinder effective AI integration.
- Inform the design of professional development programs that build AI literacy and pedagogical innovation.
- Support strategic planning and resource allocation to promote equitable and sustainable AI adoption.

Ultimately, the use of an AI-adapted FICTA instrument contributes to a broader understanding of how digital equity can be advanced through faculty empowerment. It positions educators not only as users of technology but as co-creators of inclusive, forward-thinking learning environments. This chapter contributes to the growing discourse on AI in education by emphasizing the importance of faculty agency, institutional readiness, and the ethical integration of emerging technologies in pursuit of equitable learning outcomes.

6. Context, setting, and population

The setting of this chapter is within the broader context of global efforts to address digital inequities in education, particularly as they relate to the integration of artificial intelligence [19], ethical reasoning, and critical thinking into curriculum design. The setting spans a diverse range of educational environments, including K–12 schools,

higher education institutions, and online learning platforms. These settings reflect the varied landscapes in which digital equity challenges evident—ranging from urban schools with advanced technological infrastructure to rural or underserved communities with limited access to digital tools and connectivity [20].

The primary population of interest focuses on educators with consideration for the students they serve. A spectrum of considerations are included: socio-economic backgrounds, geographic locations, and levels of digital access and literacy. This diversity is essential to understanding how digital equity—or the lack thereof—affects learning outcomes, engagement, and long-term opportunities in a technology-driven world.

These educators are faculty members and curriculum developers, who serve as the architects of educational experiences. Their ability to integrate AI tools, foster ethical awareness, and promote critical thinking is central to the success of any digital equity initiative. These educators face a range of challenges [21], from institutional constraints and policy limitations to gaps in their own digital competencies. As such, this chapter also explores faculty readiness and motivation, using tools like the adapted Faculty's Information and Communication Technology Access instrument to assess their engagement with AI in teaching. By focusing on these populations within varied educational contexts, this chapter aims to illuminate the systemic and human factors that influence digital equity. It provides a foundation for developing responsive, inclusive curricula that not only bridge the digital divide but also prepare learners and educators to thrive in an increasingly complex and interconnected digital society [22].

7. Data collection and analysis

This chapter investigates the current state of digital literacy and the integration of artificial intelligence [1] in education through a qualitative research design grounded in faculty perspectives. The study is guided by four research questions:

1. How can curriculum developers effectively integrate digital literacy and critical thinking skills into course content to promote student success in the information age?
2. What challenges do educators face in implementing responsive curriculum development?
3. What support systems can be put in place to overcome these challenges?
4. How can the integration of AI education into the curriculum enhance students' adaptation of advanced technologies and their societal impact?

To explore these questions, data were collected through semi-structured interviews with faculty members across various educational institutions. The interview protocol was developed using an adapted version of the Faculty's Information and Communication Technology Access [5] instrument, which was modified to focus specifically on AI-related competencies and experiences.

The adapted FICTA framework provided a structured lens for examining four key dimensions of faculty engagement with AI:

- *Access*: Availability of AI tools and platforms, institutional support, and infrastructure.
- *Skills*: Faculty proficiency in using AI tools for instructional and research purposes.
- *Usage*: Frequency and diversity of AI applications in teaching, curriculum design, and student engagement.
- *Motivation*: Internal and external drivers influencing faculty adoption of AI technologies.

Interview questions were designed to elicit rich, narrative responses that captured both the practical realities and reflective insights of educators. Participants were encouraged to share their experiences, challenges, and aspirations related to AI integration, with particular attention to how these tools influence their ability to foster critical thinking among students.

This qualitative approach allowed for the identification of nuanced barriers—such as institutional policy constraints, time limitations, and ethical concerns—as well as enablers, including professional curiosity, peer collaboration, and student demand. The data also revealed patterns in how faculty are adapting their pedagogical strategies, rethinking their roles, and navigating the evolving expectations of digital-age teaching.

By grounding the inquiry in the adapted FICTA framework, this study not only captures the current landscape of AI use in education but also provides actionable insights for institutions seeking to support faculty in developing equitable, innovative, and future-ready curricula.

The data analysis in this study was grounded in a qualitative framework, using the adapted Faculty's Information and Communication Technology Access (FICTA) instrument to structure and interpret faculty responses. Semi-structured interviews were coded according to four key dimensions—access, skills, usage, and motivation—allowing for a nuanced understanding of how educators engage with AI tools in their teaching practice. This thematic analysis revealed patterns of both barriers and enablers, such as institutional constraints, ethical concerns, and professional curiosity. By systematically examining these themes, the analysis illuminated the real-world challenges educators face and the conditions that support successful AI integration. These insights directly informed the study's findings, highlighting the need for targeted professional development, equitable infrastructure, and clear policy guidance. Ultimately, the analysis provided a robust foundation for the chapter's implications, emphasizing the importance of faculty empowerment and institutional readiness in advancing digital equity through curriculum development.

8. Findings

This section presents key findings from faculty experiences with integrating artificial intelligence [1] into curriculum design, particularly as a tool to foster critical thinking and digital literacy. The findings are organized to directly address the four guiding research questions of this study.

8.1 How can curriculum developers effectively integrate digital literacy and critical thinking skills into course content to promote student success in the information age?

Faculty reported that AI tools offer unique opportunities to embed digital literacy and critical thinking into learning experiences. Educators who actively use AI in their teaching describe how these tools can:

- Encourage students to evaluate the credibility and bias of AI-generated content, fostering critical analysis.
- Support inquiry-based learning by prompting students to ask better questions and refine their thinking.
- Enable real-time feedback and content generation, which students can critique and improve upon.
- Serve as a springboard for ethical discussions around data privacy, authorship, and algorithmic bias.

These practices suggest that curriculum developers can integrate AI not just as a technological enhancement, but as a pedagogical catalyst for deeper learning and reflection.

8.2 What challenges do educators face in implementing responsive curriculum development?

Despite the promise of AI, faculty face several barriers that hinder responsive curriculum innovation:

- *Institutional constraints*: Policies often restrict access to certain AI platforms due to concerns over data security and academic integrity, limiting experimentation.
- *Time limitations*: Faculty cite a lack of time to explore, learn, and integrate new tools into their teaching, especially given existing workloads.
- *Ethical uncertainty*: Concerns about student data privacy and the transparency of AI outputs create hesitation around full adoption.
- *Digital skill gaps*: Not all educators feel confident using AI tools, particularly those unfamiliar with prompt engineering or digital content evaluation.

These challenges highlight the need for institutional clarity, protected time for innovation, and targeted professional development.

8.3 What support systems can be put in place to overcome these challenges?

Faculty emphasized the importance of systemic support to enable meaningful AI integration. Key recommendations include:

- *Professional development*: Ongoing training in AI literacy, digital pedagogy, and ethical technology use is essential to build faculty confidence and competence.
- *Collaborative learning environments*: Peer mentoring, interdisciplinary design teams, and communities of practice help educators share strategies and troubleshoot challenges.
- *Infrastructure and access*: Equitable access to AI tools, reliable internet, and technical support must be ensured for both faculty and students.
- *Policy guidance*: Clear institutional frameworks around acceptable AI use, data protection, and academic integrity provide the confidence needed to innovate responsibly.

These support systems are critical for scaling responsive curriculum development and ensuring that innovation is inclusive and sustainable.

8.4 How can the integration of AI education into the curriculum enhance students' adaptation of advanced technologies and their societal impact?

Faculty observed that students who engage with AI tools in the classroom develop not only technical fluency but also a more critical and reflective stance toward technology. AI integration enhances student learning by:

- *Demystifying AI*: Students gain hands-on experience with AI platforms, learning how they function and how to use them effectively.
- *Fostering ethical awareness*: Classroom discussions around AI-generated content naturally lead to conversations about bias, misinformation, and responsible use.
- *Promoting adaptability*: Students become more comfortable navigating digital tools, preparing them for a rapidly evolving workforce.
- *Encouraging innovation*: By experimenting with AI in creative tasks, students learn to think beyond consumption and toward co-creation and problem-solving.

These findings suggest that AI education, when thoughtfully integrated, can empower students to become informed, ethical, and adaptable participants in a technology-driven society.

9. Conclusions

The significance of building digital equity through curriculum development—particularly by integrating artificial intelligence [5], ethics, and critical thinking—cannot be overstated in our increasingly interconnected and technologically advanced world [23]. As digital technologies continue to shape how we learn, communicate, and participate in society, the imperative to ensure equitable access to these tools becomes not only a pedagogical concern but a moral and civic responsibility.

Digital equity is more than just providing devices or internet access; it encompasses the ability to use digital tools meaningfully, critically, and ethically. In this context, curriculum development becomes a powerful lever for change [24]. By embedding digital literacy, ethical reasoning, and AI fluency into learning experiences, educators can equip students with the skills they need to navigate a complex digital landscape—one marked by rapid innovation, information overload, and growing concerns about misinformation, surveillance, and algorithmic bias.

This chapter has shown that student-centered and problem-based learning approaches are particularly effective in promoting these competencies [2]. These pedagogies not only enhance academic achievement but also foster deeper engagement, creativity, and reflective thinking. When paired with AI tools, they offer new possibilities for personalized learning, collaborative inquiry, and real-time feedback—while also raising important questions about the role of technology in shaping knowledge and power.

Importantly, this work aligns with the United Nations Sustainable Development Goals [4], particularly those focused on quality education, reduced inequalities, and innovation. By addressing the multifaceted challenges of digital equity, this chapter contributes to a broader vision of inclusive, empowered, and future-ready education systems. This chapter asserts that curriculum and teaching strategies developed in the twentieth century model will not adequately foster the flexible, well-rounded skills humans need to think critically in a thriving AI-driven world [25].

Looking ahead, the focus must be on sustaining this momentum through institutional commitment, cross-sector collaboration, and continuous professional development. Educators must be supported not only in acquiring technical skills but also in cultivating the critical and ethical sensibilities needed to guide students through the digital age [26, 27]. Policymakers and educational leaders must prioritize equity in technology adoption, ensuring that innovation does not exacerbate existing disparities but instead becomes a force for inclusion and empowerment [28].

Ultimately, this chapter calls for a reimagining of curriculum as a dynamic, responsive, and justice-oriented practice—one that prepares students not just to succeed in a digital world, but to shape it with integrity, empathy, and purpose [29].

Supplementary information

For access to the empirical data that supports the findings presented in Section 8, please refer to the supplementary report available at: <https://doi.org/10.5281/zenodo.1234567>. This report includes anonymized interview transcripts, coding frameworks, and thematic analysis matrices used in this study.

Appendix A. Adapted FICTA

The adapted FICTA is designed to assess various aspects of individuals' engagement with artificial intelligence (AI) platforms, focusing on accessibility, motivation, skills, and instructional applications. By evaluating responses to the questionnaire, researchers and educators can identify areas for improvement and develop targeted interventions to enhance AI integration and digital equity in educational settings (**Table A1**).

Physical access—Generative AI platforms	Frequency: 1 not at all–5 all the time
1. Chat GPT	
2. Meta AI	
3. Gemini	
4. Claude AI	
5. Jasper AI	
6. CoPilot	
7. Notion AI	
8. Bard	
9. Bing	
10. Other	
External motivational access	Agreement: 1 strongly disagree–5 strongly agree
11. Using AI provide me with information that would lead to better decisions.	
12. Using AI will be of no benefit to me.	
13. Using AI can improve my work performance.	
14. Using AI can be enjoyable.	
External motivational access	Agreement: 1 strongly disagree–5 strongly agree
15. Seeing other teachers using AI inspires me.	
16. I want to use AI because my superiors expect me to use it.	
17. I wish to use AI because my students think that I should use them.	
18. I am interested to adopt AI because my university provides enough technology support.	
Operational skills access	Agreement: 1 strongly disagree–5 strongly agree
22. I feel comfortable in using AI.	
23. It is easy for me to create a prompt using AI.	
24. I feel difficulty when using AI.	
25. I can use content that I find using AI.	
Informational skills access	Agreement: 1 strongly disagree–5 strongly agree
26. I always know what search terms to use when using AI.	
27. I can use advanced options to reach my required information.	
28. I feel confident to evaluate the sources of the information found using AI.	
29. I feel comfortable to synthesize information from AI	
30. It is easy for me to retrieve a content from AI.	
31. I can easily choose from results from AI.	

Strategic skills access	Agreement: 1 strongly disagree–5 strongly agree
32. I can make a choice by using AI.	
33. I can reach my intended goal while using AI.	
34. It is easy for me to work toward a specific goal using AI.	
35. I can gain benefits from using AI.	
36. Using various AI tools, I feel confident in achieving my goals.	
37. I feel confident in making important decisions with the help of the AI.	
General usage access	Frequency: 1 not at all–5 all the time
38. I search information of my interest using AI.	
39. I use AI to support my research activities.	
40. I use AI of the primary search tool.	
41. I use AI to create letters, reports and/or papers.	
42. I prepare presentations using AI.	
43. I store and manipulate data in a spreadsheet program using AI.	
Instructional usage access	Frequency: 1 not at all–5 all the time
44. I use AI for communication about assignments among students.	
45. I use AI for enhancing students' content learning.	
46. I use AI for facilitating students' group work.	
47. I use AI to improve students' problem-solving skills.	
48. I use AI for the delivery of my instruction.	
49. I use AI to communicate with students.	
50. I prepare learning materials using AI.	
51. I develop critical thinking skills among students with the help of AI.	
52. I use AI to encourage peer-feedback among my students.	

Table A1.
Adapted faculty's information and communication technology access (FICTA).

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Chapter 4

Information Literacy in Engineering Education

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Abstract

This work presents a comprehensive exploration of teaching information literacy (IL) within engineering education, emphasizing its critical role in developing competent, ethical, and sustainability-oriented engineers. Information literacy encompasses the ability to recognize information needs, locate and evaluate diverse sources, and apply knowledge effectively in engineering contexts. Critical thinking, data analysis, and ethical decision-making are integral to IL, ensuring reliability and rigor in design, research, and professional practice. Pedagogical strategies for embedding IL include problem-based learning, flipped classrooms, design thinking workshops, service-learning projects, inquiry-based learning, gamification, collaborative research, concept mapping, and the jigsaw method. Each approach fosters critical evaluation of information, teamwork, and real-world problem-solving. The integration of IL aligns with ABET learning outcomes and sustainability competencies, promoting lifelong learning, effective communication, ethical reasoning, and responsible engineering practice. Concrete examples illustrate successful implementations, and recommendations for curriculum design, technology use, and faculty-librarian collaboration are provided. Overall, cultivating IL in engineering students equips them with the skills necessary to navigate complex information landscapes, address contemporary societal and environmental challenges, and contribute to sustainable and innovative engineering solutions.

Keywords: information literacy, engineering education, critical thinking, sustainability, problem-based learning, design thinking, service learning, inquiry-based learning, pedagogy

1. Introduction

Information literacy (IL) is broadly understood as the capacity to recognize the need for information, to locate and access relevant sources, to critically evaluate their credibility and usefulness, and to apply them effectively in specific contexts [1]. At its core, IL is not simply a technical ability to search for information, but a higher-order cognitive and ethical competency that enables individuals to engage in informed inquiry, construct knowledge, and make sound decisions.

The fundamental aspects of IL include the recognition that information is produced and disseminated within social, cultural, and disciplinary frameworks, and that its authority is context-dependent [2]. As such, IL involves both critical awareness of the nature of information and practical strategies for its retrieval and use. Its

purpose extends beyond immediate problem-solving to fostering lifelong learning, adaptability, and responsible citizenship in an increasingly data-driven society [3].

For engineers in particular, IL serves as a foundational skill for professional practice. Engineering problems are inherently complex and open-ended, requiring practitioners to navigate diverse sources such as technical standards, patents, scholarly literature, and regulatory documents. In this context, IL empowers engineers to transform raw data and information into actionable knowledge, supporting innovation, ethical decision-making, and effective communication. Thus, IL is best conceived as a dynamic and integrative skill that underpins both academic success and professional competence in engineering education.

1.1 Relation to other skills

Information literacy (IL) does not exist in isolation; rather, it is deeply interconnected with a range of other competencies that together enable effective participation in academic, professional, and civic life. Among these, digital literacy and digital equity are especially significant.

Digital literacy is often defined as the ability to use digital technologies to find, evaluate, create, and communicate information [4]. While digital literacy emphasizes technical proficiency with tools and platforms, IL extends beyond technical access to include critical engagement with the authority, credibility, and ethical dimensions of information [5]. The two skills are therefore complementary: digital literacy provides the technological fluency to interact with digital environments, whereas IL ensures that such interactions are thoughtful, evaluative, and purposeful. For engineering students, this interdependence is particularly important, as professional practice increasingly relies on digital repositories, simulation software, and large-scale data analytics.

Digital equity refers to fair access to digital tools, resources, and skills necessary to fully participate in society [6]. It is a prerequisite for meaningful IL development. Without equitable access to digital infrastructures and resources, learners are disadvantaged in developing IL competencies, as they cannot practice locating or evaluating information effectively. Conversely, embedding IL instruction into curricula contributes to advancing digital equity by equipping all learners, regardless of background, with the skills to navigate information landscapes critically and responsibly.

Beyond these, IL is also related to critical thinking (evaluating sources and evidence), ethical reasoning (acknowledging intellectual property and addressing misinformation), and communication skills (synthesizing and presenting information for varied audiences). These competencies form an integrated skill set essential for professional engineers, who must not only access technical data but also interpret it, apply it to problem-solving, and communicate results responsibly to diverse stakeholders.

1.2 Key components

Information literacy (IL) is a multidimensional competency that can be broken down into several essential components or sub-skills. These elements provide a systematic structure for understanding how individuals recognize, engage with, and apply information in academic and professional contexts.

- Recognizing the information need—The initial step of IL involves identifying gaps in knowledge or areas where additional information is necessary [7]. For engineers, this often manifests in defining technical specifications, identifying design constraints, or formulating research questions.
- Locating and accessing information—Once the need is established, learners must develop the ability to identify relevant information sources and retrieve them effectively. This includes using databases, digital repositories, patents, technical standards, and scholarly literature [8].
- Evaluating information—Critical evaluation is central to IL. It involves assessing the credibility, relevance, authority, and accuracy of information. Engineers must also consider issues such as data validity, reproducibility of results, and compliance with industry standards [1].
- Organizing and managing information—Effective use of information requires strategies for categorizing, storing, and retrieving knowledge over time. In engineering, this may include the use of reference management tools, data visualization, and knowledge management systems [9].
- Applying information—This component focuses on integrating information into problem-solving, innovation, and decision-making processes. Engineers use information not only to validate solutions but also to justify design choices, optimize processes, and ensure compliance with ethical and regulatory frameworks [10].
- Ethical and legal use of information—Ethical responsibility is a crucial sub-skill, encompassing respect for intellectual property, avoidance of plagiarism, and awareness of copyright and licensing issues. For engineers, this extends to responsible data use, safety considerations, and the societal implications of technological decisions [11].
- Reflective and lifelong learning—Finally, IL involves a metacognitive dimension—the ability to reflect on one's own information practices and adapt strategies over time. This supports lifelong learning and professional adaptability in a rapidly evolving information landscape [12].

Together, these components demonstrate that IL is not a single act of information retrieval but a complex, iterative, and ethically grounded process. For engineering students, mastery of these sub-skills ensures that they can navigate diverse information ecosystems, critically evaluate sources, and responsibly transform information into actionable knowledge.

1.3 Importance for engineers and engineering education

Information literacy (IL) is a foundational competency for engineering professionals, as it directly contributes to effective problem-solving, innovation, and ethical decision-making. In engineering practice, projects often involve complex, open-ended challenges that require integrating knowledge from diverse sources, including technical literature, industry standards, patents, regulatory documents, and

experimental data. IL equips engineers with the ability to identify relevant information, critically evaluate its credibility and applicability, and synthesize it into actionable solutions. By doing so, engineers can make informed design decisions, anticipate potential risks, and optimize systems in alignment with professional and societal expectations [13].

The relevance of IL extends beyond traditional technical tasks to emerging industry trends. In today's data-driven environment, engineers increasingly work with large datasets, simulation outputs, and interdisciplinary knowledge. Mastery of IL enables professionals to navigate this information landscape efficiently, ensuring that analyses are evidence-based, innovations are grounded in reliable information, and solutions comply with legal, ethical, and environmental standards [14]. Moreover, IL supports lifelong learning, a critical requirement in engineering fields where technological advancements and standards evolve rapidly.

From a societal perspective, IL empowers engineers to address global challenges such as sustainability, cybersecurity, public health, and infrastructure resilience. By fostering the ability to critically evaluate data and its sources, engineers can make responsible decisions that consider environmental, social, and ethical impacts. Furthermore, the integration of IL into engineering curricula ensures that graduates not only possess technical knowledge but also the competency to navigate complex information ecosystems, collaborate across disciplines, and contribute meaningfully to society [11].

2. Integration of IL competencies in engineering education

Engineering education aims not only to develop technical knowledge but also to cultivate competencies essential for professional practice, lifelong learning, and societal impact. Information literacy (IL), critical thinking, and sustainability awareness are increasingly recognized as core competencies that must be integrated throughout the curriculum to prepare engineers for complex, real-world challenges.

2.1 Alignment with competency frameworks

Embedding information literacy (IL) and critical thinking into engineering education not only enhances students' professional readiness but also directly aligns with established competency frameworks such as The Accreditation Board for Engineering and Technology student outcomes and global sustainability competencies. These connections highlight the role of IL as a foundational skill that underpins technical expertise, ethical awareness, and socially responsible practice.

2.2 ABET learning outcomes

The Accreditation Board for Engineering and Technology [15] outlines specific learning outcomes expected of engineering graduates. IL and critical thinking competencies contribute significantly to meeting these expectations:

- a. Ability to apply knowledge of mathematics, science, and engineering.
Information literacy enables students to locate, evaluate, and synthesize reliable technical sources, ensuring that engineering decisions are grounded in robust evidence [1].

- b. Ability to design and conduct experiments, as well as analyze and interpret data. Critical thinking supports rigorous data evaluation by helping students identify uncertainty, recognize bias, and draw meaningful conclusions from experimental results [16].
- c. Ability to communicate effectively. IL fosters research-supported communication by developing skills in academic writing, citation practices, and ethical reporting of findings, strengthening engineers' ability to share knowledge with diverse audiences [17].
- d. Recognition of the need for, and an ability to engage in lifelong learning. IL encourages ongoing skills in evaluating emerging sources of information and technologies, preparing engineers for continuous professional development in a rapidly changing field [10].
- e. Knowledge of contemporary issues. Integrating sustainability within IL equips students to understand and address contemporary engineering challenges, ensuring their solutions are environmentally responsible and ethically sound [9].

2.3 Sustainability competencies

Beyond ABET, engineers must also demonstrate competencies related to sustainability, particularly in alignment with the United Nations Sustainable Development Goals (SDGs). Information literacy plays a vital role in developing these competencies, which include:

Understanding the environmental, social, and economic impacts of engineering decisions. IL provides the tools to access and evaluate interdisciplinary data on sustainability issues, enabling holistic and responsible decision-making [18].

Applying life-cycle thinking and systems analysis in design. Through IL, students learn to identify relevant standards, research, and case studies that support systems-level approaches to sustainable engineering [19].

Using interdisciplinary data to propose solutions aligned with the SDGs. Engineers must integrate knowledge from multiple fields, including environmental science, economics, and social sciences. IL empowers them to navigate these diverse information landscapes to propose feasible, ethical, and innovative solutions [20].

By aligning IL with both ABET learning outcomes and sustainability competencies, educators can demonstrate that IL is not an “add-on” skill but an essential dimension of engineering professionalism. This integration strengthens the case for embedding IL systematically across the engineering curriculum and supports the development of engineers who are both technically competent and socially responsible.

2.4 Key recommendations

Based on current research and best practices in engineering education, the following recommendations are proposed for effectively implementing information literacy (IL):

1. Integrate IL into existing courses. Embedding IL in lab exercises, design projects, and research assignments ensures relevance and reduces the need for additional curriculum space. Authentic application within engineering tasks enhances student engagement and retention [21].

2. Adopt a scaffolded approach across the curriculum. Progressive skill development—from basic source identification to critical evaluation and synthesis—allows students to build competence over time. Early exposure followed by reinforcement in advanced courses aligns with both learning theory and professional practice [22].
3. Foster faculty-librarian collaboration. Partnerships between engineering faculty and information specialists provide expert guidance, discipline-specific relevance, and sustainable instruction. Librarians bring expertise in databases, citation management, and digital tools, complementing faculty knowledge [1].
4. Use authentic, problem-based learning activities. Assignments that mirror real-world engineering challenges, such as design projects or case studies, demonstrate the practical value of IL skills. Problem-based learning promotes critical thinking, ethical reasoning, and interdisciplinary integration [23].
5. Incorporate assessment and reflection. Formative and summative assessments, including annotated bibliographies, research reports, and reflective journals, provide feedback on skill development and reinforce accountability. Reflection fosters metacognition and lifelong learning habits [22].
6. Address digital equity and accessibility. Ensuring all students have access to digital resources, tools, and tutorials promotes equitable skill development. Differentiated instruction and scaffolding help accommodate diverse levels of prior digital literacy [8].
7. Focus on transferable and adaptive skills. Emphasizing critical evaluation, ethical information use, and adaptive searching strategies prepares students to navigate rapidly evolving information landscapes. This approach supports lifelong learning and aligns with engineering professionalism [6].

Awareness of *common pitfalls* helps educators avoid practices that may undermine information literacy (IL) skill development. The following “don’ts” highlight typical mistakes and their potential negative impacts:

1. Do not treat IL as a standalone or peripheral topic. Presenting IL in isolation, without integration into engineering coursework, can lead students to perceive it as irrelevant, reducing engagement and skill transfer to real-world tasks [7]. Embedding IL into design projects, labs, or research assignments contextualizes learning and demonstrates its direct applicability to engineering practice.
2. Do not assume students possess digital literacy skills. Assuming prior digital proficiency can leave some students behind, creating inequities and gaps in skill acquisition. Students may struggle with database searches, evaluation of sources, or citation management [7]. Providing scaffolding, tutorials, and differentiated support ensures all students build foundational skills before advancing to complex IL tasks.
3. Do not rely solely on traditional lectures. Lecture-based instruction alone limits opportunities for active learning, critical thinking, and skill application. Stu-

dents may memorize procedures without developing the ability to evaluate, synthesize, or ethically use information [6]. Incorporating active learning strategies, such as problem-based learning, case studies, and project-based exercises, fosters deeper understanding and practical competence.

4. Do not neglect assessment and feedback. Without meaningful assessment, instructors cannot measure skill acquisition or provide corrective guidance. Students may continue ineffective information practices, reducing their readiness for professional challenges [4]. Formative and summative assessments, coupled with constructive feedback, reinforce learning and promote reflection and self-directed improvement.
5. Do not ignore ethical and legal dimensions. Overlooking ethical issues, such as plagiarism, data integrity, and responsible sourcing, can foster poor research habits and undermine professional standards [1, 2]. Explicit instruction in ethical information use, intellectual property, and responsible data management cultivates professional responsibility and integrity.
6. Do not overlook the need for continuous adaptation. Teaching static skills without accounting for evolving technologies and information sources can render instruction outdated, leaving students unprepared for modern engineering contexts [4]. Focusing on transferable skills—critical evaluation, adaptive searching, and lifelong learning—prepares students to navigate changing information landscapes.

2.5 Attention points: Critical factors for implementing information literacy in engineering education

Successful implementation of information literacy (IL) in engineering education requires attention to several critical factors that influence both the effectiveness and sustainability of skill development.

1. Institutional support and policy integration. The formal recognition and institutionalization of IL within the curriculum, policies, and strategic plans ensures sustainability and consistency across programs. Lack of institutional support can result in fragmented instruction, limited resources, and undervaluation of IL in engineering education [1].
2. Faculty engagement and professional development. Faculty buy-in is crucial for embedding IL in authentic engineering contexts. Continuous professional development, including training on information resources, teaching strategies, and assessment methods, empowers instructors to deliver effective IL instruction [7].
3. Alignment with learning outcomes and competency frameworks. IL should be explicitly mapped to engineering learning outcomes and competencies, such as problem-solving, critical thinking, and lifelong learning. Alignment ensures that skill development contributes directly to students' professional readiness and assessment criteria [11].

4. Resource availability and accessibility. Adequate access to digital libraries, databases, and research tools is essential for equitable skill development. Limited resources can create barriers to learning and hinder students' ability to practice and apply IL skills effectively [12].
5. Integration of ethical and societal considerations. Emphasizing ethical information use, data integrity, and responsible sourcing is critical for developing professionally competent engineers. Neglecting these dimensions may result in poor research practices and compromised professional judgment [24].
6. Continuous evaluation and feedback mechanisms. Ongoing assessment of both instruction and student learning ensures that IL initiatives remain effective and responsive to evolving educational and professional contexts. Feedback loops enable iterative improvement and reinforce skill acquisition [25].
7. Cultural and contextual sensitivity. Recognizing the diversity of student backgrounds, prior knowledge, and institutional contexts is crucial. Tailoring IL instruction to accommodate varying needs enhances engagement, equity, and learning outcomes [16].

2.5.1 Student perspective: Engagement and experience in information literacy instruction

Incorporating students' perspectives is critical for the effective design and delivery of information literacy (IL) instruction in engineering education. Understanding how students respond to various approaches allows educators to tailor instruction, anticipate challenges, and foster active engagement.

1. *Student responses to instructional approaches.* Students often respond positively to active, context-based learning methods, such as project-based learning, case studies, and collaborative problem-solving exercises. These approaches allow learners to see the direct relevance of IL skills to real engineering tasks [22]. Conversely, purely lecture-based or abstract instruction may result in low engagement or difficulty transferring skills to authentic engineering contexts.
2. *Addressing common student challenges.* Many students struggle with evaluating the credibility of information, navigating complex databases, and integrating diverse sources into cohesive solutions [7]. Scaffold instruction by introducing skills incrementally, provide step-by-step guides, and incorporate formative assessments and feedback loops to build confidence and competence. Offering peer mentoring and library support sessions can also address gaps in experience.
3. *Involving students in skill implementation.* Engaging students in co-creating learning activities or assessment criteria fosters ownership and motivation. Examples include having students design research tasks, select relevant information sources, or participate in reflective exercises evaluating their learning process [8]. Encouraging self-assessment and reflective practice helps students internalize IL competencies as transferable skills rather than isolated tasks.
4. *Promoting a positive learning experience.* Clear articulation of learning objectives, relevance to engineering practice, and integration with existing coursework

increases student buy-in. Providing real-world examples, industry case studies, and opportunities to apply IL in collaborative projects enhances engagement and demonstrates the practical value of these skills.

3. Pedagogical approaches for critical thinking and information literacy

The effective teaching of information literacy (IL) in engineering requires pedagogical strategies that not only build technical knowledge but also cultivate critical thinking. The following approaches highlight methods that engage students in evaluating, analyzing, and applying complex information in engineering contexts.

1. *Problem-based learning (PBL)*. Problem-based learning engages students in authentic, open-ended problems, such as optimizing renewable energy systems or designing sustainable infrastructure. These scenarios require students to gather, evaluate, and synthesize information from multiple sources, including scientific literature, technical reports, and standards. PBL supports critical thinking by situating IL within real-world constraints, encouraging iterative inquiry, and promoting decision-making under uncertainty [26].
2. *Case studies*. The use of case studies allows students to analyze historical engineering failures (e.g., the Tacoma Narrows Bridge collapse) or sustainable innovations (e.g., advancements in solar technologies). By critically examining errors, assumptions, and contextual factors, students develop evaluative judgment and learn to recognize the consequences of flawed or incomplete information [27]. This approach reinforces the importance of evidence-based reasoning and ethical responsibility in engineering practice.
3. *Simulation and modeling exercises*. Simulation and modeling activities require students to use specialized software to test design alternatives, analyze system performance, and assess the impact of uncertainty. These exercises integrate IL with computational skills, as students must source accurate input data, validate results, and justify methodological choices [28]. Engaging with simulations helps learners understand the limitations of models and the importance of critically evaluating assumptions in technical analysis.
4. *Collaborative projects*. Group projects encourage peer-to-peer learning, collective problem-solving, and the exchange of diverse perspectives. Through collaborative inquiry, students engage in critical argumentation, challenge one another's assumptions, and refine their interpretations of data [29]. These interactions foster both IL and communication skills, preparing students for interdisciplinary teamwork in professional engineering contexts.
5. *Collaborative research assignments*. In collaborative research projects, students work in teams to investigate engineering topics, prepare technical reports, and present findings. This method enhances communication skills, fosters interdisciplinary awareness, and reinforces IL competencies by requiring students to synthesize diverse sources of information [30]. Collaboration also encourages peer learning, where students share strategies for locating and evaluating information.

6. *Librarian-led workshops*. Workshops led by academic librarians offer targeted instruction in areas such as database navigation, citation management, source evaluation, and ethical use of information. Librarians bring specialized expertise to scaffold students' research skills [1]. These workshops are particularly effective when aligned with course assignments, ensuring that students can apply newly acquired IL skills immediately within their engineering coursework.
7. *Embedded curriculum modules*. Embedding IL modules into courses such as introductory engineering, laboratory sessions, design projects, and capstone experiences provides students with repeated opportunities to practice and refine IL skills across contexts. This integration helps normalize IL as a core component of engineering education rather than an "add-on" skill [21]. Scaffolded exposure ensures that IL development progresses in tandem with increasing disciplinary complexity.
8. *Technology-enhanced learning*. Digital tools such as citation management software (e.g., Zotero and Mendeley), institutional research databases, and collaborative platforms (e.g., Overleaf and GitHub) support student engagement with IL tasks. Technology not only streamlines workflows but also reflects professional engineering practices where digital competencies are essential [23]. Incorporating such tools into instruction helps students develop transferable skills for both academic and workplace contexts.
9. *Flipped classroom*. In the flipped classroom model, students engage with instructional content (e.g., recorded lectures, readings, or tutorials) before class, allowing in-class time to focus on applying IL skills to complex tasks. For example, students may review a tutorial on using engineering databases at home and then work collaboratively in class to analyze search strategies or evaluate the credibility of retrieved sources. This approach fosters active learning and allows instructors to provide immediate feedback [31].
10. *Inquiry-based learning (IBL)*. IBL emphasizes student-driven questioning and investigation. Rather than being given problems with predefined solutions, engineering students identify researchable questions and pursue evidence-based answers. This process mirrors professional engineering inquiry and requires mastery of IL sub-skills such as formulating queries, accessing specialized resources, and evaluating the reliability of data [32].
11. *Scaffolded assignments*. Scaffolding introduces IL skills gradually across a series of assignments, moving from simpler tasks (e.g., identifying peer-reviewed vs. non-peer-reviewed sources) to more complex activities (e.g., synthesizing interdisciplinary literature in a capstone project). This structured progression reinforces learning by connecting IL to increasing levels of cognitive complexity [11].
12. *Reflective practice and learning journals*. Reflective writing encourages students to critically assess their own research processes, decision-making, and information use. Learning journals can include reflections on search strategies, source evaluation criteria, and ethical considerations in using technical data. Reflection

supports metacognition and deeper engagement with IL as a lifelong learning competency [33].

13. *Gamification and challenge-based learning.* Gamification applies game-based elements such as points, leaderboards, or timed challenges to motivate students to practice IL skills. For example, students could participate in a “database scavenger hunt” to locate specific standards or patents. Challenge-based learning, in turn, situates IL within authentic, socially relevant problems (e.g., engineering solutions aligned with the UN Sustainable Development Goals), motivating deeper engagement [34].
14. *Service-learning projects.* Service-learning links IL to community-based engineering projects, such as designing sustainable infrastructure or improving public health technologies. Students must gather and analyze diverse sources of information to address real stakeholder needs, simultaneously practicing IL skills while developing civic responsibility and ethical awareness [35].
15. *Faculty-librarian collaboration.* Collaborative teaching between engineering faculty and librarians provides students with discipline-specific IL instruction embedded directly into coursework. Faculty contextualize the engineering application, while librarians offer expertise in advanced research strategies, databases, and citation practices. This partnership model has been shown to enhance IL competency development [2].
16. *Concept mapping and visual knowledge representation.* Using tools like mind maps or concept mapping software, students visually represent relationships between sources, concepts, and evidence. This helps them organize complex technical information and critically evaluate the scope and depth of their research [36].
17. *Socratic dialog/structured debate.* Through guided questioning and debate on engineering controversies (e.g., nuclear power, AI ethics, or climate engineering), students learn to support claims with credible sources, recognize biases, and evaluate competing evidence. This method fosters both critical thinking and ethical reasoning [34].
18. *Design thinking workshops.* Design thinking provides a structured yet flexible framework for teaching information literacy (IL) within engineering education. Through its stages—empathize, define, ideate, prototype, and test—students are required to gather, analyze, and apply information that is often user-centered and context-specific. For example, during the empathize stage, students must seek diverse sources of information, such as interviews, surveys, or community data, and critically evaluate their reliability and relevance. As they move into the ideation and prototyping phases, they integrate this information into innovative solutions, testing their ideas against real-world constraints and user needs. This approach situates IL not as an isolated academic exercise, but as an embedded competency within the creative and problem-solving processes central to engineering practice. By linking IL to design thinking, students learn to treat information as both a resource and a design material, thereby strengthening their capacity for innovation, adaptability, and ethical decision-making in professional contexts [37].

4. Practical examples of successful implementations

4.1 Case example: Problem-based learning (PBL) in renewable energy design

4.1.1 Context

At a large European technical university, a third-year course on Sustainable Energy Systems introduced a semester-long PBL project. The challenge presented to students was to design a solar-powered water pumping system suitable for rural communities in Sub-Saharan Africa, where reliable access to electricity is limited. The project required balancing technical feasibility, cost efficiency, and environmental sustainability, reflecting real-world constraints engineers often face.

4.1.2 Problem framing

Students worked in interdisciplinary teams of 4–6 and were given only a broad design brief: “Develop a solar-based solution for water pumping that is reliable, affordable, and sustainable in resource-limited settings.” No prescribed sources were provided, pushing students to independently identify, retrieve, and evaluate relevant information.

4.1.3 Information literacy (IL) integration

Faculty collaborated with the engineering library to embed IL instruction at three key project milestones:

1. Problem exploration (weeks 1–2). Librarians introduced students to engineering databases such as IEEE Xplore, Scopus, and others.

A workshop focused on distinguishing between peer-reviewed research, patents, trade publications, and international standards (ISO, IEC).

Teams completed a short exercise comparing two sources on photovoltaic efficiency (one a peer-reviewed article and the other a blog post), discussing differences in credibility, bias, and technical accuracy.

2. Design development (weeks 4–8)

Teams were required to prepare an annotated bibliography justifying each source based on criteria such as authority, accuracy, currency, and relevance.

A citation management tool (Zotero) was introduced to help teams organize and share references.

Faculty reviewed bibliographies and provided formative feedback on gaps (e.g., overreliance on websites, missing standards, and lack of economic data).

3. Final design and reflection (weeks 10–12)

Students were asked to include a “Source Justification Section” in their final report, explaining why specific data (e.g., solar irradiation figures, cost estimates, or pump efficiency rates) were considered trustworthy.

Teams reflected on how information quality affected their design decisions, linking IL directly to engineering outcomes.

4.1.4 Challenges encountered

Many students initially over-relied on open web searches (e.g., blogs, Wikipedia, and commercial websites) and neglected peer-reviewed and standards-based sources. Some teams struggled to integrate economic and social data alongside technical information, highlighting the interdisciplinary nature of sustainability-focused projects. Time pressure made students reluctant to invest in thorough source evaluation.

4.1.5 Outcomes and impact

Teams that engaged deeply with IL instruction produced designs with higher technical rigor. For example, one group combined IEEE standards for photovoltaic panels with World Bank reports on rural electrification costs, leading to a design that was both safe and economically viable.

Assessment rubrics showed measurable improvement in source variety and evaluation quality compared to earlier cohorts where IL was not explicitly integrated.

Faculty noted a stronger link between data-driven decisions and final prototypes, demonstrating that IL reinforced both engineering competence and ethical responsibility.

4.1.6 Lessons learned

Embedding IL instruction at multiple project milestones was more effective than a single library workshop. Requiring annotated bibliographies and source justifications pushed students to think critically rather than merely collect references. Cross-disciplinary IL instruction (technical, economic, social) better prepared students for the complex challenges of sustainable development engineering.

4.2 Case example: Flipped classroom for information literacy in civil engineering

4.2.1 Context

In a second-year Civil and Environmental Engineering course at a North American university, instructors redesigned a unit on sustainable infrastructure assessment using a flipped classroom approach. The goal was to shift class time from passive lecture to active engagement with information literacy skills that are critical in evaluating sustainability-related data, reports, and standards.

4.2.2 Structure of the flipped model

1. Pre-class preparation: Students were assigned short video lectures and curated online modules covering key IL concepts, such as identifying scholarly vs. trade sources, evaluating government reports, and using citation tools. Each module included low-stakes online quizzes to ensure accountability.
2. In-class activities: Class time was dedicated to applying these IL skills to real-world engineering cases, such as evaluating data on urban stormwater management systems or comparing LEED certification guidelines with local building

codes. Faculty and librarians facilitated group discussions, ensuring that students critically interrogated their sources rather than accepting them at face value.

3. Post-class integration: Students worked on a mini-project, preparing a comparative analysis of at least three different types of information sources (peer-reviewed article, government report, and industry white paper) used to justify a design recommendation.

4.2.3 Information literacy (IL) integration

The flipped format created multiple entry points for IL development:

Scaffolding: Pre-class modules introduced foundational concepts like credibility, authority, and relevance [1].

Application: In-class workshops emphasized how to apply these IL concepts within authentic engineering contexts, requiring students to validate sustainability data, identify limitations, and address potential bias.

Reflection: Post-class assignments required explicit justification of chosen sources, reinforcing critical evaluation and ethical use of information.

4.2.4 Challenges encountered

Some students resisted the flipped format, perceiving the pre-class videos as “extra work.” Uneven preparation meant that a few students came to class without having engaged with the material, limiting group productivity.

Faculty initially underestimated the time needed for students to critically analyze multiple, conflicting information sources in class.

4.2.5 Outcomes and impact

Students demonstrated higher source diversity in their mini-projects compared to prior cohorts taught *via* traditional lectures. Surveys indicated increased student confidence in using databases and Engineering Village, as well as in evaluating the reliability of government and industry reports. Faculty observed that students were more engaged during class discussions, often debating the relative merits of using government reports versus peer-reviewed literature in infrastructure decision-making.

4.2.6 Lessons learned

Providing guided worksheets for pre-class videos improved student accountability and preparation. Combining librarian expertise with faculty facilitation strengthened IL instruction, ensuring students received both technical and research-focused perspectives. Embedding IL into an authentic engineering problem (sustainability in infrastructure) increased student motivation and transferability of skills.

4.3 Case example: Design thinking for information literacy in biomedical engineering

4.3.1 Context

In a second-year Biomedical Engineering Innovation course at a U.S. university, faculty implemented Design Thinking workshops to foster creativity while

embedding information literacy (IL) into the problem-solving process. The workshops followed the Stanford school model: empathize, define, ideate, prototype, and test [37]. The chosen challenge was to develop a low-cost wearable device for monitoring cardiovascular health in underserved communities.

4.3.2 Structure of the design thinking approach

1. Empathize: Students conducted interviews with community members and healthcare professionals, requiring them to critically evaluate information gathered from diverse and sometimes informal sources.
2. Define: Teams synthesized their findings into clear problem statements supported by background research from peer-reviewed journals, WHO public health databases, and biomedical engineering standards.
3. Ideate: Students brainstormed potential solutions while incorporating evidence-based practices and emerging technologies identified in scholarly and industry publications.
4. Prototype and test: Low-fidelity prototypes were developed and tested, with students documenting their process and decisions using collaborative tools (Miro, Overleaf).

4.3.3 Information literacy (IL) integration

Diverse source evaluation: Students compared scholarly evidence (e.g., medical device patents and IEEE Xplore research) with contextual data (e.g., community health reports and NGO publications).

Ethical and cultural considerations: Students critically reflected on data bias, particularly the overrepresentation of high-income contexts in wearable tech studies, aligning with ACRL's Framework [1].

Iterative information use: Each phase of the workshop required students to revisit sources, identify gaps, and refine their evidence base.

4.3.4 Challenges encountered

Students initially struggled to integrate community-based information with scientific literature, often privileging peer-reviewed sources without considering social dimensions. Time constraints limited the depth of user engagement in the empathize phase, leading to reliance on secondary sources in some cases. Some students viewed IL as a "supporting skill" rather than a core driver of innovation.

4.3.5 Outcomes and impact

Projects demonstrated an improved ability to synthesize interdisciplinary evidence, including technical, social, and ethical dimensions. Teams that engaged deeply with local health reports and NGO data produced more contextually relevant prototypes compared to those relying only on technical papers. Faculty observed increased student motivation and ownership of learning, with many students noting that the iterative design process helped them "see information as dynamic, not static."

4.3.6 Lessons learned

Embedding structured reflection prompts (e.g., “Which gaps exist in your information base?”) improved students’ ability to integrate diverse data. Collaboration with librarians and community partners enriched both technical and contextual IL dimensions. Positioning IL not as a “background skill” but as a creative enabler made students more likely to engage with it meaningfully.

4.4 Case example: Challenge-based learning (CBL) in sustainable engineering

4.4.1 Context

In a final-year Capstone Project for Environmental Engineering, Challenge-Based Learning (CBL) was adopted. Students tackled the real-world challenge of designing a water purification system for a rural community in a low-income region, aligned with the UN Sustainable Development Goals (SDG 6: Clean Water and Sanitation).

4.4.2 Structure of the challenge-based learning approach

Big challenge: Provide safe, sustainable, and affordable drinking water.

Guiding questions: Students identified sub-questions (e.g., “What contaminants are most prevalent in rural groundwater sources?” “Which purification technologies balance cost and efficiency?”).

Solutions and implementation: Teams designed prototypes that were informed by technical literature, case studies from NGOs, patents, and WHO standards. They also had to prepare a community outreach plan.

4.4.3 Information literacy (IL) integration

Required multi-source research, combining technical reports, local health surveys, patents, and open-access engineering literature.

Students engaged in uncertainty analysis, recognizing data gaps in water quality reports.

Ethical use of community data was discussed, linking IL with responsible research practices.

4.4.4 Challenges encountered

Students struggled with information overload, particularly in managing interdisciplinary sources (public health, environmental science, and engineering). Some relied too heavily on Western-based solutions, overlooking local context until prompted by reflection activities.

4.4.5 Outcomes and impact

Students developed advanced IL skills, particularly in synthesizing technical and social knowledge for applied engineering problems. Assessment rubrics showed stronger justification of design decisions and clearer communication of limitations. Community partners noted that students’ proposals demonstrated greater social responsibility and contextual awareness than in previous years.

4.4.6 Lessons learned

Embedding scaffolding sessions on source evaluation early in the project reduced overload later. Partnering with local organizations provided authentic data and enhanced student accountability. Reflection journals helped students connect IL, ethics, and sustainability, reinforcing lifelong learning skills.

4.5 Service-learning for information literacy: Sustainable energy solutions

4.5.1 Context

A senior-level Electrical Engineering course partnered with a local non-profit focused on renewable energy access in rural communities. Students were tasked with evaluating and recommending solar microgrid solutions to meet local energy needs, aligning with SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action).

4.5.2 Structure of the service-learning approach

1. Community partnership: Collaboration with local technicians, residents, and NGOs to identify energy challenges.
2. Project scope: Teams conducted feasibility studies on solar panel placement, energy storage options, and cost-efficient designs.
3. Deliverables: Students produced technical reports, feasibility assessments, and community-friendly guides explaining energy use and maintenance.

4.5.3 Information literacy (IL) integration

Source gathering: Students accessed peer-reviewed renewable energy research, government energy reports, and industry white papers.

Critical evaluation: Emphasis on assessing credibility, currency, and relevance, including cross-checking technical specifications against local needs.

Ethical considerations: Students learned to present recommendations transparently, acknowledging limitations, assumptions, and potential environmental impacts.

4.5.4 Challenges encountered

Difficulty reconciling technical data with local resource constraints. Balancing academic rigor with accessible communication for community stakeholders. Limited data availability on local energy consumption patterns required creative information gathering.

4.5.5 Outcomes and impact

Students demonstrated stronger IL skills, particularly in evaluating diverse sources for technical and practical relevance. Community partners implemented several student-suggested solutions, leading to measurable improvements in energy access. Reflection exercises enhanced students' understanding of ethical responsibilities in technology deployment and social sustainability.

4.5.6 Lessons learned

Early involvement of community members ensures realistic project scope and relevant data collection. Structured IL activities (annotated bibliographies, source comparison exercises) scaffold learning and support decision-making. Combining technical analysis with community engagement strengthens both engineering competence and social responsibility awareness.

4.6 Example: Sustainable urban drainage systems

4.6.1 Context

Civil and environmental engineering students investigate stormwater management solutions for urban areas. The project integrates IL and sustainability (SDG 6 and SDG 11—Sustainable Cities).

4.6.2 Structure

Question formulation: Students ask, “Which sustainable drainage solutions are most effective for reducing urban flooding in our city?”

4.6.3 Information gathering (IL integration)

Access peer-reviewed journals on hydrology and green infrastructure. Review technical standards, municipal reports, and case studies. Evaluate sources for credibility, currency, and applicability.

Analysis and synthesis: Compare data from different sources (e.g., rainfall patterns and soil permeability). Integrate experimental or simulation data with literature findings.

Presentation and application: Develop proposals supported by evidence from evaluated sources—present findings to faculty, peers, and city planners.

4.6.4 Challenges

Students may initially rely on easily accessible but low-quality online sources. Integrating diverse types of information (scientific data, municipal reports, GIS data) can be complex.

4.6.5 Outcomes and impact

Enhanced IL skills, including source evaluation, citation, and ethical reporting. Improved ability to make data-driven engineering decisions. Students gained experience in sustainable, real-world problem-solving.

4.6.6 Lessons learned

Structured IL instruction (e.g., librarian workshops and guided source evaluation exercises) improves outcomes. Linking IL tasks to tangible engineering problems increases engagement and relevance. Reflection activities help students internalize the connection between IL and professional engineering practice.

4.7 Example: Environmental engineering—Sustainable urban development-Jigsaw Method

4.7.1 Implementation

Students are divided into “expert groups,” each responsible for researching one subtopic:

- Water management and treatment
- Air quality and pollution control
- Renewable energy integration
- Sustainable transportation systems

Each expert group conducts research using peer-reviewed journals, government reports, technical standards, and reputable databases. They critically evaluate sources for credibility, relevance, and currency (IL skills). After completing their research, students are reorganized into mixed “jigsaw groups,” so each group has one expert from every subtopic. Each expert teaches their subtopic to the group, explaining findings and citing sources. The group then collaboratively develops an integrated urban sustainability plan.

4.7.2 IL integration

Student’s practice locating authoritative sources and evaluating their quality. They synthesize diverse information into a coherent plan. Ethical and accurate citation of all sources is emphasized.

4.7.3 Learning outcome

By the end of the project, students demonstrate the ability to critically evaluate information, integrate interdisciplinary knowledge, and collaboratively produce evidence-based engineering solutions.

5. Conclusion

Information literacy (IL) is a foundational competency for engineers, encompassing the ability to recognize information needs, locate, evaluate, and apply information effectively, and communicate it ethically [1]. In engineering education, IL is critical for informed decision-making, research, design, and sustainable problem-solving. By integrating IL into curricula, educators prepare students to navigate complex information landscapes, think critically, and respond to real-world challenges.

Engineers must distinguish between different information sources, including peer-reviewed journals, technical standards, patents, trade publications, and online resources. Evaluating credibility, accuracy, currency, and relevance ensures the reliability of design, research, and development efforts [30]. Critical thinking complements IL by enabling students to analyze data, identify biases, assess uncertainty, and consider ethical implications in engineering decisions [38].

Effective pedagogical approaches for embedding IL in engineering education include problem-based learning (PBL), flipped classrooms, technology-enhanced learning, design thinking workshops, inquiry-based learning, service-learning projects, gamification, collaborative research assignments, concept mapping, and the jigsaw method. In PBL, for example, students may optimize renewable energy systems by evaluating multiple data sources [23]. In flipped classrooms, students prepare through pre-class readings and engage in critical analysis discussions during class [17]. Design thinking workshops require students to empathize with stakeholders, define problems, ideate solutions, prototype, and test, embedding IL within creative innovation processes. Service-learning projects allow students to address community-based engineering challenges, fostering social responsibility, ethical awareness, and practical IL skills [35]. Concept mapping and the jigsaw method support collaborative learning by visually organizing information and sharing expertise among peers [39].

Integration of IL aligns with ABET learning outcomes, supporting students' ability to apply knowledge of mathematics, science, and engineering, design and conduct experiments, communicate effectively, engage in lifelong learning, and understand contemporary issues including sustainability [9, 40]. Furthermore, IL supports sustainability competencies, enabling students to consider the environmental, social, and economic impacts of engineering decisions, apply life-cycle thinking, and propose solutions aligned with the United Nations Sustainable Development Goals [41].

To implement IL successfully, educators should embed IL modules across courses and projects, employ active and authentic learning strategies, integrate digital tools for research and data management, and encourage ethical and sustainable engineering practices. Faculty-librarian collaborations, ongoing assessment of IL skills, curriculum scaffolding, and alignment with accreditation standards strengthen institutional support and sustainability of IL initiatives.

In conclusion, teaching information literacy in engineering education equips students with essential skills for data-driven decision-making, ethical reasoning, and lifelong learning. By combining critical thinking, active learning approaches, and sustainable practices, educators foster engineers capable of addressing contemporary global challenges with responsibility, creativity, and rigor.

Acknowledgements

This work was supported by a grant from the National Program for Research of the National Association of Technical Universities: GNAC ARUT 2023.

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Digital Literacy Space and Value Re-Orientation in Nigeria: A Critical Examination of the National Orientation Agency's Mandate

Mustafa Adedeji Tukur

Abstract

It is acknowledged that technological revolution within the digital space has greatly impacted societies around the world with the enduring implications for human social interactions. Such phenomena have also witnessed some alterations in the value re-orientation landscape essentially, as a result of the wider embrace of the digital technology across demography and its attendant consequences for societal value system. These phenomena however, are not exclusive as they have persistently assumed a global dimension. This paper highlights the responses of successive governments in Nigeria to the global digital revolutionary trend as could be demonstrated through the initiation of several policies and programmes aimed at value re-orientation of the citizenry with the adoption of the digital tools of socialization. The paper has therefore, adopted an exploration of some relevant literature while examining the efforts by the Nigerian governments in the adoption of the digital technology tools in the tasks of societal value re-orientation and behavioral change communication. It is further argued that, if appropriately deployed, the digital technology has the tendencies to impact positively and offer the needed impetus for changing the value re-orientation landscape in Nigeria. The paper however, submits that the Nigerian government and its institutional mechanism for value re-orientation must strive further in exploring the digital space and its tools of engagement towards building an ethically balanced Nigerian society.

Keywords: behavioral change, digital technology, e-governance, ethical revolution, value re-orientation

1. Introduction

The continued wave of the digital space revolution has no doubt, impacted significantly societies and human interactions. The access to the digital space is also becoming widely embraced while its adoption, even by the state and non-state actors alike,

has assumed some unprecedented dimensions in the recent times. The Nigerian state and its various institutions have not been left out in this digital revolution epoch by the efforts to institutionalize the concept of e-governance in the delivery of essential state services. Efforts at value re-orientation by governments, particularly in Nigeria, have also been taken beyond the use of the traditional tools of mass media, such as radio and television, newspapers, bulletins, magazines and other extant media of mass communication with the embrace of the new media outlets. The changing civic space as well as the growing consciousness among citizenry no doubt, needs some commensurate efforts by the government in response to the increasing demographic complexities and their implications for the society.

Though, successive governments in Nigeria have initiated series of value re-orientation programmes, relying most essentially on the state-owned media outfits as part of the deliberate policies of the government. Such efforts have also been seen to have evolved within the changing dynamics of the global events. With the increasing embrace of the new media as a tool of communication, it could be argued that the tendencies for some negative implications on the societal values should not be over-emphasized. For instance, at the turn of the era of globalization which also accompanies the emergence of the digital technology, citizens' engagement for participatory governance has become more inclusive, but with many negative tendencies for social anarchy. However, the identification of such negative tendencies in the deployment of the digital technology has also in the present, offered a veritable window for the Nigerian government in reaching out to citizens more adequately and timely than with the use of the traditional media. In the opinion of Tukur [1], the accessibility to the social media windows, and most significantly, the use of the digital technology platforms, such as Facebook, Instagram, X (Twitter), WhatsApp, among other evolutionary new media platforms of citizens' engagement has been found effective by the government in their utility for fostering state-citizens interactions.

Similarly, according to Bieh and Boroh [2], value systems as a significant reflection of the societal history and culture are a social construct and therefore, serve as the basis of what informs their overall image. Invariably, the value system explains the metrics upon which behavioral norms are measured in their acceptable socialization patterns as well as in their interactions with the larger world. The Nigerian society, like any other society around the world, strives in its several efforts to evolve acceptable national values reflective of its diversity and age-long cherished ethos and nuances. Though, such efforts have remained herculean in spite of the successive governments' determination to realize that objective. The Nigerian state, as a post-colonial construct, had been confronted with plethora of challenges of nation-building since independence in 1960, part of which had culminated in a 30-month civil war. In the aftermath of that internal civil war, there were bold initiatives of several centripetal policies aimed at national integration and rebuilding a more unified Nigerian state. Aside the popular 3Rs (Reconciliation, Rehabilitation and Reconstruction) policy of General Yakubu Gowon at the conclusion of the civil war, measures were also put in place to evolve other enduring policies around sustainable value re-orientation programmes such as the National Youth Service Corps (NYSC) scheme as a veritable platform for national integration among other centripetal policies for national unity and cohesion.

It is apposite to assert that efforts at value re-orientation have been one recurring policy thrust of every successive government particularly, the military administrations with such policy preferences predicated on the nature and the character of the military as a state institution known for its command-chain system and strict

disciplinary outlook. For instance, the military administration of General Murtala Muhammed, which succeeded General Gowon military administration, embarked on stringent measures against official corruption at a larger scale with many public office holders and public servants relieved of their positions and appropriately sanctioned as a precedent to the administration's stance on official graft and other vices. The highpoint of the policy thrust of the successive military governments in Nigeria lies most significantly, in providing corrective measures against the ills of the society and this had always been put forward as part of the basis for their intervention in political governance.

The above contention can be reinforced with the military coup d'état, which ousted the democratic government of President Shehu Shagari in December, 1983, and the assumption of power of Buhari/Idiagbon military government. The attempt by the Buhari/Idiagbon military government to come up with a policy on War Against Indiscipline (WAI) served as a bold step towards reassuring the Nigerian citizens of its avowed stance against the monsters of indiscipline and other societal vices including corruption across levels. Similarly, the succeeding military government of General Ibrahim Babangida, which was birthed in the circumstance of a palace coup d'état, made further efforts in sustaining and enlarging the scope of its value re-orientation programmes beyond the somewhat rigid and inflexible approaches of the previous regime of Buhari/Idiagbon military government. General Babangida had adopted a more suasive approach to value re-orientation and behavioral pattern programme under the aegis of MAMSER (Mass Mobilization for Self Reliance, Social Justice and Economic Recovery), which later metamorphosed into National Orientation Agency (NOA), following its merger with other relevant agencies of the federal government in August, 1993.

While taking recourse to the above explications, it could also be averred that though, these value re-orientation programmes had been put in place in the period prior to the era of the digital technology, but their impacts have however, been more felt on the citizenry through the much available traditional means of mass communication most especially, the print and electronic media. It could also be noted that, such was an era of the state-dominated media landscape whereby, the electronic media ownership was much under the exclusive control and domination of the federal and state governments in Nigeria. That exclusive media environment had equally flourished with the existence of a near-authoritarian political regime of the military, which provided the veritable ground for a wider acceptability of the value re-orientation programmes of the military government of the period. MAMSER was ostensibly more acceptable as well embraced as a household name within the length and breadth of the Nigerian society. In a more explicit context, MAMSER and its corporate image also had some positive implications for the Babangida military administration as its flagship programme for mass mobilization, in what later became a watershed in its ill-fated transition to democracy programme between 1987 and 1993.

It is also important to note that, with the advent of electoral democracy in Nigeria in 1999, and beginning with Chief Olusegun Obasanjo administration, there has been a realization of the need for continued efforts at value re-orientation through mass mobilization and citizens' engagement. The Obasanjo's civilian administration, which also marked another phase of the return to democracy in 1999, had launched a value re-orientation programme tagged the "National Rebirth" which served as the continued reaffirmation of the necessity to rid the country's social landscape of the already identified vices such as official graft in our national life. This effort was explicitly demonstrated with the establishment of antigraft agencies as the Economic

and Financial Crimes Commission (EFCC), the Independent Corrupt Practices and other Related Offences Commission (ICPC), alongside the constitutionally established Code of Conduct Bureau (CCB), and Codes of Conduct Tribunal (CCT). In furtherance of the policy measures in strengthening value re-orientation policies and programmes, the Buhari civilian administration also reenacted efforts in that direction with the launch of the National Ethics and Integrity Project towards strengthening policy against corruption and other economic crimes.

As it stands currently, the President Tinubu's administration desire to reawaken the national value re-orientation programmes became more visible with the soon to be inaugurated National Values Charter (otherwise known as the National Identity Project) under the aegis of the National Orientation Agency (NOA). The National Values Charter represents a paradigm shift in Nigeria's value re-orientation trajectory as it is targeted at creating a new social contract between the Nigerian citizens and the government relying heavily on the adoption of the digital technology. Arguably, the Nigeria's value re-orientation landscape has been greatly altered by the digital technology revolution and the relevance of the state institution as the National Orientation Agency (NOA) became highly enhanced. Since its transmutation into a broader value re-orientation and policy communication agency of the Nigerian government in 1993, the National Orientation Agency has also continued to adapt itself to the changing dynamics of the media space. It has in the recent times, redefined its mandate of communicating government policies, programmes and activities through citizens' engagement and adapting its modus of operation to the changing media landscape. Remarkably, the fortification of its activities through the adoption of the digital technology in its further appeal to realizing the operational philosophy of policy communication and citizens' engagement portends a positive future for Nigeria's behavioral change and the value re-orientation landscape at large.

2. Overview of Nigeria's value re-orientation landscape: Survey of literature

Inasmuch as scholarly interventions have provided some illuminating perspectives to the question of value re-orientation in Nigeria and elsewhere, literature is also replete with diverse contributions in this particular direction. For instance, Abideen [3] views value re-orientation as that process, which also includes means, methods and ways of effecting attitudinal change towards a set of objects, which have been identified as negative attitudes in a given society or organization. It is further perceived as the effort towards redirecting citizens' attention to the acceptable social, economic, cultural, intellectual, political, moral and esthetic norms. Value re-orientation also explains the level of consistency made by the people and the society or organization in reviving or restoring the earlier bastardized values for which they were previously identified with. Thus, value re-orientation serves as the pathway for the acquisition of new set of values capable of instilling a more appropriate norm for better citizenship and the society.

For Bieh and Boroh [2], the concept of value re-orientation could be examined from the double point of analysis. For clarity, value has been explained within the academic prisms of the sociological and anthropological angles. It connotes what is cherished or regarded as important by individuals or social group with the expression of anything that offers utility, quality or importance. It could also be woven around standards of conduct, efficiency or worth, which a society approves or

endorses, maintains and even transmits to its members or future generations. It is further explained as a conception explicit or implicit, distinctive of an individual or a characteristic of a group, which impacts the process of selection of modes, means and end of action. Value is thus summarized as moral principles and standards, which individuals uphold as important, with that mutual acceptance of the ethical or moral metrics, which are desirable and adequate within a cultural milieu. Bieh and Boroh [2] concluded that culture is peculiar and has its unique value system with different levels of mores, rules and norms for appropriate regulation, evaluation and sanctions.

On the other hand, Bieh and Boroh [2] also explain the concept of value re-orientation rather from the standpoint of the orientation process designed to reconnect the people to the expected or the desired level of acceptable norm as regards their knowledge of or belief in previously cherished values.

According to Shittu and Gamde [4], value connotes what is worthwhile and acceptable to either individual or groups and such is to be accepted as the embodiment of good traits as responsibility, reliability, honesty, obedience, faithfulness, truthfulness, decency and discipline. This argument also reinforces the fact of value as being inherent in the people as a measure of acceptable norms, which must be adequately passed down from one generation to another generation in a carefully designed socialization process. Perhaps, value can be summed as the effort by which the society ensures the preservation of its cherished norms towards maintaining some levels of social equilibrium.

Similarly, Ajoku and Ochoma [5] argue that value and morality can be equated as depicting the set of acceptable conduct of behavior in the society. Through the centuries, among the major challenges that have confronted philosophers and educators, has been related to the problem of values. To them, values have the tendencies to influence people's behavior and serve as the measure for evaluating the actions of people in the society. While relating that to domain of education, values also serve as the paramount yardstick, which is usually deployed for regulating the educational system for the overall positive development of the society. Value has also been defined as the study of such concepts as good, bad, desirable, beautiful, ugly etc. and it tends to examine the justification of judgments that involves these concepts, the logic of the argument by which they are supported or challenged". They further aver that value re-orientation on the other hand, explains the attempt at redirecting the attention of the citizens towards the acceptance of social, economic, cultural, intellectual, political, moral and aesthetic norms of the society.

In their own modest contributions to the question of value re-orientation and effective leadership, Tafiya et al. [6] maintain that value re-orientation could only be appropriately predicated on effective leadership. The fact that effective leadership remains a sine qua non to value re-orientation also presupposes the argument that for any society to achieve the task of maintaining the requisite standards of moral values, the place of leadership in the provision of appropriate direction can never be overemphasized. Similarly, because the task of value re-orientation is one of the major roles of leadership, such has also placed the burden of compliance of value re-orientation on those who have been bestowed with that mandate of leading and directing the affairs of men and the society. It is also explainable that the reason why the task of value re-orientation falters in any society can be put at the failure of leadership.

In the expression of Njoku [7], at the core of every human culture or ethos of any culture is a mark of its fundamental values. Value is the assertion of acceptable standards, ideal way of conduct and living virtuous life in society, and it cannot function in the vacuum of socio-cultural environment. However, certain values have

been identified to be fundamental to all societies, and at base of that is the family as the basic unit of the society. Invariably, the focal point of any societal value system takes its roots in the family, which translate into the collective values that make up the societal value systems in its entirety. In furtherance of that expression is another plausible argument of the influence of religion on the value system of the society. Religion as the bastion of man's moral rectitude also serves a major metric for regulating human conduct while also providing the socialization platform for inculcating the right ethical conducts based on the religious inclination of the adherents. Though, religion has also been faulted in its centrifugal tendencies in a multiple society like Nigeria due to some incessant crises usually instigated within the secular space of the country. But by and large, religion has to a large extent offered that needed recipe for the promotion of acceptable value system in a multiple society as Nigeria.

While considering the role of effective parenting and socialization for value re-orientation in Nigeria, Okoroafor and Njoku [8] argue that the fundamental task of any society lies in the ability to reproduce itself by nurturing members whose behaviors, desires and goals are in consonance with the desirable and acceptable norms of such society. That through a well thought-out process of socialization, the society needs and desires could also translate the needs and desires of the individual members of that society. The highpoint of this explication lies in the assumption that, societal acceptable norms and ethical codes of conduct can easily be assimilated by all members of the society, if such a society also holds on tenaciously to the set of the acceptable codes of conduct. While making equal reference to parenting as a vital instrument of family construct, it is equally inferred that, effective parenting can offer the needed fundamental support in the sustenance of the society codes of ethical conduct and its value system as a whole.

On a concluding note, the Nigeria's value re-orientation landscape no doubt, is also replete with adequate legal and policy frameworks with a robust socio-behavioral provision, which have provided the needed impetus for its continued sustenance, irrespective of the array of challenges threatening its existence. For instance, Chapter 23 (23) of the 1999 Nigerian Constitution made a copious provision for what is generally known as the National Ethics or the National Core Values as follows: Discipline, Integrity, Dignity of Labour, Social Justice, Religious Tolerance, Self-Reliance and Patriotism.

These constitutional provisions, aside the National Ethics and Integrity Policy document as put together by the Economic and Financial Crimes Commission (EFCC), in conjunction with the National Orientation Agency (NOA), and the Office of the Secretary to the Government of the Federation (OSGF), coupled with the recently adopted National Value Charter Project (otherwise known as the National Identity Project) of the National Orientation Agency (NOA), the Nigerian ethical value re-orientation landscape has continued to portend that promising future for the Nigerian state. The need to bridge the gap of distrust, which has long existed between the citizens and those who manage the affairs of the country, also requires such avowed commitment beyond the symbolic and official gesture through socio-legal frameworks and policy documents. The commitment to the expression of voluntary adherence of the citizens to these provisions is much required to effect any positive change.

3. Methodology

This study is essentially literature based and therefore, interrogates relevant documented sources both in empirical and theoretical perspectives. However, the

secondary data-dependent nature of this study has afforded it to draw its inspirations extensively from previous relevant studies by considering a literature survey method and the critique of such extant sources in arriving at some propositions. Furthermore, this paper will critically examine the Nigeria's value re-orientation landscape while also reviewing the successive institutional mechanisms established for that purpose, and their various methodologies including the adoption of the digital literacy tools in the delivery of the tasks of value re-orientation and behavioral change communication at large. This paper aims to appraise the Nigeria's value re-orientation ecosystem both in its historical context as well as in the pathways to enriching efforts towards building an ethically balanced Nigerian society.

4. National Orientation Agency and the Nigeria's value re-orientation landscape

4.1 National Orientation Agency in historical perspectives

The evolution of the National Orientation Agency could be described as quite an eventful trajectory for the fact of it being one of the institutional legacies of the military rules in the Nigerian political history. As previously noted, past efforts by the military regimes in Nigeria had been largely modeled on its peculiar nature as an institution of the Nigerian state, and also in consonance with political agenda of transiting the country into a democratic governance environment. The establishment of the National Orientation Agency can also be located within those premises as an institution whose birth was to herald the new democratic governance environment through the mobilization and active engagement of the citizens in the transition to civil-rule programme of the General Ibrahim Babangida military administration. Sequel to this period, MAMSER had existed along with other vital institutions of the government as the National Orientation Movement (NOM), War Against Indiscipline (WAI), as well as the Public Enlightenment Department under the Federal Ministry of Information and Culture, all of these machineries of the government operating separately in their overlapping mandates of value re-orientation, mass mobilization and citizens' engagement. According to Babangida [9], prominent among these institutions was MAMSER established previously on the 25th of July, 1987 as part of the recommendations of the political transition bureau led by Dr. Samuel Joseph Cookey to fashion out the political transition modalities for the country in the entire transition to civil-rule agenda of the Babangida-led military administration.

However, in furtherance of the conviction of the Babangida's military administration to consolidate and harmonize government's efforts in the areas of value re-orientation and mass mobilization of the citizens, the National Orientation Agency (NOA) came into existence following the merger of the aforementioned institutional machineries, including MAMSER via the Military Decree 100 of August 16, 1993. The National Orientation Agency as it endures till date, like many institutions of the Nigerian government, has undergone several reforms in the efforts to reposition it for optimal performance of its mandate. The Agency has at some periods been placed under the direct superintendence of the Presidency since the era of the military administration and only under the democratic administration of Chief Olusegun Obasanjo that it was brought under the control of the federal ministry of information as its supervising ministry.

Importantly, the extant legal instrument which established NOA, that is, the Decree 100 of 1993 had since been transmuted into the Act of the National Assembly (Act of the National Assembly 100) in reflection of the democratic outlook of the political dispensation in the country. As an Agency of the federal government, it is headed by a Director General whose appointment is at the instance of the President of the country on a 5-year renewable term. The Agency also has a Governing Board whose membership is drawn from both the government and the organized private sectors of the country with the mandate to direct the affairs of the Agency in line with its legal instrument of operation.

Recognizing its mandate and the peculiar political structure of the Nigerian state, NOA is aligned with the federal structure of the country for ease of its operational mandate across the length and breadth of Nigeria. Invariably, it has its National Headquarters office in the Federal Capital Territory (FCT) in Abuja, six newly established zonal offices across the six geopolitical zones of the country, 37 state directorate headquarters offices for the 36 states of the federation including the FCT directorate, and 774 local government formations located at the local government areas and serving as the base and the arrowheads of the Agency programmes implementation across Nigeria. Because of the operational mandate of NOA, it has functional 16 departments, each headed by a Director at its National Headquarters, and most of which are also replicated at the 37 state directorates level for optimal delivery of its mandate of value re-orientation and citizens' engagement at the grassroots. These 16 functional departments have 8 programme-based and another 8 administrative-based departmental structures at the National Headquarters.

4.2 Objectives of the National Orientation Agency

The objectives of the National Orientation Agency, as provided in the extant legal instrument of the Decree 100 of 1993, according to National Orientation Agency handbook [10], are to ensure that government programmes and policies are better understood by the general public and perform the following specific objectives:

1. Mobilize favorable public opinion for such programmes and policies.
2. Establish feedback channels on all aspects of Nigerian national life.
3. Encourage informal education through enlightenment activities and publications.
4. Fostering respect for Constituted Authorities; and instilling in the citizens, a sense of loyalty to the fatherland.
5. Establish appropriate national framework for educating, orientating and indoctrinating Nigerians towards attitudes, values and culture, which project individual's national pride.
6. Awaken consciousness of Nigerians to their responsibilities to the promotion of national unity, citizens' commitment to their human rights to build a free, just and progressive society.
7. Ensure and uphold leadership by example.

8. Develop among Nigerians of all ages and sex, social and cultural values and awareness, which will inculcate the spirit patriotism, nationalism, self-discipline and self-reliance.
9. Encourage the people to actively and freely participate in discussions and decisions on matters affecting their general welfare.
10. Promote new sets of attitudes and culture for the attainment of the goals and objectives of a united Nigerian state.

4.3 Functions of National Orientation Agency

In a similar manner, according to the National Orientation Agency Handbook [10], the Agency specifically performs the following functions:

1. Enlightenment of the general public on government policies, programmes and activities.
2. Propagate and promote the spirit of dignity of labour, honesty and commitment to qualitative production, promotion and consumption of home produced commodities and services.
3. Mobilization of favorable public opinion and support for government policies, programmes and activities.
4. Re-orient the populace about power, its use and proper role of government in serving the collective interest of Nigerians.
5. Collection, collation, analysis and provision of feedback from the public to government on its policies, programmes and activities.
6. Propagate the need to eschew all vices in public life including corruption, dishonesty, electoral and census malpractice, ethnic, parochial and religious bigotry.
7. Establish social institutions and framework for deliberate exposure of Nigerians to democratic norms and values for a virile, peaceful, united, progressive and disciplined society.
8. Arouse the consciousness of all categories of Nigerians to their rights and privileges, responsibilities and obligations as citizens of Nigeria.

As the National Orientation Agency strives to stay dynamic, relevant and impactful in its mandate as stated above, it has also remained consistent to its objectives amidst operational challenges in its over three decades of existence as an institution of the Nigerian government. These operational challenges are not limited to poor budgetary allocations for its 818 operational locations across the country, but lack of tools and other operational logistics to carry out its enormous mandate has further characterized it as an ineffectual institution in Nigeria. However, with the new democratic government of President Bola Ahmed Tinubu, which came into power on the

29th of May, 2023, the National Orientation Agency hopes to relive itself with a new lease of life and wake up to its mandate and the expectations of the Nigerian citizens. Similarly, the new management of the Agency under the leadership of Mallam Lanre Issa-Onilu is also determined to change the value re-orientation landscape in Nigeria with the commitment to enhance the Agency's visibility and operational bandwidths in realization of that objective.

The value re-orientation ecosystem in Nigeria has not only witnessed a major turn-around in response to the changing dynamics of the sociological realities as well as the global context of the technological revolution. The Nigeria's value re-orientation landscape has consistently remained open to the embrace of the digital technology with the increasing deployment of the tools of the new media by the National Orientation Agency in its effective delivery of the task of value re-orientation and citizens' engagement in Nigeria. The Agency's radical departure from other traditional methodologies of mass mobilization and value re-orientation, such as Town Hall Meeting/Community Dialog, Door-to-Door/Foot-slugging, Theater for Development, Distribution of IEC (Information, Education and Communication) Materials among others, has also provided another prism to its genuine commitment towards meeting up with its renewed mandate as encapsulated in the National Values Charter (otherwise known as the National Identity Project).

5. National Orientation Agency and the digital literacy space in Nigeria

The adoption of e-governance in Nigeria has no doubt, brought a lot of respite into the public service at large. In the expression of Oghuvbu et al. [11], the formulation of the Nigerian National Information Technology (NNIT) strategy in the year 2000 marked a momentous turning point in the Nigerian public administration with the intention of enabling the country to be fully integrated into the global revolution of the digital literacy agenda particularly, within Africa. Ideally, the concept of e-governance has been adopted in the Nigerian public service, which is to further enhance service delivery and promote citizens' engagement with the overall objective of allowing the citizenry to reap the benefits of the government. To this end, Abasilim and Edet [12] opine that e-governance has been adequately deployed to tackle challenges of service delivery while also resolving specific societal concerns in the areas of education, wealth creation, poverty eradication, job creation, health and agriculture.

In realization of its pivotal role in the critical mandate of policy communication and advocacy as well as in feedback mechanism, the National Orientation Agency has not relented in this direction by yielding to the changing dynamics of its operational environment. This effort has been equally reflected in its organizational system while adapting itself to these changing realities. The paradigm shift in its delivery schemas as regards communicating government policies, programmes and activities is reflective of the demographic considerations and the appropriate tools of socialization for the delivery of these tasks to the wide array of the Nigerian citizens. On the other hand too, the changing paradigm, which has received the Agency's radical move towards changing the public perspectives of its erstwhile conservative posture in the discharge of the critical task of communicating policies, programmes and activities beyond the traditional media of communication. In another realization of the evolving popular culture and its steady embrace within the context of the digital literacy in Nigeria, it is also apt to aver that the National Orientation Agency within the period of 2023, when its current helmsman and Director General, Mallam Lanre Issa-Onilu

assumed office, has drastically moved away from its erstwhile docile posture to that of an effective public service agency.

As digital literacy is becoming a sine qua non and inevitable for human social interactions, the Agency's determination to deliver its mandate and the engagement with the complex demographics of the Nigerian society has occupied the priority place, despite its limiting operational environment. As the digital literacy space cannot exist in the vacuum of the contents of delivery to the wide arrays of audience, it is also pertinent to remark that many of the activities of the National Orientation Agency have been carefully designed and directed towards the targeted audience and stakeholder groups for effective delivery of such contents, using the appropriate media of communication, including the new digital literacy media space. This development has placed the National Orientation Agency in the public glare and offered the positive perspectives of the Nigerian public about its continued relevance and utility as a Nigerian public institution.

The National Orientation Agency strive for actions and relevance can only become realizable, if it also comes to terms with the changing dynamics of its operational environment and the necessity of the conviction for changing the value re-orientation ecosystem amidst antisocial vices and the growing misdemeanors within the Nigerian society. As a pivotal institution, and in the most recent times, the Agency drives the Nigerian society through its many strategic public education and advocacy such as its flagship programmes and activities as CLHEEAN and the National Values Charter (otherwise known as the National Identity Project). CLHEEAN is an acronym for the Agency's innovative activities carefully woven around the thematic areas of identified focus upon which its value re-orientation programmes are targeted. The acronym stands for C (Crime), L (Lawlessness), H (Health), E (Education), E (Environment), A (Abuse), N (Nationalism). Further to the realization of the CLHEEAN thematic agenda, and as previously reiterated, the Agency had also embarked on some major structural reorganization in reflection of this objective, with its functional and programme-based departments renamed. These new departments are: Health and Social Care Department, Abuse, Rights and Narcotics Department, Environment, Climate and Energy Department, Community Safety, Awareness and Compliance Department, Community Outreach and Development Department, Youth Engagement and Inclusion Department, Civic, Values and Democracy Education Department, and Media and Communication Department.

5.1 National Orientation Agency digitization initiatives

In consonance with the National Orientation Agency determination towards leveraging technology for enhanced national engagement and changing the value re-orientation ecosystem in Nigeria, several innovative measures are generated in this direction. Aside the use of the major traditional mass media outfits with national appeal, the Agency also maintains a Content Factory, which is at the forefront of its engagement and public education to the wide mass of the Nigerian demography. The newly established NOA TV and NOA Radio are part of the new efforts in complementing media partnership with the major traditional electronic media outfits nationwide, while its weekly online publication, "The Explainer", equally serves in a similar capacity in the area of print media of communication. Essentially, the NOA Content Factory as noted, is dedicated to creating and disseminating contents that not only inform but also inspire positive actions, participations and mobilization of all citizens towards building a more informed, inclusive and engaged Nigerian society.

By and large, the reinvigoration of NOA through the aggressive digitization of its media engagement beyond the extant traditional socialization methodologies is aimed not only at enhancing its operational bandwidths but to enlarge its demographic dragnet, considering the increasing consciousness of the Nigerian youth who obviously dominate the country's population structure.

5.2 The National Orientation Agency content factory and the digital literacy space in Nigeria

In the further clear expression of its manifest determination to changing the value re-orientation landscape in Nigeria, the National Orientation Agency Content Factory is a robust and well-articulated digital hub for dissemination of necessary information on policies, programmes and activities of the government. It also serves as a platform of interface and engagement with the Nigerians of all ages, class, gender and groups. The Content Factory has also served as effective tool of operations for the Agency's workforce particularly, its field operations staff located in the 36 States including the Federal Capital and the 774 Local Government formations of Nigeria. It provides real-time online accessibility essentially in the discharge of duties and feedback mechanism routines of the field operations. The Content Factory components are as follows:

- a. The Curator: This is an AI (Artificial Intelligence)-powered data management platform whereby, with the deployment of AI, the Agency is able to maintain and constantly update its demographic database, providing capacity for well-targeted and highly effective strategies and communication. The Curator serves in the capacity as a workstation in providing support system for the Agency most essentially, in the provision of its important role of feedback mechanism mandate. The platform has been effectively deployed in the fulfillment of its feedback mechanism function through collation and compilation of timely reporting bothering on citizens' reactions to government policies, programmes and activities as well as in civil intelligence gathering and early warning reporting system.
- b. National Hackathons: Because of the demographic reality, which has constantly placed the youth at the majority category in Nigeria population distribution, the National Hackathons are a dedicated platform targeted at this critical segment. This platform has been so designated as to serve as a digital forum for the Nigerian youth, both at home and in the diaspora in serving to foster unity among them while contributing to essential discourse of national importance. The National Orientation Agency has been at the forefront of the promotion of an inclusive Nigerian society as adequately demonstrated through its various programmes and activities.
- c. Insight Data: Relying on its operational structure, which has also provided accessibility to its various stakeholders who are mostly located at the grassroots of Nigeria, the Agency achieves its mandate of public engagement, attitudinal change and value re-orientation, media engagement, digital presence through its well-established presence with now, four structural platforms at its National Headquarters, the newly created 6 Zonal Offices, the 36 State Directorates and the Federal Capital, and the 774 Local government Formations across Nigeria. The Insight Data tool has equally afforded the Agency to actively involve the public, instilling the right values and attitudinal change, mobilizing the citizens

for positive national development, engaging with the media for information sharing, shaping public perception, and utilizing various platforms to engage with citizens in combating misinformation, mal-information, disinformation and fake news at large.

- d. The Mobilizer App: This is another AI (Artificial Intelligence) dedicated platform devoted to engaging the youth, both at home and in the diaspora. It is also essentially in recognition of the demographic strength of the Nigerian youth and their positive impacts towards contributing to national development. The need to involve the youth has been one major identifiable tool that the National Orientation Agency has adequately relied on particularly, in the ceaseless efforts of creating the enabling environment for inclusivity.
- e. The Explainer: As part of its efforts in complementing the traditional media tool of engagement and providing a timely dissemination of necessary information to the Nigerian citizens on the activities of the government, The Explainer publication as a weekly online platform is an innovative digital tool of engagement, which seeks to simplify, clarify government policies and issues around national development for the consumption of the citizens. It also serves as one of its highly innovative digital tools for feedback mechanism with the aim of bridging the gap between government and citizens, ensuring transparency and fostering a well-informed citizenry.
- f. The Social Media: In reflection of the widely embraced popular culture most especially, among the growing population of the youth, and their level of consciousness, effervescence and the engaging reactions to societal issues, the National Orientation Agency has also maximally deployed the social platforms of engagement in complementing its digital tools. The necessity of the Agency to maintain its active presence within the social media space is not only apt but that provides another window for its essential role in the feedback mechanism mandate as such also becomes a very reliable source of gauging the reactions of the citizens to government policies, programmes and activities. Its workforce spread across Nigeria has also made effective use of the digital tool, as earlier emphasized, in their official routines and internal communication strategy. The Agency's official social media handles are: @NOA_Nigeria on X (formerly Twitter), @noa_nigeria on Instagram, National Orientation Agency, Nigeria on Facebook, and @noa_nigeria on YouTube channel.

Furtherance to the fulfillment of its mandate to the Nigerian society, the National Orientation Agency and its renewed efforts towards realizing that, has also designed and implemented series of programmes and activities with its flagship National Values Charter (otherwise known as the National Identity Project) with various components directed at different segments of the Nigeria's demographic compositions. The aim of the National Values Charter, according to National Orientation Publication [13], is to strengthen the bond between the citizens and the government through a symbolic social contract compact as a blueprint to implement the National Identity Project. This symbolic Charter is divided into two broad sections: the Nigerian Promise (That is, 7 Core Promises made by the Country as represented by all elected and appointed public office holders) and the Citizen's Code (7 Core Commitments to the Nigerian State and fellow citizens (That is, the 7 Point Obligations of the citizenry

to the nation). The 7 Core Commitments of the Nigerian Promise are: Equality; Democracy; Entrepreneurship and Employment; Peace and Security; Inclusivity; Freedom and Justice; and Meritocracy. On the other hand, the 7 Citizen's Codes are: Discipline; Duty of Care; Tolerance; Leadership; Transparency; Environmental Awareness; and Resilience.

The National Identity Project has been well demonstrated with other engaging programmes and activities, which have been rightly targeted at younger demographics particularly, citizens of school age ranging from the basic to the tertiary levels of education in Nigeria. The rationale for these ambitious programmes can be premised on our earlier submissions of the need to capture the most active segment of the Nigerian citizenry within the demographic dragnet of the Agency's programme and activities on value re-orientation. Such programmes include school-based value re-orientation activities on drug abuse, cultism and membership of nocturnal groups, cybercrime, ritual killing, getting-rich syndrome, among other social vices. The nationwide Campus debate and mentorship programme for students of tertiary institutions in Nigeria, and the TV Cartoon Series on national television outlets for pupils at the nursery and primary schools level are integral parts of the programme contents of the National Identity Project.

6. Challenges of digital literacy and value re-orientation in Nigeria

It is a truism to assert that the digital revolution has impacted the human societies in many ways. The digital technology has not only redefined the human conducts and behaviors but also, the engagement between the government and the citizens. In the opinion of Tukur [1], the utility of technology is no longer the exclusive preserve of the state, as it has become tools of social interactions and citizens' engagement for participatory governance, even beyond the territory of the states. More often than not, the digital space has been noted to promote the negative influence and distortion of values system in Nigeria. With the unfettered access of the citizens to the cyberspace and the freedom of expression it offers, many have been so exposed to negative values from foreign countries, which often promote instability and revolt against the government. This negative development has however, prompted the National Orientation Agency to also embark on local contents television cartoon series specifically targeted at young Nigerians of pre-nursery up to primary schools age as an effort towards discouraging the exposure to negative foreign values.

There is no doubting the fact that citizens enjoy the fundamental rights of expression and peaceful association in any civilized society, but such must also be conducted within the limit of the law. The accessibility to the digital space particularly, through the social media such as the Facebook, X (Twitter), Instagram and WhatsApp, has always provided the platform for such inalienable rights of the citizens. However, this accessibility has in many ways further exacerbated the misuse of the digital literacy space for negative purposes. The negative deployment of the social media by the citizens has served to promote incidences of fake news, misinformation, mal-information and disinformation, and thereby, possibly instigate mayhem and violence as could be witnessed during the devastating #ENDSARS# protests across Nigeria in 2020. In reactions to such ugly incidences, the National Orientation Agency as an institution of the Nigerian government has many times activated its counter-narrative public campaigns in negation of such abuse of the digital literacy space because of their tendencies to cause civil unrest.

More importantly, the continued upsurge of the popular culture accompanied by the audio and visual contents and their wide embrace by the youth who are popularly regarded as the “Gen Z” could be seen in their strong influence to prompt and embolden the new generation of citizens to reactions against the government. The power of the popular music and the somewhat image of the revolutionary artistes who dominate the social and musical space in Nigeria are major factors because of their negative influence within the value re-orientation landscape in Nigeria. Aside the official reactions of the National Orientation Agency to these negative influences, the National Broadcasting Commission, the institutional regulatory framework for the broadcast industry in Nigeria, had many times equally sanctioned many of such negative audio and visual contents, which could instigate unnecessary public reactions and agitations against the government.

Without overemphasizing the critical place of funding in the performances of government institutions in Nigeria, one of the challenges, which have persistently served as the major hurdle to the operations of the National Orientation Agency, also remains within the poor budgetary provision for its activities. Over the years, the Agency has continued to contend with inadequate funding while limiting the ability to discharge its mandate in the era of digital technology. Aside limited funding to engage the services of its numerous media partners for wider coverage and visibility, the funding challenges have more than necessary prevented the Agency from investing in digital technological tools required in the deployment of the value re-orientation contents to the Nigerian public. With 818 operational formations across Nigeria, the National Orientation Agency is remarkably known for being a Nigerian institution without life of its own due to the challenges of poor budgetary provisions.

Related to the chronic challenge of poor funding is the problem of logistic and other operational utilities, which has also become another defining characteristic of the Agency over the years. Problems of operational utilities, such as decent office accommodations, operational vehicles, office furniture and equipments, poor staff welfare and motivation among other operational limitations, have plagued the Agency over the years with little or no respite in sight. For instance, many of its operational offices are poorly maintained where they exist, more are operating in rented accommodations with accumulated unpaid rents, old and non-functional office equipments, non-availability of operational vehicles, and ill-motivated workforce among other identified challenges. These challenges are critical to the operation of the Agency in meeting up with its mandate of value re-orientation and attitudinal change as well as in the fulfillment of the aspirations of the Nigerian citizens for a better and ethically balanced society. The material condition of an essential state institution as the National Orientation Agency and the welfare of its workforce remain critical to the realization of such ambitious aspiration and also germane to activating any meaningful value re-orientation and attitudinal change project in a complex society as Nigeria.

7. Conclusion/recommendations

This paper has attempted to reflect the contending issues around the digital literary space and value re-orientation in Nigeria. The paper provided the historical overview of value re-orientation with the hindsight of the efforts of successive governments towards instilling the right attitudinal patterns in Nigeria. It also sought to embark on an extensive critique of some relevant literature, which have remarked diverse intellectual perspectives on value re-orientation and behavioral change

policies of the government in Nigeria. Though, the central focus of this paper is on the digital literacy space and its implications for value re-orientation and attitudinal change patterns in Nigeria, it is also essential to emphasize that the era of digital technology has brought some hope for the value re-orientation landscape in Nigeria, in spite of its negative challenges.

The National Orientation Agency has however, in the recent times, strived to remain more reinvigorated by its increased bandwidths and visibility relying on both the traditional and the digital media of communication. In complementing such efforts, the Agency also hopes to use its new flagship programme, the National Values Charter (also known as National Identity Project), to serve as the catalyst for effecting the desired change in the value re-orientation landscape in Nigeria.

On the basis of the assumptions offered by this paper, the following recommendations are put forward:

- As a necessity towards building a more democratic and an inclusive society, efforts on value re-orientation should be strengthened for promoting digital democracy and citizens' engagement through the digital literacy space in Nigeria.
- The agency of government saddled with the mandate of policy communication in Nigeria, that is, the National Orientation Agency should be more alive to its responsibility by activating conversations and counter-narrative measures through the deployment of the digital literacy space towards containing the increasing incidences of fake news, misinformation and disinformation, as well as the prevailing ethical concerns and social vices.
- Adequate budgetary provisions are also necessary for the agency of government saddled with the task of attitudinal value change towards investing in the digital technology tools in the fulfillment of its mandate of value re-orientation and the mission for building an ethically balanced society.

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Section 3

Challenges: Governance, Ethics and Risks in the Digital Transformation

A Study of Resolving Ethical Issues of Digital Health Technology: Learning from United States and Europe Union

Fateme Tavallaei

Abstract

Advancements in digital health improve access to health services by numerous emerging ethical challenges. This study employs a scoping review to find these issues from the experiences of the United States and Europe as the pioneers. A systematic search was conducted across PubMed, Scopus, IEEE Xplore, Europe PMC databases, and Google Scholar. Following rigorous screening, 103 out of 513 relevant articles published between 2020 and 2025 were selected. The findings indicate that privacy and data security, informed consent and transparency, quality of care and accountability are the most frequently cited ethical challenges. Other significant issues include education, adoption, and trust, equity and equal access, legal framework and regulations. Some studies mention the algorithmic transparency and bias, and human interaction and workload. Key ethical strategies include the privacy protection and data security, education, awareness, and human engagement, development of ethical, legal, and regulatory frameworks, transparency and informed consent assurance, improvement of user-centered design and secure technologies. Moreover, implementation challenges such as technology adoption and user training, technical and infrastructure challenges, stakeholder coordination and management, legal, ethical, and policy issues, financial, motivational, and access issues, data quality and technology accuracy were also highlighted. Proposed implementation strategies include training and empowerment to overcome organizational and cultural resistance, improvement of managerial and organizational processes, and enhancement of stakeholder engagement, coordination and collaboration, and improvement of technology infrastructure. Ultimately, this study highlights interdisciplinary approaches with key challenges, research gaps, and practical lessons in digital health, providing valuable insights for policymakers and researchers.

Keywords: digital health, ethical issues, implementation issues, EU, USA

1. Introduction

Digital technological advancements in healthcare improve the quality of care, access to services, and enhance population health. Technologies, such as artificial

intelligence (AI), telemedicine, and wearable devices, play a pivotal role in transforming health systems [1, 2]. However, the rapid expansion of these technologies has also introduced numerous ethical and operational challenges that may hinder their acceptance and effective utilization [3]. Two of the most critical ethical challenges in digital health are the protection of patient privacy and the security of sensitive health data. With the increasing volume of digital health data and the complexity of data processing technologies, the risks of privacy breaches and misuse of personal information have escalated [4]. Regulations such as the General Data Protection Regulation (GDPR) in the European Union (EU) strive to ensure data protection through coherent legal frameworks; nonetheless, the full and effective implementation of these regulations continues to face significant challenges [5]. Additionally, emerging technologies like blockchain offer promising solutions for enhancing data security and transaction transparency [2]. Informed consent of users is another vital issue in digital health. The design of user-centered consent management tools and educating patients about their data rights and transparent consent processes play a crucial role in fostering trust and active user engagement [3]. This is particularly important in artificial intelligence-based research that analyzes multimodal and multisource data [6]. Algorithmic transparency and the manner in which data are utilized constitute another significant challenge that has gained prominence with advances in artificial intelligence and machine learning in healthcare. Providing clear information to users regarding the types of data collected, the purposes of data use, data recipients, and employing explainable algorithms are among the recommended strategies to enhance transparency and accountability [2]. This issue has also been emphasized in studies involving remote monitoring projects, highlighting the importance of transparent interaction between patients and technology [6]. Furthermore, digital equity and ensuring equal access to digital health technologies, particularly for vulnerable groups, represent key concerns in health policymaking in the USA and EU [7]. The development of supportive policies, multilingual education, and user-centered design involving stakeholder participation have been identified as effective approaches to reduce disparities and promote digital health equity [8]. Some challenges exist in the implementation of digital health technologies. Technical and infrastructural issues, resistance from users and healthcare teams toward new technologies, the need for continuous training and empowerment, and coordination among stakeholders are among the primary barriers that can impact the quality and effectiveness of digital health services [1, 9]. Moreover, novel payment and financing models are being developed in the EU to support costly and innovative treatments, which may contribute to the financial sustainability of digital health systems [8]. Given the growing importance of digital health and its ethical and implementation complexities, the present scoping review aims to identify ethical and practical challenges and propose strategies from experiences in the USA and EU to develop effective frameworks in digital health and facilitate the responsible and equitable adoption of emerging health technologies.

2. Methods

This study was designed and conducted using the scoping review methodology, which is considered an appropriate and efficient approach for identifying, mapping, and comprehensively analyzing the existing literature on the broad and complex topic of digital health and its associated ethical and implementation challenges [10].

Scoping reviews enable the examination of a wide scope of the subject, identification of research gaps, and determination of research priorities.

2.1 Search strategy and databases

Data collection involved searching four reputable and well-established databases: PubMed-MEDLINE, Scopus, IEEE Xplore, and Europe PMC. Additionally, Google Scholar was utilized to cover gray literature. This selection was made to ensure the comprehensiveness of the search and access to up-to-date and credible scientific sources in the field of digital health and related regulations in the USA and EU.

Search keywords were developed based on the main research concepts, including “Digital Health,” “Ethical Challenges,” “Implementation Barriers,” “Privacy,” “Data Security,” “Regulation,” “United States,” “European Union,” “Telemedicine,” “Mobile Applications,” “Data Privacy,” “HIPAA,” “GDPR,” “e-health,” “Informed Consent,” “Ethics,” “Data Governance,” and related combinations. These keywords were selected according to the research question framework and in consultation with digital health experts to ensure a comprehensive and targeted search.

2.2 Inclusion and exclusion criteria

Selected articles were required to be published between 2020 and 2025 and written in English. Only original research articles from peer-reviewed journals were included, while review articles were excluded to focus on empirical evidence and primary data. Studies had to pertain to digital health in the Americas and Europe or be related to regulations applicable to these regions (e.g., GDPR or HIPPA (Health Insurance Portability and Accountability Act)). Duplicate records, articles outside the specified timeframe, outside the digital health domain, or outside the targeted geographic scope were excluded.

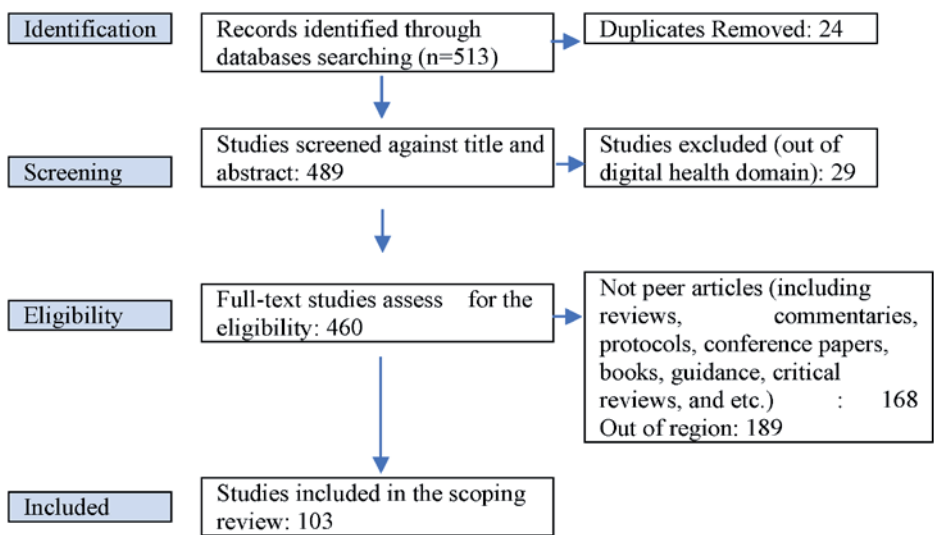


Figure 1.
PRISMA diagram.

2.3 Screening and article selection process

Initially, 513 records were retrieved from the preliminary searches. After removing duplicates and applying the inclusion and exclusion criteria, 103 articles were selected for detailed review. The screening process involved reviewing titles, abstracts, and then full texts, conducted independently by two researchers and resolving the discrepancies through consultation. This process adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 guidelines, as shown in **Figure 1**.

2.4 Data analysis

Data extracted from the articles included ethical and implementation challenges in digital health as well as proposed strategies. Qualitative analyses were conducted to provide a comprehensive mapping of these concepts.

3. Result

3.1 Characteristics of the reviewed articles

Initially, a comprehensive search was conducted using keywords related to digital health, telemedicine, mobile applications, health, ethics, data protection, algorithmic bias, data governance, United States, Europe, GDPR, and HIPAA. Advanced search strategies were applied across multiple databases, including IEEE Xplore, Scopus, PubMed-MEDLINE, Europe PMC, as well as Google Scholar for gray literature. This search yielded a total of 513 articles. After applying the inclusion criteria described previously and removing duplicates and irrelevant records, 103 articles remained for detailed analysis.

The selected articles were systematically reviewed, and relevant data were extracted using a predesigned Excel sheet with coded fields including: “Title and Author(s), Year of Publication, Geographic Region, Technology Used, Health Intervention, Ethical Challenges, Ethical Strategies, Implementation Challenges, Implementation Strategies, Regulations and Standards, and Other Themes.” The main features of the reviewed studies are depicted in **Figure 2**.

The studies revealed that among the 103 selected articles, 47 were published in 2023, 13 in 2021, 19 in 2024, 12 in 2022, 7 in 2020, and 5 in 2025, indicating an increasing trend in publication over the past 5 years and underscoring the growing importance of digital health issues in the USA and EU. Of these, 64 studies were related to the USA or involved multinational data including the U.S. and focused on HIPAA regulations, while 39 studies pertained to the EU (including Germany, France, Italy, Belgium, Sweden, Denmark, Spain, Ireland, Luxembourg, Switzerland), and the United Kingdom and GDPR-related research. This distribution highlights significant differences in research focus between the U.S. and other regions, particularly Europe.

The objectives of studies have centered on impact evaluation [2, 9, 11–31], conditional examining [1, 5, 8, 32–47], identifying challenges [15, 18, 23, 27, 30, 31, 36, 47–56], developing new technologies [6, 10, 13–16, 20, 38, 57–62], data analysis [3, 9, 42, 63–68], feasibility studies [19, 22, 35, 69–72], validating tools and methods [7, 19, 24, 37, 46, 73], comparative studies [2, 39, 41, 74, 75], process improvement [8, 76, 77], and designing research processes [11, 78].

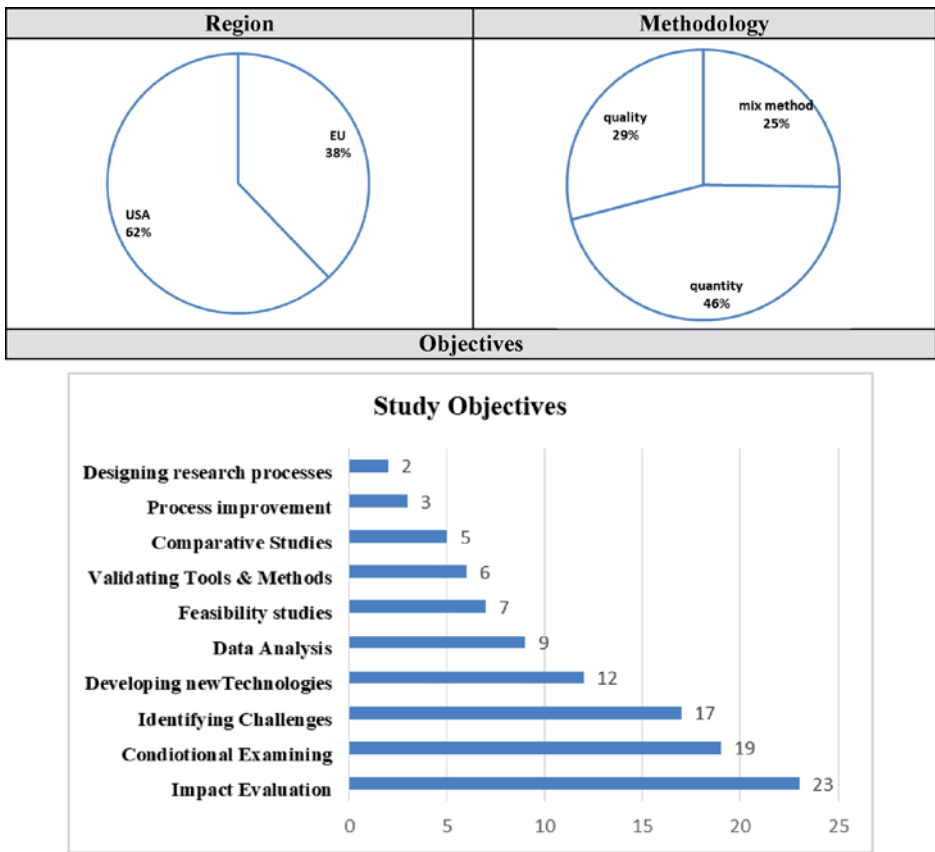


Figure 2.
Characteristics of studies.

Methodologically, the number of studies that employed quantitative approaches is 47, including big data analysis, statistical modeling, randomized controlled trials, cohort studies, regression and descriptive/inferential analyses, registry data analysis, machine learning algorithms, advanced statistical modeling, and latent class analysis [5, 9, 12–16, 20, 22, 23, 25–31, 33, 35, 40, 42, 49, 50, 54, 55, 57, 60–62, 64–73, 75–77, 79–89], qualitative approaches is 30, including semi-structured and in-depth interviews, focus groups, thematic analysis, content analysis, and conceptual analysis [1–4, 7–9, 32, 36–41, 46, 47, 52, 53, 56, 59, 71, 74, 76, 77, 82, 85, 90–95], and mixed methods is 26 including surveys, video analysis, participatory design, usability evaluation, and multimedia data analysis [2, 6, 9, 11, 17–19, 21, 24, 34, 43–45, 48, 51, 58, 59, 63, 78, 96–102]. This methodological diversity reflects the broad and multifaceted approaches to research in digital health.

The technologies utilized across these studies encompassed the Telehealth and Precision Medicine Technologies including platforms for precision medicine, remote management, Emergency Medical Services, video-based communication, online education, and real-time reporting systems to deliver healthcare remotely [1, 16, 18–20, 22, 36, 59, 60, 69, 78, 79, 90, 91], Digital Health Applications and Remote Monitoring including interactive apps, blockchain-based apps, mental health apps, voice call apps, COVID-19 contact tracing, location tracking, exercise adherence tools, and digital

or paper-based health monitoring technologies [9, 12–14, 23, 25, 37, 44, 47, 52, 58, 70, 71, 80–83, 92, 93, 97–99], Telemedicine Platforms and In-Person Care including video-based and remote communication systems, specialized medical equipment, EMS platforms, online education, electronic health applications, video telehealth, and portable devices like laptops and tablets [13, 17, 38, 51, 61, 62, 64, 74, 76], Online Education and Wearable Technologies including digital courses, wearable sensors for tracking movement and heart rate, interactive simulations, digital learning resources, virtual platforms, and health-related apps [21, 29, 56], Blockchain Technology and Smart Contracts [2, 31, 48], Artificial Intelligence, Machine Learning, and Large language Models [6, 8, 49, 65, 84, 85], Digital Health Technology and Remote Medicine [3, 11, 32, 42, 45, 46, 55, 66, 86, 87, 96], Electronic Health Communication Technology and Digital Platforms [4, 5, 15, 33–35, 53, 67, 73, 77, 94, 102], Digital Tools and Analytical Software [9, 30, 43, 50, 68, 72, 75, 88, 95], Laboratory Technologies and Data Modeling [7, 26, 41, 100], Interactive Technologies and Educational Simulations [39], Online Programs and Interventions Especially in Mental [24, 28, 54, 57, 101], Pain Control and Medication Tools [40]. This variety underscores the significant role each technology plays in advancing digital health objectives.

Digital health interventions covered a wide range, including informed [11, 33, 34, 45, 51, 53, 61–63, 70, 77, 86, 103], health monitoring and remote care (telehealth) [1, 9, 16, 17, 37, 64, 69, 79, 84, 87, 94, 96, 99], data diagnosis and analysis [6, 14, 25, 26, 31, 55, 66, 71, 72, 75, 89, 100], support for patients and caregivers [7, 13, 21, 27, 32, 35, 38, 40, 43, 65, 81, 91], data management and digital health records [2, 4, 5, 41, 46, 67, 88, 93, 95], health policy and equity improvement [8, 36, 54, 59, 68], health applications and platforms [20, 47, 83], chronic pain management [50, 57, 80], team collaboration [18, 58], promotion of healthy lifestyles [23, 28], contact tracing and infectious disease control [48, 97], mental health [3, 19, 24, 30, 42, 44, 49, 52, 90, 98, 102], access to specialized care [12, 15, 22, 74, 76, 78, 82, 92], training and online interventions [29, 39, 56, 60, 73, 101], ethical compliance [85], and other technologies and tools.

3.2 Ethical challenges and strategies

Through reviewing numerous articles, overarching themes about ethical challenges (presented in **Table 1**) and ethical strategies (presented in **Table 2**) have been

Ethical Challenges	Explanations (References)
Privacy and Data Security	Privacy in General [2, 7, 11, 14, 16, 18, 19, 21–25, 32, 33, 35, 37, 48, 52–55, 59, 62–64, 66, 69, 71, 76, 78, 79, 81–83, 86–88, 90–92, 95, 96] Transparency in Data Usage [26, 43, 71] Assurance of Data Transfer [12] Data Security in Transmission and Storage [9, 74] Transparency in Algorithms and Data Complexity [1, 9, 34, 53] Technology Credibility and Response Accuracy [38, 44, 51, 80, 89, 99] Data Security in Virtual Environments [13, 41, 90] Compliance with Data Security Standards [58] Fear of Data Misuse [97] Fear of Losing Control Over Personal Information [47] Intrusive Advertising [47] Privacy of Data Related to Vulnerable Groups [28, 29, 40, 50, 72, 100–102] Misinformation Dissemination [65] Data Confidentiality [20, 27, 30, 31, 49, 57, 75, 101]

Ethical Challenges	Explanations (References)
Informed Consent and Transparency	Accurate Understanding of Real Consequences and Consideration of Individual Differences in Concept Perception [5, 6, 9, 11, 14, 25, 61, 63, 70, 77, 79, 81, 83, 86, 98] Transparency in the Consent Process without Misleading User Interfaces [2, 4, 5, 66] Risk of Data Misuse [5, 19, 52, 95] Risk of Data Transfer [5] General Informed Consent [12, 96, 101] Transparency in Data Use for Care Quality or Other Purposes [22, 43, 59, 62] Consideration of Various Dimensions of Consent [51] Difficulty in Obtaining Electronic Consent [13] Patient Informed Decision-Making [27] Informed Consent for Vulnerables and Protection of their Rights [28, 29, 40, 50, 57, 102]
Quality of Care and Accountability	Duty of Timely Alerting and Reporting [3] Ensuring Accountability Regarding Disseminated Information [65] Possibility of Service Personalization through User Interfaces [44] Maintaining Virtual Care Quality [13, 16, 22, 37, 65, 69, 79, 87, 99] Preserving the Quality of Human Interactions between Therapist and User [15, 91] Lack of In-Person Diagnostic Tests Like Spirometry and Sputum Sampling [17] Accuracy of Remote Assessments [38, 64, 89] Transparency and Absence of Data Distortion [85] Technology Effectiveness [52] Maintaining Adherence to and Balance in Patients' Dependence on Technology [23, 49] Safeguarding Health, Well-being, and Managing Psychological Concerns [41, 42, 94]
Education, Adoption, and Trust	Education challenges: Precise Filtering to Prevent Data Disclosure [72], Insufficient Training to Overcome Language Barriers [67], Inadequate Education to Address Technological Complexities [2, 32], General Lack of Training [73] Trust Challenges: Trust in the Accuracy and Reliability of Labels [72] and Ensuring User Trust in Respecting Cultural and Social Diversity [7] Acceptance Challenges: Technology Acceptance in Rural Areas [18], and Broader Technology Acceptance [21, 34, 35, 39, 53, 56, 74, 78, 90, 92]
Equity and Equal Access	Unequal Access to Technology and Digital Literacy (Especially Among Vulnerable Populations) [5, 18, 29, 30, 40, 50, 57, 102] Equitable Access to Technology and Services [1, 8, 36, 78, 87] Limited Access to Email and Discrimination in Patient Selection [28, 85, 86] Restricted Access to Digital Resources [67]
Legal Framework and Regulations	Attention to Legal Gaps and the Absence of Guiding Frameworks [3, 46] Mechanisms to Ensure Compliance with Laws, Protocols, and Principles [31, 54, 68, 95] Adherence to Standards [58] Legal Challenges in Emergency Situations [63] Transparency in Policy and Resolving Multiple Complex Legal Ambiguities [4, 93] Laws on Data Use and Sharing in Different Contexts [26, 71, 75, 100] Categorization of Technology-related Laws [94] Respect for the Rights of Research Participants [55]
Algorithmic Transparency and Bias	Algorithmic transparency [1, 6] Incorrect Information Analysis due to Data Bias [9, 14] Prevention of Misinformation Dissemination [65] Data Control [88] Accuracy and Non-Discrimination in Data Use and Validity [27, 85, 89] Transparency in the Use of Location Data [8, 36, 71].
Human Interaction and Workload	Workload [15, 19] Maintaining Patient-Therapist Interactions [15, 20, 24, 76, 82, 91]

Table 1.
Ethical challenges.

Ethical Strategies	Explanations (References)
Transparency and Informed consent Assurance	Privacy by Design: integrating privacy protection into the initial system design [5] Data Anonymization and De-identification: techniques, such as pixelation, blurring, data anonymization, and obtaining informed consent [28, 29, 48, 54, 55, 66, 72, 96] Secure Storage and Encryption: use of HIPAA-compliant platforms, data encryption, decentralized storage, and blockchain technology [2, 19, 48, 58, 71, 81, 97] Access Control and Secure Data Management: limiting data types collected, restricting access to research teams, no sharing with third parties, and secure data handling [16, 21, 64, 66, 71, 74, 90] Monitoring and Accountability: human and automated oversight of compliance with regulations (GDPR, HIPAA), human review of data analysis, and breach response plans [5, 9, 22, 65, 72, 76, 98] User and Staff Education and Awareness: training users, patients, care teams, and staff, training awareness about data rights and consent implications, designing consent processes aligned with digital literacy [2, 12, 16, 18–25, 30, 33–35, 62, 64, 69, 74, 76, 81, 90] Transparency and Information Disclosure: providing clear, understandable information to users about data use, ensuring transparency in data collection, usage, policies, and processes [2, 5, 6, 18–20, 26, 47, 63, 65, 69, 72, 76, 81, 90, 97, 98] Ethical Compliance and Protection of Vulnerable Groups: ensuring data confidentiality, obtaining informed consent, adhering to human research ethics standards, providing psychological and cultural support, and guaranteeing equal access to interventions [26, 28–31, 40, 47, 54, 55, 57, 100–102] Use of Alternative Digital Identities and Awareness of Organizational Advertising Motives: protecting privacy through alternative identities and recognizing advertising motives [47] Emerging Technologies and Decentralized Architectures: employing blockchain and decentralized architectures to preserve privacy [2, 48, 97]
	Transparent and Understandable Communication (simple language, visual charts, text segmentation, precise information about data type and usage purpose) [5, 14, 18, 26, 41, 43, 45, 67, 86, 89, 101] Consent Management Tools (user-centered dashboards for consent control, standardization of informed consent processes) [5, 26, 65, 86, 89] Designing Consent Processes Tailored to Digital Literacy (co-designing forms and processes with users, using simpler language, text segmentation, and participant involvement in form design) [5, 45, 89] Monitoring Consent and Transparency (ensuring contract transparency, multi-stakeholder accountability, multi-governance, continuous and automated regulatory compliance monitoring) [5, 26, 65, 76]
	Continuous and Specialized Training (educating users, patients, healthcare staff, research teams, and researchers about privacy protection, data security, and ethics) [4, 5, 15, 32, 37–39, 42, 46, 50–52, 56, 59, 61, 67, 70, 73, 76, 77, 79, 80, 82, 87, 91, 92, 95, 99] Increasing Digital Literacy and Awareness (active education, interactive methods, multilingual training, and attention to cultural issues and diversity) [67, 73, 76–78, 89, 91, 95, 103] Active Stakeholder Participation (involving users and patients in the design and review of policies and technologies) [5, 51, 59, 77, 82, 89] Psychological and Cultural Support (family education, psychological counseling, special support for vulnerable groups, such as the elderly and emergency patients) [30, 42, 49, 50, 99]
Development of Ethical, Legal, and Regulatory Frameworks	Developing and Implementing Ethical Frameworks (including Accountability, Human agency, Privacy, and Transparency) [1, 3–5, 7, 8, 13, 36, 46, 59, 63, 65, 68, 85, 88, 98] Compliance with International Laws and Standards (adherence to GDPR, HIPAA, and other data protection regulations) [5, 7, 13, 27, 75, 94, 98] Ethical Evaluation and Accountability Assurance (use of checklists, advisory boards, ensuring transparency and multi-stakeholder accountability) [3, 8, 59, 68, 75, 93, 94] Developing Supportive and Equitable Policies (attention to justice, cultural diversity, and equal access) [7, 36, 59, 93]

Ethical Strategies	Explanations (References)
Improvement of User-Centered Design and Secure Technologies	User-centered and Participatory Design (designing simple, transparent, and understandable interfaces with continuous user feedback) [11, 53, 83] Secure and Explainable Technologies (using transparent algorithms, encryption technologies, and secure platforms) [6, 44]

Table 2.
Ethical strategies.

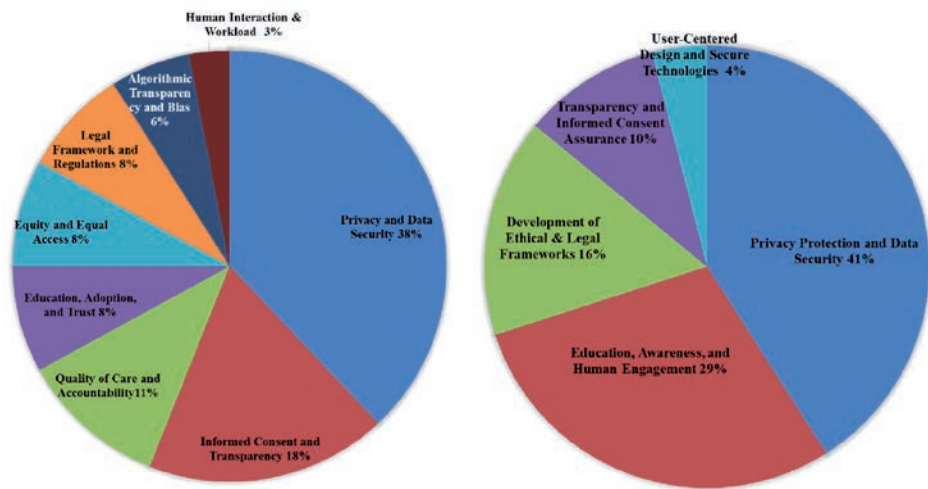


Figure 3.
Ethical challenges and strategies.

identified. Additionally, **Figure 3** illustrates a map showing the distribution of topics within these domains.

3.3 Implementation challenges and strategies

Some themes occasionally overlap with ethical concepts, either reinforcing or undermining them, and are related to implementation science. These themes are presented in **Table 3** under the titles of implementation challenges and implementation strategies.

4. Discussion

Due to the key role of digital technologies in improving health systems and enabling rapid and widespread access to healthcare services through tools (such as telemedicine), the quality of life for millions of people will be significantly impacted. However, these advancements also face challenges including privacy protection, informed consent, technology acceptance, and more. As leading regions in this field, the USA and EU can offer valuable lessons for other areas. Therefore, this article aims to study the experiences of these two regions in developing digital health systems

Implementation Challenges	Implementation Strategies
<i>Technology Acceptance and User Education</i> (including user resistance, training, interaction, technology acceptance, patient education, treatment management, and training effectiveness) [1, 5, 6, 12, 14–16, 43, 45–47, 58, 60, 61, 63, 70, 72, 76, 79–81, 97, 98] <i>Technical and Infrastructure Challenges</i> (including technical problems, device limitations, data integration, new technology development, and technical support) [1, 5, 6, 11, 13, 15–17, 46, 48, 61, 63, 65, 70, 72, 79, 80, 86]. <i>Stakeholder Coordination and Management</i> (including interinstitutional coordination, recruitment and retention of participants, big data management, cross-sector collaboration, and stakeholder engagement) [5, 6, 51, 95] <i>Legal, Ethical, and Policy Issues</i> (including lack of uniform guidelines, privacy concerns, data protection laws, ethical acceptance, and multi-stakeholder accountability) [3–5, 47, 48, 76, 88, 96, 97] <i>Financial, Motivational, and Access Issues</i> (including costs, health and digital inequalities, access limitations, and motivation for technology use) [44, 48, 67, 86] <i>Data Quality and Technology Accuracy</i> (including model accuracy, data quality assurance, evaluation of new technologies, and limitations of physical assessments) [6, 66, 84].	<i>Educational and Empowerment Strategies</i> (training patients, users, care teams, researchers, blended learning, continuous empowerment and support) [1–7, 9, 11–25, 27–35, 37–39, 41–47, 49–52, 57–65, 67, 69–71, 73, 74, 76–83, 85–93, 95, 97–99] <i>Process and Management Strategies</i> (protocol development, continuous feedback, participatory design, policy development, center coordination, and data management) [3–9, 12, 13, 28, 31, 36, 40, 41, 46, 47, 51–53, 56, 58, 60, 61, 63, 66, 68, 72, 75, 77, 79, 84, 86, 93–97, 100–102] <i>Coordination and Collaboration Strategies</i> (infrastructure enhancement, data security assurance, technology development, algorithm improvement, and legal frameworks) [1, 5, 6, 8, 13, 26, 27, 43, 44, 48, 54, 55, 58, 63, 68, 72, 75, 79, 86, 95, 97] <i>Addressing Organizational and Cultural Resistance</i> (interorganizational coordination, data quality assurance, active stakeholder engagement, participatory design, cultural and regional adaptation) [1, 5, 6, 43, 48, 51]

Table 3.
Implementation challenges and strategies.

from the perspective of digital ethics and to draw benefits from them. The findings indicate that the main objectives across studies include impact assessment, situational analysis, challenge identification, development of novel technologies, data analysis, feasibility studies, and others. Furthermore, a wide range of quantitative, qualitative, and mixed methods have been employed, underscoring the importance of a multifaceted methodological approach in this research domain.

The primary focus of the employed technologies encompasses a diverse range, including Telehealth and Precision Medicine Technologies, Digital Health Applications and Remote Monitoring, and Telemedicine Platforms alongside In-Person Care. For example, in a study about web technologies, related tools were utilized, including digital technologies such as an automated tool developed with Python programming for data collection and analysis. Additionally, algorithms were employed to assess compliance with GDPR principles to ensure privacy protection and obtain informed user consent [5].

The primary areas of digital health application are informed consent, telehealth, and data diagnosis and analysis. For example in a study about an artificial intelligence-cloud-based platform, an evaluation was conducted to help patients better understand the expected surgical outcomes and an increase in patient informed consent and satisfaction with the overall treatment experience [27]. In another study focused on telehealth with the development of a remote therapeutic monitoring

platform for movement disorders, the researchers utilized wearable technologies, mobile health platforms, and digital biomarkers to identify disease onset, symptoms, medication-related fluctuations, side effects, and treatment response within a remote monitoring application, which successfully enhanced ease of access [9]. In another study focused on the detection and analysis of patient-derived data, machine learning methods were employed for the early diagnosis and prediction of Alzheimer's disease with combination by federal learning to enable decentralized handling of sensitive patient data and facilitate collaboration among institutions while preserving patient privacy and model trustworthiness [6]. In another study, digital technologies were utilized to support patients and caregivers within the context of smart and healthy aging in Europe. These technologies help create an environment that extends beyond the physical space for older adults and facilitate the integration of community-based health and social care services [7].

The most frequently reported ethical challenges pertain to Privacy and Data Security, as well as Informed Consent and Transparency. One of the studies encompassing most of these themes focuses on ethical considerations in the application of artificial intelligence tools for older adults, particularly those with Alzheimer's disease and related dementias. In this study, efforts were made to safeguard privacy and data security by requiring detailed explanations on how sensitive data would be protected and security standards enforced to prevent unauthorized access. Regarding the enhancement of quality of care and accountability, the unique characteristics and needs of this vulnerable population were incorporated into the design of technologies and evaluation processes, aiming to improve clinical decision-making and support personalized care while responding effectively to care outcomes. Moreover, developers were expected to demonstrate how the expansion and increased accessibility of these technologies to underserve or rural communities would be achieved, thereby addressing existing inequities. To promote algorithmic transparency and mitigate bias, attention was given to identifying and managing potential biases within AI algorithms. Developers were required to explain how their technologies operate fairly and without discrimination across diverse groups, which in turn fosters greater user trust and acceptance [85]. In another study examining the implementation of alternative electronic or telephone consent methods instead of obtaining in-person consent for patients with endovascular stroke—particularly in the context of the COVID-19 pandemic—concerns were raised regarding informed consent and transparency. It is crucial that patients and their legally authorized representatives are fully informed and able to make autonomous decisions, ensuring that their self-determination is not compromised. Another concern highlighted in this research pertains to adherence to the legal framework and regulations, the implementation of electronic consent must comply with local laws across different geographic regions to safeguard patients' rights. Regarding human interaction and workload, the study explains that in-person consent imposes a significant workload on healthcare staff, whereas alternative electronic methods not only facilitate human interaction but also reduce the burden on clinical personnel [63].

The most frequently proposed ethical solutions pertain to privacy protection and data security. Another important factor that can act either as a barrier or as a facilitator in addressing ethical challenges in digital health is the role of implementation factors. In this study, the greatest challenges were related to technology acceptance and user education, as well as technical and infrastructure challenges, while the most prominent strategies focused on educational and empowerment approaches and process and management strategies.

It is observed that research has paid comparatively less attention to specific ethical challenges such as human interactions and oversight, workload, and algorithmic bias, indicating a need for further studies in these areas. Additionally, there is a demand for research that simultaneously addresses executive, technological, and ethical challenges in an integrated manner. Multidisciplinary and interdisciplinary approaches can help fill this research gap. Moreover, deeper investigations into technology acceptance and user education are necessary.

This study, by focusing on executive and ethical challenges and proposing solutions from leading countries in digital health, has provided an integrated approach in this field and clearly illustrated the position of digital health. It offers a coherent analytical framework for categorizing challenges and strategies to guide policy-makers and managers. Furthermore, the regional priorities of the United States and Europe emerge from this research, and the proposed strategies can be adapted considering the priorities of the target region. User education and empowerment are identified as key factors for the implementation of digital health, while transparency and accountability are recognized as effective elements in addressing ethical challenges.

5. Conclusion

This study aimed to provide lessons learned by examining approaches to addressing ethical challenges in digital health from the USA & EU as the pioneers. Through this scoping review, many and diverse problems in both ethics and operations related to digital health technologies have appeared. Privacy and data security challenges were identified as among the most significant and frequently encountered, with privacy protection recognized as a key strategy. Other critical strategies for resolving ethical challenges in digital health included transparency and assurance of informed consent, education, awareness, and user engagement, development of ethical, legal, and regulatory frameworks, as well as the advancement of user-centered design. The study sought to adopt a multidimensional perspective by integrating technological and executive viewpoints. Because making digital health solutions responsible relies on increasing algorithm transparency, digital equity, accountability, and trust. It is also very complicated to deploy information technology (IT) effectively when you have technical infrastructure restricted, users reluctant, and both education and stakeholder coordination to manage. Managing those needs strategies that cover technical, legal, and social dimensions together. It is important to invest in strong systems, rules everyone can use, consider users' needs, keep everyone trained, and partner with stakeholders to build ethical, equal, and effective digital health systems. In the end, using different approaches combined is necessary to get the best results from digital health for healthcare. Future research should focus on existing gaps, such as the integration of digital health with human oversight, algorithmic bias, and workload management.

Despite providing an overview of the ethical challenges in digital health, this study has limitations due to focusing only on articles in English and USA & EU restricts, so caution is advised in generalizing. Keywords and publication years may also influence the research outcomes. Rapid technological changes represent another factor that warrants attention. Overall, this research can serve as a comprehensive guide for advancing both scholarly and practical objectives in the implementation of digital health and overcoming its ethical barriers.

Acknowledgements

The text was translated from Persian into English using Perplexity, employing its academic writing features.

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Perspective Chapter: Financial Risk Management in the Age of Digital Transformation – Challenges and Opportunities in Africa

Nesrine Gafsi

Abstract

The rapid digitalization of financial services is transforming the economic landscape of Africa, creating new opportunities and extremely high risks. The present paper takes into account the evolving nature of financial risk management (FRM) in the age of digitalization with specific reference to African economies. This study aims to explore how new technologies such as artificial intelligence (AI), financial technology (FinTech), and blockchain are impacting risk management processes in African financial institutions. It also explores the challenges associated with cybersecurity risks, regulatory loopholes, and digital financial inclusion. The research employs a mixed-methods approach, combining qualitative analysis of policy frameworks with quantitative data from financial sector reports. A review of emerging literature and case studies in selected African economies provides insights into the trends and effectiveness of digital financial risk reduction approaches. As financial technology enhances operational effectiveness and financial inclusion, it also exposes African economies to new vulnerabilities, including cyber attacks, regulatory issues, and systemic risks in the use of financial technology. Policymakers and financial institutions must make proactive regulatory measures, invest in cybersecurity, and enhance risk management frameworks to become resilient in a more digitalized financial environment. The digital financial infrastructure of Africa must be strengthened by a concerted effort from governments, financial institutions, and technology providers. If security and regulatory problems are addressed, Africa can utilize digital finance to promote economic stability and sustainable growth.

Keywords: digital transformation, FinTech, risk assessment, risk mitigation, digital finance, cyber risk, artificial intelligence in finance, blockchain risk, big data analytics, cloud computing in finance, RegTech, real-time risk monitoring, algorithmic risk models, machine learning for risk prediction, operational risk in digital systems, cybersecurity in financial services, data governance, technology-driven compliance, financial innovation risks

1. Introduction

A perspective evaluating the impact of digital transformation on the African financial sector from the viewpoint of financial risk management is provided. There is much literature discussing the impact of digital transformation on the banking industry, but little on financial risk management. The article aims at narrowing the gap. The emergence of financial technologies and systems brings both potential improvement and novel challenges for financial risk management, especially in the developing world. Several major challenges faced by policymakers and regulators in the era of digital transformation are explored.

From the management science perspective, Financial Risk Management (FRM) aims at minimizing the financial loss of financial institutions in chaotic environments. The FRM includes Asset Risk Management (ARM) and Liability Risk Management (LRM). In response to asset risks generated by clients' investments, financial institutions launched and promoted the sale of various insurance services like fixed currency, fixed interest rate, and universal insurance over the counter. With the emergence of credit cards, financial institutions, especially banks, encourage cardholders to borrow cash with consumption loan businesses. In general, the ARM requires financial institutions to evaluate and monitor the financial positions of their clients, with the decrease in the capacity of evaluating and monitoring clients, there had silently taken foot a financial crisis that almost dragged the West economies into the quagmire [1]. Beyond that, facing Internet giants such as Amazon, Google, and Facebook, the position of many small banks will be further squeezed by more resourceful large competitors, which will tend to assign more funds to FinTech-based bank management systems. On the regulatory side of LRM, the Central Bank is responsible for the financial stability of an economy as well as the smooth running of the payment system [2]. With the rapid development of digital payments, cryptocurrency is gradually accepted by the public. But the legality of cryptocurrency always raises questions in both China and many African countries. Central banks have to balance between controlling cryptocurrency transactions and abiding by WTO commitments. A full ban can be construed as a trade barrier; therefore, partial liberalization tends to be upheld. Where if the CB suppresses the trading of cryptocurrency totally, it is short of doubt to be accused of violating WTO regulations. Thus the CB has to maintain a degree of trade liberalization even in the trade of cryptocurrency [3, 4].

1.1 Definition and importance of financial risk management

Traditionally seen as an after-the-fact control mechanism, risk management is increasingly being actively applied at earlier stages. This chapter addresses this trend with specific reference to Sub-Saharan Africa. The objective of this article is to analyze some of the implications of this change, focusing on Sub-Saharan African countries. In particular, the aim is to: (a) review recent trends in the development of financial risk management products and services in the area, considering problems and opportunities related to financial system development and the role of external assistance in this sector; and (b) identify major challenges and constraints facing African banks and financial institutions regarding the development and promotion of financial risk management policies and strategies. Some implications in terms of donor coordination and technical assistance priorities and modalities will be discussed as well [5–7].

1.2 Concept and impact of digital transformation in finance

Digital transformation has been taking place at breakneck speed in all sectors related to economic and societal activities, and the process is accelerating year by year [8]. Digitalization harbors the potential to improve the functioning of financial services and influence the behavior of financial institutions and markets. It is confirmed, among other things, that the introduction of digital cash has the potential to disrupt current practices and institutions, including central banks and commercial banks. Models of this transformation are far from being conclusively developed. While discussions are very advanced on certain technological devices (in particular, blockchains), everything that affects behavior is more nascent. The penetration of the various innovations and devices should be induced by concepts between regulation, macroprudential control, and good governance. Africa is the region with the lowest access to digital services but also the one with the most progress and the fastest progress.

Great hopes are placed with regard to the potential of digitization to increase the efficiency and effectiveness of financial services. Such an acceleration will remove part of the burden represented by the suppression of “paper money,” reducing handling costs. More generally, such a change is expected to increase the competition and efficiency of banking services. In small African countries, standalone ATM terminals are being installed in supermarkets or other places frequented by a minimum- or medium-income population that cannot have access to a bank account, which emphasizes the use of smartphone ATM functionalities. On another hand, in many Sub-Saharan African countries such as Tanzania, Kenya, Uganda, South Africa, etc., the penetration of smartphones has been transiting to penetrate into rural areas, allowing for a revolution in the role played by bank agents. This is so that even in the remote and hardly accessible areas, the population would at least have access to the principal cash services, like the possibility to deposit or withdraw funds by integrating the community of “financial exclusion.” Hence, the functions played by bank agents will not be restricted to a mere physical presence and the delivery of cash services like those stipulated by the scenarios presented in the base case but would extend to a variety of services (credit, microcredit, bank transfers, payment of bills like the purchase of prepaid cards, payment of public utilities, etc.), like the ones of bank branches under a sort of “bank mobile” perspective, without which it would not be possible to cater to the needs of the population living in decaying surrounding areas or in a fragile zone [9, 10].

2. Overview of financial risk management in Africa

Africa has been experiencing fast financial changes, evolving trends, and developing organizations. Particularly, the African banks have gone through a “rather remarkable upgrading of their service quality and financial performance” [11]. However, financial stability remains a critical challenge across the continent, which calls for the further development and enhancement of financial risk management. Given its importance, recent studies have been dedicated to understanding financial risk management in Africa, particularly focusing on the examination of current practices, implications, and the examination of the factors that are reshaping financial risk management in African finance.

In the region, there is a call for further research and discussion on the dynamics to help build a platform for sharing knowledge and experience between African

countries. First of all, it is essential to become familiar with the current status of financial risk management in Africa. As is known, “financial markets’ risks are inherently different compared to the historically more common operational and credit risks that have typically made up the bulk of the financial risks borne by banks” [12]. Nevertheless, a recent study claims that Africa has not been effectively utilizing financial derivative instruments to hedge financial risks, such as credit risk, exchange rate risk, inflation rate risk, and interest rate risk. The scarcity of financial derivative instruments plays a significant role in explaining why markets and industries in Africa are more vulnerable to financial risks. Panel data estimations suggest that inadequate use of financial risk management strategies and instruments results in significant additional losses within both African financial and corporate sectors.

2.1 Key risk factors in the African financial landscape

The African financial landscape has undergone profound changes in the past two decades, with digitization characterized by the fast expansion of mobile networks being one of the main game changers. The African continent is the world’s second-largest, and its population is set to double by 2050, reaching 2 billion. Technological progress in a large number of countries is offering African countries many opportunities within the digital sector, given that over the past decade, on average, African countries have been among the world’s fastest-growing economies. Recently, there has been a boom in payments, lending, insurance, and infrastructure, as tech companies are moving to finance and finance companies are looking for techs. Yet the regulatory environment is beginning to get more complex for these firms as they are national or pan-African and the legal frameworks are still largely influenced by colonial laws and fragmented. As the continent’s finance becomes more volatile due to a lack of developed adequate instruments and skilled professionals, the convergence of finance with up-to-date technologies is leading to new risky paths or, as the regulators turn it, shadow banking [13].

Starting in the mid-1990s with the first mobile phone services, by the early 2010s more than 50% of the continent’s population had a mobile subscription. Moreover, the number of mobile network providers grew fast from less than 10 in the mid-1990s to more than 100 by the early 2010s, hence drastically dropping the access costs. The ambivalence of the telecom companies is crucial in grasping their tie with the financial sector. Voice is the main source of earnings for traditional telcos, and these are the ones that still lead the income stream, but its contribution is bound to fade away in favor of new technological innovations in the sector. FinTechs that incorporate some financial characteristics into their operations are known as TechFin. Efforts by authorities and businesses to enforce regulation in this area have been significantly more spot-on, instructing foreign and domestic vendors to abandon the practice [14].

3. Digital transformation trends in African financial institutions

The world of serving customers financially is becoming continuously more complex. With that in the picture, there is a need to understand changes and trends that will form the future of financial services in Africa. Digitalization, and in its wake the use of digital technologies, have changed the shape of financial services from service design and delivery to customer behavior and regulations. This change has brought challenges and opportunities for financial institutions in various markets. There are noticeable trends in technology and customer behaviors that should be tracked and

researched to stay ahead of the competition. African financial institutions need to understand and align with these trends for future prosperity. For many financial institutions in Africa, the challenge of keeping up with digital transformation is evident. Many institutions are hampered by legacy infrastructure or regulations [2]. Enabling comprehensive financial policy and regulations often lags behind the pace of digital innovation, as legislation can be slow with the technological changes. Africa also comes with its own context, difficult for the rest of the world to understand. In many cases the growth of the financial sector has been much slower compared to other industries; however, the growth of the African financial sector in recent years has been rapid and often driven by digital advancements. The competition is high, and service providers are less able to accommodate slackness. Furthermore, many service users are new to transacting within a financial system and have leapfrogged from a cash-based economy straight to digital transactions, resulting in a change from an environment where trust could be established through face-to-face communication and interactions. This new digitally enabled market environment and the opportunities and challenges of prospective digital transformations have gone mostly unnoticed in the wider debate on new technologies in business innovation across Africa [15].

3.1 Adoption of FinTech solutions

Africa has experienced a remarkable mobile phone revolution in the past two decades. From being a near technology derelict continent, where the landlines were sparse and expensive and the mobile penetration was reaching just 1% in some countries, it became the fastest-growing mobile technology region in the world. By 2018, more than 245mn unique mobile users were accessing the internet, and 1.48 bn mobile subscribers are predicted by 2025. There are 15% more mobile internet users in Africa compared to the global average. The share of internet traffic that is on mobile phones in Africa is 52%, whereas the global average is 48%. African users take a leap to engage in mobile commerce, with the price of the commodity service in many places being \$0.75. Apps allow borrowed one-off goods and services for users while tracking payments and providing business recommendations. Ride-hailing platforms also offer their services on the continent. Africa provides the preferred payment system in cash. In Kenya, telecom giants leverage their cheap payment services to provide credit access to their subscribers. Nevertheless, many countries have lagged in terms of legislation and the growth of illegal banking systems. At the same time, in 2018, the most commonly used operator was spotted for violating money regulatory laws, usually providing anonymous and undocumented services. Nigeria has this informal credit, in which land operators are used as outlets that exchange space on the internet with cash in the offline world. Finally, the high cost of mobile internet and the presence of bad connectivity in Africa pose a special problem to FinTech. Another problem arises from the weak infrastructure necessary for the operation of FinTech. Africans are sometimes paid through mobile systems and are, as a result, poorer because of the lack of trust issues and hot money turnover policies [16].

4. Challenges of financial risk management in the digital age

Digital financial transactions are vulnerable to a host of potentially devastating internal and external fraud and malpractice attacks. Scenarios for losses due to hacking, system failure, employee dishonesty, financing fraudulent transactions, securities market manipulation, and information theft, as well as fines and penalties

for non-compliance, are difficult to quantify. Illustrative scenarios might focus on cumulative loss to business and reputation over a given number of years or can encompass single large loss events. Exponential growth in time and the magnitude of market changes make it more challenging to detect adverse trends. Exposure to financial market risks may be hard to quantify due to the illiquidity of investments and severe market-wide price corrections when liquidity dries up. Macrosimulations may be more appropriate than traditional probabilistic approaches. As the regulatory environment becomes more onerous, asset managers are looking increasingly closely at risk management techniques, especially in fund selection. Investment in information and computing is vital for risk identification and control, as are sound recruitment and training policies [8]. Training may have to be centralized to achieve economies of scale. Risk control options include changing operational infrastructures, adjusting management strategy, reducing short-term trading, increasing long-term positioning, divestment of low-risk, low-return ventures, avoiding offshore funds, counterbalancing strong performance with higher risk management, regular stress testing and simulation exercises, top-down quantification of firm-wide acceptable loss levels and monetary constraints, especially in the period after a loss event. Investment goals and their weightings are re-specified, as are market perceptions of “market neutral” strategies. Pre-event distressed security trade and policies for non-discriminatory applications are in place to further limit reputational risks. Configuration is made to tighten due diligence arrangements, and investigation protocols for those employed or contracted by an information provider in lower-wage countries are drafted. Business continuity and company contingency plans include steps to counter negative media coverage. Coordination failure and flow-back are major topics of discussion within the industry and with suppliers [17, 18].

4.1 Cybersecurity threats and data privacy concerns

Financial institutions play a significant position in the funding of the economy by uniting savers and seekers of credit. Financial organizations should promise the security and privacy of the financial information of their clients. With the enlarged utilization of online banking in Africa, countermeasures against threats and vulnerabilities associated with online banking require being put in place. This consists of financial institutions being aware of the latest cyber security threats, vulnerabilities, and trends. There is a disturbing increase in cyber threats all over the world, and Africa is not an exception. To lower the threat, financial institutions need to offer security of the highest standards [19].

The financial sector is a major target of cybercrimes applying Internet-oriented ways of committing crimes such as ATM malfunctions, malware, and phishing. Cybersecurity threats from untrusted third parties like hackers and criminals are a worldwide recognized urgency in Africa. Moreover, Africa lags in data privacy practices and executions. This critical situation of cybersecurity threats and data privacy concerns affects the credibility of the burgeoning e-finance outreach in Africa. The exercise relies on open-source intelligence data in aggregation with a survey and uses it to present a situation analysis of cybersecurity threats and data privacy concerns in Africa [20]. Implementing effective controls necessitates both situation analysis and vulnerability management, emphasizing the current threat landscape and how it impacts the Internet’s security and Africa. The approach is structured, highlighting incident handling mechanisms and concepts before discussing the actual situation analysis, the collection type used, the initiating repository sources that were

employed, and the vulnerabilities identified. The situation analysis and security intelligence generated is focused on vulnerabilities that were highlighted for action by pertinent stakeholders.

5. Opportunities for enhancing financial risk management through digital transformation

For countries operating with a top-down economic model, governments are designing and implementing flagship digital policies aimed at reshaping how these economies function. An area of particular focus is the financial services sector. The logic here is clear enough: outdated, manual, and paper-based financial institutions lie at the crux of a national economic bottleneck. An era when these cumbersome incumbents could blithely continue on through inherited and embedded advantages is long gone. To survive, and hopefully prosper, these entities and the bureaucracies that regulate them are nowadays compelled to digitally upskill. The specter of obsolescence invariably concentrates the mind. Corresponding to this wave of digital revolution either breaking over or drawing closer to the shores of developing countries is a rapidly expanding ecosystem of FinTech entities. It has long been clear that key-value public infrastructure, upon which wealth and power can be thought of as circulating in a positive feedback loop, is a necessary precondition to sustainable economic growth. Digitalization is the latest black box, which may unpack a salve to a viciously self-reinforcing cycle of underdevelopment. However, hand in hand with the positive opportunities are a number of formidable challenges and risks engendered by this techno-economic transformation. These include increased financial sector misconduct, a proliferation of cyber threats, and the marginalization, and in some cases persecution, of non-technologically literate citizens by an emerging regime of digital authoritarianism [2].

The dislocative effects seen in settled systems are increasingly mirrored in the online world, where marginalized populations most bear the brunt of the change. A deliberative strategy to forestall these disadvantages is consequently the need of the hour. An almost universally popular refrain for these strategic considerations is greater investment into “cybersecurity.” The oversimplification of the cyber threats facing developing countries is an error obvious to those operating in the field. In reality, the exposure of developing world consumer finance to cyber threats is... pretty limited. Nonetheless, cybersecurity, unlike bricks-and-mortar national infrastructure, does double as a highly versatile blunt tool to plug up, or at least temporarily mitigate, a wide variety of different economic, social, and political maladies [12].

5.1 Automation and AI in risk assessment

In recent years, there has been an increasing number of studies on the impacts of automation and artificial intelligence in business and financial services in developing countries. The adoption of new technologies in risk assessment by financial institutions, such as machine learning and artificial intelligence, and the use of alternative data sources have the potential to increase the democratization of access to credit. In South Africa, Sub-Saharan Africa’s most developed economy, location data is predominantly available in digital format, and location data relevant to potential risk factors in a commercial bank loan contract are used to assess and predict default probabilities for personal loan customers. More precise predictions are enabled by utilizing

gridded location data than are possible with conventional methods, and acceptances of loan applications are comprehensively assessed by the bank, including the potential borrower's ability to service additional debt, the affordability of the credit requested, and perceived risk [21, 22].

It has implications for banks' risk management practices, but the grade is not always predictive of a customer's repayment behavior. A machine learning model trained on location-based and conventional data predicts the probability that a newly originated loan will have consecutive monthly repayments missed. Model fit to the bank's past behavior is compared, and then how well the model predicts observed delinquency in a range of customer demographics is assessed. The approach generally outperforms traditional analysis-based methods with a reliable effect size across various sub-groups. It identifies customers representing particularly high or low relative risk where the bank's existing risk toolkit often fails. In particular, the model is much more effective for females, those living far from work or the city center, and loan purpose groupings including education and "other" loans [23].

6. Conclusion

For the markets of Africa, the present decade is characterized by a rapid change in regulation, increasing competition, and technological innovations. At the same time, the new opportunities in digitization are enormous. Even in this fast-changing environment, future resilience against emerging risks will determine the success of each institution. Regulatory requirements are changing rapidly all over the world. It is expected that those changes will be more dramatic in the markets where regulation was weak until recently. Still, at a time when customer risks are hard to predict and competition is taking new shapes, most actors do not have the vision or means to adapt to changes in risk management easily. This time of global growth in interconnected digital systems also brings new threats to the African market for which local tools have been mostly inadequate. Cyber risks—threats arising from interconnected economic and information systems—are growing at the same pace as the market itself. When the malware attack reached the national health system in Africa, its vulnerabilities became obvious to everyone, including the customers and operators of the insurance market. At the same time, traditional insurance is considered as a tool useful only for physical damages and known risks. Further trust in the industry is undermined by a long story of abuses and decade-long oblivion of the current global challenges in insurance products [12]. On the other hand, a similar accelerated growth in global climate and interconnected production chain risks results in the value chain becoming more integrated and the risks more strongly correlated. On the continent, there are additional threats from public infrastructure and power system vulnerabilities. It is made obvious by the accident at a dam, where corruption in the construction and threats of a terrorist attack joined in increasing chain risk transitions. However, in this negative context lay the biggest opportunity of all. The risk management systems that are being developed now have a direct influence on how the market will look like in the next 30 years. Where it might be impossible to adapt market norms in health, employment, infrastructure, and social services, local agricultural market risks may be cheap to mitigate with new reinsurance products. If the risk-taking and risk-sharing models are chosen wisely, the emerging market system, coalitions of new insurers, start-ups, technology, and other market entities might be resilient to the risks of the twenty-first century and beyond [24, 25].

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Section 4

Digital Transformation in Action: Policies and Strategies for Social Transformation

Bridging the Digital Divide in the South African Public Sector: Assessing Digital Literacy Gaps and Capacity-Building Strategies

Andrew Enaifoghe

Abstract

The study aimed to bridge the digital divide by assessing digital literacy gaps and capacity-building strategies within South Africa's public sector workforce. Digital transformation is fundamental to contemporary government; nonetheless, notable gaps in digital literacy remain within South Africa's public sector, obstructing efficient service delivery and innovation. This study examines the scope and characteristics of digital literacy disparities among public sector personnel at national, provincial, and municipal levels of government. The research employed a mixed-methods approach, integrating quantitative surveys with qualitative interviews and focus groups to assess digital capabilities, access to digital resources, and the effectiveness of current training programs. Results indicate significant differences affected by geographic location, age, and departmental resources, with rural and under-resourced offices encountering the most substantial difficulties. The research also identifies structural obstacles, such as uneven training programs, inadequate infrastructure, and a reluctance to undergo digital transformation. The report recommends specific capacity-building measures and legislative initiatives to promote a digitally inclusive and future-ready public workforce. The results enhance the overarching discussion on e-governance and digital equity in underdeveloped environments.

Keywords: digital transformation, public sector, workforce, digital divide, digitally inclusive, digital resources

1. Introduction

The chapter explored the digital divide by assessing digital literacy gaps and capacity-building strategies within South Africa's public sector workforce. A multifaceted approach is essential to bridge the digital gap and enhance South Africa's public sector workforce, emphasising digital literacy evaluation, capacity-building, and infrastructure development. This entails assessing existing digital literacy levels, offering customised training programs, and ensuring access to technology and reliable Internet connectivity, particularly in underprivileged areas [1].

In the digital era, proficiency in information and communication technologies (ICTs) is essential for effective governance, public service delivery, and citizen engagement [2]. As governments globally adopt digital transformation, the necessity for technologically proficient public sector personnel has intensified [3]. In South Africa, this necessity is especially urgent due to the country's ongoing efforts to modernise public administration and address socio-economic disparities through e-governance projects.

Despite national promises to promote digital inclusion, considerable differences in digital literacy persist across various tiers of the South African public sector [4]. These disparities are frequently exacerbated by variables such as unequal access to digital infrastructure, inconsistent training initiatives, and varying degrees of technological experience among personnel. Rural and under-resourced departments have exacerbated obstacles that hinder their full capacity to engage in digital transformation initiatives [5].

To facilitate digital transformation, equal importance must be assigned to the development of digital skills and infrastructure. Central to investing in digital skills development is the following administration and assessment of digital training programs. This chapter evaluates techniques for the effective management of digital training programs, utilising a defined data-gathering methodology to quantify a globally recognised digital literacy index. Such an index necessitates a dynamic definition of digital literacy, attuned to the evolving landscape of the digital economy.

2. Research objectives

Investigate the current state of digital literacy among public sector employees. And identify key challenges and disparities (e.g., rural vs. urban, generational, and departmental).

2.1 Literature review

Ultimately, rectifying digital literacy deficiencies is not just an issue of operational efficiency, but also a crucial measure for guaranteeing fair access to public services and promoting a more responsive and open government [6, 7]. Digitalisation is swiftly transforming the global economy. Research indicates that the recent global epidemic served as a catalyst, accelerating the rate of digital transformation [8–10]. There is a growing necessity to possess digital literacy abilities to navigate the contemporary world effectively.

Digital literacy is defined as the ability to proficiently utilise technology in a manner that promotes personal, commercial, and societal advancement [11]. It encompasses knowledge, critical analysis, and technical proficiency in utilising technology instruments. The cumulative effect of digital technology developments, including the Internet of things (IoT), big data, robots, and artificial intelligence (AI), is transforming the functioning of individuals, economies, and society [12, 13]. Individuals currently reside in an information age, whereby Internet connectivity serves as the fundamental instrument for obtaining essential information and digital material required to navigate our everyday lives.

Comprehending the use of the Internet and other technologies is essential for helping individuals achieve their objectives [11]. The capacity of communities and individuals to engage in the expanding social and economic transformation, to get benefits from it, and to be enhanced by it, increasingly relies on the learning and use of digital skills [11]. Digital skills encompass the competencies and knowledge necessary to interact with digital technology for personal, social, political, and economic

objectives [14]. The global adoption of digital skills in rural and township populations is largely absent from public discourse, as the issues surrounding broadband access dominate countless research in both developed and developing nations.

2.2 Digital technologies and inadequate infrastructure

Research indicates that although economically disadvantaged populations face restricted access to digital technologies due to inadequate infrastructure, the primary issue lies in the insufficient availability of training in digital technologies and the inadequate acquisition of digital skills [6, 15]. The majority of individuals from rural and township areas in South Africa lack the requisite skills to effectively utilise information and communication technology, particularly those who are unskilled, unemployed, or untrained. The World Economic Forum Global Competitiveness Report in 2018 ranks South Africa 116th out of 140 nations for the digital capabilities of its people [16]. South Africa has one of the most elevated levels of inequality within its socio-economic spectrum. The distinction among cities, suburbs, townships, and rural areas is a significant issue.

Historically marginalised populations continue to face disadvantages in the current era of digital change [11]. The digital literacy gap in these neighbourhoods significantly hinders the nation's progress and future [17]. Consequently, it is prudent to prioritise rural and township areas in public discourse regarding the possibilities of digital change. In the digital age, possessing digital literacy is essential for enhancing individuals' capacity to engage in the economy. Thus, bridging the digital gap by equipping all individuals with essential digital skills for success in today's technology-driven world is of paramount global significance.

Digital competencies, particularly digital literacy, provide opportunities for empowerment to marginalised populations nationwide [17]. Consequently, coordinated measures must be undertaken to enhance digital literacy among individuals in rural and township communities, alongside the implementation of skills projects. This study encompasses an examination of both published and unpublished research materials. The review's findings suggest that although the country is progressing towards the Fourth Industrial Revolution, it has significant obstacles in bridging the digital gap. Three Digital illiteracy is a considerable constraint in underprivileged populations, alongside issues related to infrastructure and expenses. It is essential to provide digital skills training programs in disadvantaged communities [18].

The SETA should endeavour to be inventive and opportunistic in enhancing digital literacy among underprivileged areas. In this context, the Food and Beverages Manufacturing Sector Education and Training Authority recognises the growing need for digital skills development in rural and township populations. Digital literacy presents opportunities that can transform the livelihoods of individuals in historically marginalised communities [19]. The objective of this research is to identify the digital skills requirements in rural and township areas in South Africa. This research investigates the current status of digital literacy in South Africa's rural and township communities, the challenges hindering the advancement of digital skills in these areas, and potential collaborative efforts between the SETA and other organisations to promote digital skills development.

2.3 Defining digital literacy

Digital literacy encompasses not only fundamental computer skills but also the ability to access, evaluate, create, and communicate information using digital

technology. The European Commission defines digital competence in 2018 as comprising information and data literacy, communication and cooperation, digital content production, safety, and problem-solving. In public administration, digital literacy is essential for delivering efficient services, managing data effectively, and promoting citizen engagement [4, 20].

Digital literacy is a complex concept that has undergone considerable evolution over the last 20 years. Linked initially to fundamental computer skills, it now encompasses a broader range of competencies necessary for efficiently and ethically navigating the digital landscape. Academics and organisations have proposed several definitions, highlighting the intricate and context-dependent nature of digital literacy.

3. Terminology and frameworks

The European Commission [21] characterises digital competence as the assured, analytical, and accountable utilisation of digital technology for education, employment, and societal engagement. This description is implemented using the DigComp Framework, which delineates five principal domains:

- **Information and data literacy:** This includes finding, evaluating, and managing information and data in digital environments.
- **Communication and collaboration:** This involves interacting and collaborating with others using digital technologies.
- **Digital content creation:** This refers to creating and editing digital content, understanding copyright and licenses.
- **Safety:** This covers protecting personal data, devices, and well-being in the digital world.
- **Problem-solving:** This encompasses using digital tools to solve problems, innovate, and adapt to new technologies.

UNESCO [22] underscores digital literacy as a spectrum of competencies that empower individuals to access, manage, comprehend, integrate, communicate, assess, and generate information securely and suitably using digital technology. In the South African context, the National Digital and Future Skills Strategy (2020–2025) adopts a comprehensive perspective, recognising digital literacy as essential for economic participation, social inclusion, and democratic engagement. It underscores the necessity for contextually aware strategies that take into account local languages, cultural diversity, and socio-economic inequalities.

3.1 Digital literacy vs. digital skills

Although they are frequently used synonymously, digital literacy and digital skills are fundamentally distinct. Digital skills generally denote the technical proficiency in utilising digital tools (e.g., operating a computer, employing software), while digital literacy encompasses cognitive and socio-emotional aspects—such as assessing

online information [23], comprehending digital rights, and participating ethically in digital environments. This divide is especially pertinent in the public sector, where staff must not only utilise digital systems but also analyse data, engage with residents online, and maintain cybersecurity compliance.

3.2 Significance to the public sector

In public administration, digital literacy serves as a fundamental enabler of e-governance, digital service provision, and data-informed decision-making. Public officials are required to engage with digital platforms, oversee digital documents, and assist residents in utilising online services. Consequently, digital literacy is not just a technological need but an essential ability for contemporary government [24]. Furthermore, digital literacy within the public sector must be broad and adaptable, catering to the varied requirements of personnel across distinct occupations, age demographics, and geographical regions. This needs not only training but also organisational backing, leadership dedication, and a culture of perpetual learning.

3.3 Barriers to the advancement of digitalisation in public service sector

In Indonesia, a developing nation, digitalisation poses a barrier for the advancement of public services within the government [25]. This is due to the fact that public services in Indonesia have not completely integrated digital technology into their operations, resulting in this situation being a worry for several stakeholders, including politicians, scientists, and civil society. Fatimah et al. [26] identify data security, infrastructure, Internet connectivity, and human resource competency as significant impediments to the digitalisation of governmental services in Indonesia.

The Central Java Provincial Government in Indonesia has developed an electronic-based government system as a digital public service provider, aiming to enable government officials to utilise information and communications technology (ICT) to deliver services to the public [27]. The Central Java Provincial administration has a declining community satisfaction rating about the services rendered [28]. This prompts an inquiry into the potential effects of smart digital services on service quality and staff performance in digital public services. What is the significant impact of smart digital services on enhancing service quality and staff performance?

In public service organisations, civil officials must be prepared to manage digital services. Trenerry et al. [29] assert that digital transformation introduces a novel work paradigm and organisational culture inside the employee environment. Traditional methods are being supplanted by digital approaches, necessitating the acquisition of diverse skills for task execution [30]. To effectively engage with digital methodologies, it is essential to adopt a skills-oriented strategy, namely digital competence [31]. In digital competency, several critical components can promote effective digital services, including proficiency in technology utilisation.

Nonetheless, the findings remain inconclusive for generalisation within the context of public service organisations. The issue within public service professionals is their reluctance to leverage their technological expertise for the advancement of service technology. This corresponds with the diffusion of innovation hypothesis, which posits that inventions and novel behaviours may be either adopted or rejected. Transformations will alter the perception of human resources to embrace innovation and exhibit a heightened tolerance for risk [32]. Consequently, our work presents a novel idea to address the unresolved gap in later research. Digital competence empowers public sector personnel to:

- Manage e-government systems (e.g., electronic filing, digital procurement, and online licencing).
- Administer and evaluate data for evidence-driven policy formulation.
- Engage with citizens via digital platforms.
- Guarantee adherence to cybersecurity and data privacy regulations.

The OECD [33] asserts that technologically adept public workers are crucial for executing digital government policies and promoting innovation in public service delivery. In the absence of sufficient digital skills, even the most sophisticated digital infrastructure may be underused or poorly managed.

3.4 The context of South Africa

In South Africa, digital transformation is a key element of the National Development Plan (NDP) and the Public Service Digitalisation Strategy. Notwithstanding these regulatory frameworks, several studies (e.g., [34–36]) have highlighted enduring digital literacy disparities, particularly in remote areas and underfunded departments. Challenges include restricted access to ICT infrastructure, erratic training programs, and a lack of digital culture within organisations [37]. South Africa presents a multi-faceted and dynamic context for digital transformation, shaped by socio-economic disparities, historical inequities, and evolving legislative frameworks. Despite the country’s considerable advancements in digital technology adoption, the public sector still faces substantial obstacles in achieving universal digital literacy and expertise.

3.5 Socio-economic and geographic disparities

Significant disparities in income, education, and access to infrastructure characterise South Africa. These differences are reflected in the digital realm, where metropolitan regions—especially in Gauteng and the Western Cape—generally have superior access to bandwidth, devices, and digital training opportunities compared to rural provinces such as the Eastern Cape, Limpopo, and KwaZulu-Natal [36]. The digital gap affects both individuals and public officials, limiting the scope and effectiveness of e-government efforts.

3.6 The legacy of apartheid and institutional capacity

The legacy of apartheid persists in shaping institutional capacity and resource distribution within the public sector. Numerous local towns, particularly in historically marginalised regions, contend with inadequate resources, personnel deficiencies, and antiquated infrastructure [38]. These systemic challenges hinder the implementation of digital literacy initiatives and the adoption of new technology. Furthermore, the disparate quality of fundamental education throughout provinces leads to differing degrees of digital preparedness among public sector personnel.

3.7 Workforce demographics and digital preparedness

The workforce of the South African public sector exhibits diversity in age, educational background, and digital proficiency. Numerous older personnel started their

careers before the digital age and may be deficient in formal ICT training, whereas younger employees often exhibit superior digital competencies but may lack institutional knowledge [39]. The generational divide presents obstacles in information dissemination and collective digital integration. Moreover, digital literacy has not been integrated into recruiting, promotion, or performance assessment processes, diminishing the motivation for ongoing skill enhancement.

3.8 Prospects for innovation and inclusion

Notwithstanding these limitations, South Africa nevertheless offers prospects for innovation. The enhanced accessibility of mobile Internet, the proliferation of e-learning platforms, and the rising governmental commitment to adopt digital transformation provide a conducive atmosphere for advancement. Initiatives like the SAYouth, The Mobi platform, e-Government Websites, and digital ID systems exemplify the promise of inclusive digital services, contingent upon public workers possessing the requisite skills and support.

4. Obstacles to digital literacy

Obstacles to digital literacy within the public sector are complex. Common structural challenges include inadequate Internet access, outdated equipment, and financial constraints. Moreover, socio-demographic factors—including age, educational attainment, and geographic location—have a significant influence on digital competency. Resistance to change and insufficient leadership support impede digital adoption. A complex interaction of structural, socio-economic, and organisational elements shapes digital literacy in the public sector. These obstacles impede the use of digital tools and intensify existing disparities in service delivery and workforce development.

4.1 Structural obstacles

A major concern is the inequitable distribution of digital infrastructure throughout South Africa. Numerous rural and peri-urban government offices lack dependable Internet connectivity, modern hardware, and access to current software systems. The digital gap limits workers' ability to interact with e-governance systems and participate in online training programs. Vassilakopoulou and Hustad [24] argue that infrastructural deficiencies pose a significant impediment to digital transformation initiatives in developing nations.

4.2 Socio-demographic obstacles

Digital literacy levels frequently differ according to age, education, and geographic region. Senior personnel may find it challenging to adapt to new technology owing to insufficient past exposure, whereas younger staff may possess more digital proficiency but lack institutional expertise [40]. Moreover, personnel in rural or under-resourced regions may have limited chances for digital training and development. These differences result in inconsistent digital proficiency among departments and areas.

4.3 Organisational and cultural obstacles

In the public sector, institutional culture and leadership are essential in influencing digital adoption. Resistance to change, apprehension over job displacement from automation, and insufficient incentives for digital upskilling might foster an atmosphere that devalues digital literacy. Moreover, most departments lack explicit digital plans or do not include digital competencies into performance management and professional development frameworks.

4.4 Deficiencies in policy and training

Despite national policies prioritising digital transformation, a mismatch frequently exists between policy and execution. Training programs are sometimes improvised, inadequately financed, or poorly customised to the distinct requirements of several departments [41]. In the absence of continuous support and follow-up, these projects do not provide enduring enhancements in digital competence. The lack of established digital literacy benchmarks complicates the evaluation of development and the identification of areas that require assistance.

4.5 Psychological and motivational obstacles

Ultimately, personal attitudes and confidence levels substantially influence digital participation. Employees who view digital technologies as intricate or inconsequential to their responsibilities may refrain from utilising them entirely. This is exacerbated by an absence of peer assistance or mentoring, resulting in less technologically savvy personnel feeling alone or overwhelmed.

5. Research methodology

The study employs a technique to investigate the digital divide in South Africa by assessing digital literacy gaps and capacity-building strategies within the public sector workforce. It utilises a comprehensive approach that integrates both qualitative and quantitative methods. This method aims to elucidate the complex nature of the digital divide in South Africa and its impact on sustainable development. The study employed a qualitative research technique, utilising qualitative methodologies to provide an in-depth insight into the subject.

The method enables data triangulation, enhancing the reliability and validity of the findings. This research method provides a systematic and rigorous framework for analysing various perspectives on digital literacy in promoting sustainable development in South Africa. The study captures the complexity and depth of the digital divide and its impact on sustainable development through the integration of diverse data collection and analytical techniques.

5.1 Research design

The study employed a qualitative research approach to provide a comprehensive understanding of digital literacy gaps and capacity-building strategies in South Africa's public sector workforce. As the research design specifies the processes and data collecting techniques, it is essential to choose a valid and suitable design to

achieve trustworthy results [42]. Research design is the methodical structure for data acquisition. This study utilised a correlational technique to investigate the association between work motivation and employee engagement. The study utilised a qualitative technique and a cross-sectional design to investigate a topic. The research analysed interview data from 10 participants regarding various viewpoints on the role of entrepreneurship in advancing sustainable development in South Africa, grounded in a literature review on performance management and employee engagement.

5.2 Qualitative methods

The study conducted semi-structured interviews with HR and IT managers, training coordinators, and selected employees (especially in under-resourced areas). Researchers must utilise open-ended questions to encourage participants to articulate their opinions without fear of judgement [42]. Researchers conducted semi-structured interviews with participants, utilising an open-ended discussion guide due to the study's exploratory nature. This allowed the researcher to provide consistent open-ended questions to all participants, promoting more detailed and comprehensive replies. The researchers could sustain concentration on the study's aims while pursuing further clarity and comprehension. A major concern with this sort of instrument is the time necessary to complete the processes, including conducting individual interviews and coding and transcribing the results.

6. Methods of data collection

6.1 Interviews

The interview method was designed to ensure participant comfort, permitting them to refuse or withdraw their participation at any moment. All participants were required to hold a high school diploma or its equivalent, have at least 1 year of work experience, demonstrate proficiency in English, and possess prior expertise in performance management in some form.

The research intentionally picked 10 people from the designated location. The objective of employing interview techniques was to obtain thorough qualitative insights into entrepreneurs' experiences, strategies, and perspectives. The researchers analysed relevant papers from reputable South African and foreign journals to gain a comprehensive understanding of scholarly perspectives on various aspects of the topic under study in South Africa.

Thus, the researcher developed an interview guide to help participants express their views on employee engagement and performance management. The use of semi-structured interview questions and subsequent open discourse enabled participants' viewpoints and thoughts to surface clearly. All participants were asked to provide impartial and constructive feedback.

Each interview spanned 45–60 minutes, with participants encouraged to furnish supplementary data and examples to aid the interviewer in accurately comprehending and recording their perspectives. After concluding the interviews, the researcher may engage in follow-up conversations with participants, either by telephone or in-person, to determine if they require further clarification regarding their comments. This was dependent on the participants' availability.

6.1.1 Sampling

The study employed a stratified random sampling approach to ensure representation across various sectors, including national, provincial, and local government levels, as well as urban and rural offices and different age groups and job roles.

6.1.2 Focus groups

The study also organises focus groups to explore perceptions of digital literacy, barriers to digital upskilling, and suggestions for improvement.

6.1.3 Data analysis

6.1.3.1 Qualitative data

The study employed a thematic analysis to identify recurring themes and insights from interviews and focus groups, facilitating systematic analysis.

6.1.4 Ethical considerations

The study ensured that informed consent was obtained from all participants during the data collection process. It ensure confidentiality and anonymity and seek ethical clearance from a relevant institutional review board. Ethical approval was received from the University of Zululand where the research was conducted.

6.1.5 Limitations

- Potential response bias in self-reported surveys.
- Limited access to remote or under-resourced departments.

7. Data analysis and discussion of findings

(See Table 1)

Participants No	Code	Age	Sectors		Education
Participant	P01	34	Public sector employee (Urban)	Male	University graduates:
Participant	P02	29	Community advocate (Rural)	Male	Vocational training
Participant	P03	45	IT specialist - Government agency	Female	University graduates
Participant	P04	38	Senior citizen - Public service user	Male	Postgraduate degrees:
Participant	P05	50	Policy maker	Male	University graduates
Participant	P06	32	Social worker	Male	Postgraduate degrees
Participant	P07	27	Youth volunteer	Female	High school graduates
Participant	P08	40	Disabled services advocate	Male	Vocational training
Participant	P09	42	Public library staff	Female	High school graduates
Participant	P10	37	Immigrant support worker	Female	University graduates

Table 1.
Demography of the participants.

Themes	Sub-themes
Theme 1	Digital gap and enhancing digital literacy
Theme 2	Digital literacy in the public sector
Theme 3	Digital proficiency in the public sector
Theme 4	Effective digital competence in the South African public sector

Table 2.
Developing themes.

The table (**Table 2**) presents the developing themes from the study.

8. Discussion of results

Theme 1: Addressing the digital gap and enhancing digital literacy.

Digital technologies are crucial for achieving the United Nations Sustainable Development Goals (SDGs), particularly in rural areas. Digital technologies, including 5G, big data, and artificial intelligence, have permeated daily life, transforming conventional methods of work and education, and have become integral to social interactions. In recent years, bolstered by the central government, China's digital economy has experienced fast development. The selected participants were asked the following research question;

Question: *How can we address the digital gap and enhance digital literacy in the public services sector?*

Responses:

"...We need ongoing digital training programs tailored to different roles within public services. Many of us only receive one-time training, which isn't enough to keep up with evolving technologies" (Public Sector Employee -Urban Area).

"...Access is the first step. Many rural communities still lack reliable internet. Without infrastructure, digital literacy programs won't reach those who need them most" (Community Advocate - Rural Area).

"...We should integrate user-friendly platforms and provide multilingual support. Many public service users struggle not because they're illiterate, but because systems are too complex" (IT Specialist - Government Agency).

In 2023, the value added by China's main digital economy sectors exceeded CNY 12 trillion, accounting for almost 10% of China's GDP. The incorporation of digital components has revitalised rural sectors, leading to the emergence of new rural enterprises [43].

"...Workshops at community centers or libraries would help. I'd attend if someone could walk me through how to use online government services step by step" (Senior Citizen - Public Service User).

"...We need a national digital inclusion strategy that mandates digital literacy benchmarks across all public service departments, with funding tied to progress" (Policy Maker).

"...Digital literacy should be part of onboarding for new hires and regularly updated. Also, we need to train staff to assist clients who aren't digitally literate" (Social Worker).

This method enhances resource allocation in rural regions, thereby promoting rural development [44].

"...Peer-to-peer learning works well. Young people can teach older generations how to navigate digital tools, especially in community outreach programs" (Youth Volunteer - Digital Literacy Program).

"...Accessibility is often overlooked. Enhancing digital literacy must include training on assistive technologies and ensuring platforms are inclusive" (Disabled Services Advocate).

"...Libraries are already hubs for digital access. With more funding, we could expand our role in teaching digital skills and helping people access e-government services" (Public Library Staff).

"...Language barriers are a huge issue. Digital literacy programs should be culturally sensitive and available in multiple languages to truly be inclusive" (Immigrant Support Worker).

In line with the findings, figures from 2023 indicate that China had 326 million rural Internet users, resulting in an Internet penetration rate of 66.5% in rural regions, reflecting a year-on-year increase of 4.6 percentage points [45]. Despite advancements in digital infrastructure in the rural areas, the adoption of digital technology by rural families remains inferior to that of urban households.

Theme 2: Digital literacy in the public sector.

An increased investment is essential for the advancement of the digital economy [46], a view also supported by the World Economic Forum [47]. The OECD [48] acknowledges the need for increased investment to address the infrastructure challenges facing G20 nations, while also advocating for supplementary investment in training and process improvements. The selected participants were asked the following research question;

Question: *What is digital literacy in the public service sector?*

Responses:

"...Digital literacy in the public sector means having the skills to use digital tools and platforms to deliver services efficiently and securely" (Public Administrator).

"... It's not just about knowing how to use a computer—it's about understanding data privacy, cybersecurity, and how to navigate government systems responsibly" (IT Support Officer).

"...To me, digital literacy means being able to help citizens access online services, fill out digital forms, and troubleshoot basic tech issues" (Frontline Service Worker).

Supporting digital policy mechanisms are essential for managing the substantial investments required for digital infrastructure.

"...It involves the ability to adapt to new technologies, use digital communication tools, and understand how digital systems support service delivery" (Training Coordinator).

"...Digital literacy is the foundation for modern public service. It ensures staff can interact with digital platforms and help citizens who may not be tech-savvy" (Citizen Services Manager).

"... It's about understanding how digital tools can improve policy implementation and using data analytics to inform decisions" (Policy Analyst).

"...Digital literacy means being able to bridge the gap between the community and digital government services, especially for those who are digitally excluded" (Community Liaison Officer).

Policies centred solely on the supply of ICT infrastructure will not ensure that poor and middle-income areas effectively utilise these investments.

"...It includes knowing how to use internal systems for recruitment, payroll, and performance management, and ensuring staff are trained to do the same" (HR Officer in Public Sector).

"... It's the ability to teach and support the public in using e-government services, from applying for grants to accessing health records online" (Public Library Technician).

"...Digital literacy in public service is a strategic competency. It enables innovation, improves service delivery, and ensures inclusivity in a digital-first government" (Digital Transformation Consultant).

Training is essential to surmount the obstacles of technophobia and a general aversion to utilising contemporary instruments. Effectively administering digital skills training is essential to maximise infrastructure investments; however, this necessitates precise, pertinent, and representative data that accurately reflects the extent of digital illiteracy. Such data must be presented in a format that policymakers and digital trainers can utilise to ensure that training programs are appropriately aligned with the requirements of the swiftly evolving labour market, in conjunction with the demands of digitalisation within a dynamic and expanding political economy.

Hincu et al. [49] emphasise the necessity of managing the ICT facilities accessible to individuals. The authors assert that the digital gap continues to exist even in contexts of high ICT penetration, illustrating instances when new technologies or tools arise, necessitating that the populace enhance their abilities prior to fully adopting and utilising the available innovations. Abrahams and Goldstuck [50] examined this phenomenon in South Africa. They determined that there is often a five-year delay between acquiring access to digital tools and achieving proficiency in their usage. Considering these delays, a primary challenge is to assess the degree of digital adoption and the proper utilisation of digital technologies. This is a hurdle because to the scarcity of accessible and comparable data.

Theme 3: Digital proficiency in the public sector.

Worldwide, governments are progressively using digital technologies in public service provision. The efficacy of these programs is largely contingent upon the

digital preparedness of public sector personnel. The selected participants were asked the following research question;

Question: *What does digital proficiency mean for the South African public service sector?*

Responses:

"...Digital proficiency means being able to use technology confidently and securely to improve service delivery, reduce corruption, and streamline internal processes" (Government IT Manager).

"...It's about equipping staff with the skills to use digital tools effectively—from basic computer literacy to understanding e-government platforms and data systems" (Public Service Trainer).

"...For us, it means being able to access and use digital systems even with limited infrastructure. It's about making sure no one is left behind" (Municipal Clerk - Rural Area).

"...Digital proficiency is essential for implementing smart governance. It enables data-driven decision-making and more transparent public administration" (Policy Advisor).

"...It means being able to use digital health records, mobile apps, and communication tools to serve patients better, especially in remote areas" (Frontline Health Worker).

"... It's about empowering young public servants to innovate and use digital tools to engage communities, especially through social media and mobile platforms" (Youth Development Officer).

"...Digital proficiency includes using HR systems for recruitment, payroll, and performance tracking. It's also about helping staff adapt to digital change" (HR Officer in Government Department).

"...It means being able to support citizens in accessing digital government services, especially those who don't have internet or devices at home" (Public Library Coordinator).

"...Digital proficiency is critical for using auditing software, analyzing financial data, and ensuring accountability in public spending" (Auditor in Public Sector).

"... It's about using digital tools to collect data, communicate with stakeholders, and monitor service delivery in real time" (Community Development Worker).

Research from nations such India, Brazil, and Kenya indicates that digital transformation initiatives frequently fail owing to insufficient digital competencies among public personnel [16]. These findings underscore the importance of ongoing digital upskilling and institutional support.

Theme 4: The effectiveness of digital competence in the South African public sector.

Digital competence in the public sector refers to the ability of government personnel to effectively utilise digital tools, platforms, and systems to perform their

responsibilities, deliver services, and engage with citizens. Digital acceleration compels all industries to continue transforming their organisational management digitally [51]. Nevertheless, not all organisational sectors can adopt this transformation. Government organisations within the public service sector must innovate to develop effective and efficient services for the community [52, 53]. The selected participants were asked the following research question;

Question: *How effective is the digital competence in the South African public sector?*

Responses:

"...Digital competence varies widely. Some departments are advanced, but others still rely heavily on manual processes. There's no consistent standard across the board" (Provincial Government Official).

"... There's progress, especially in urban areas, but many employees still lack the confidence and training to use digital tools effectively" (2. Public Sector IT Consultant).

"...In rural municipalities, digital competence is low. We often face connectivity issues and limited access to training, which affects service delivery" (Municipal Employee (Rural Area)).

"... We've seen improvements with digital health records and mobile apps, but many staff still struggle with basic digital tasks. More hands-on training is needed" (Public Health Administrator).

"...Digital systems are in place, but the competence to use them efficiently is lacking. Many employees don't fully understand the tools they're using" (Auditor-General Office Staff).

"...Digital competence is improving, especially among younger staff. However, older employees often need more support to adapt to new systems" (HR Manager in Public Service).

"... There's a gap between policy and practice. While digital transformation is a goal, the workforce hasn't been adequately prepared or resourced" (Public Service Union Representative).

"... We're expected to help citizens use online platforms, but we ourselves don't always feel confident using them. Training is often outdated or too generic" (Citizen Services Officer).

"There's a willingness to learn, but training programs are inconsistent and not always aligned with the actual tools used in departments" (Digital Skills Trainer).

"...Digital competence is still developing. Many public servants rely on informal help from colleagues rather than structured support or training" (Community Development Worker).

As governments increasingly adopt digital technology to enhance efficiency, transparency, and accessibility, the digital competencies of public servants have emerged as a critical determinant in transforming the public sector.

9. Discussion of findings

Digital transformation enables the government to deliver more efficient, transparent, and responsive services to meet community requirements. The impact of digital technology on human behaviour alters individuals' perceptions and opinions on the capacity of government organisations to deliver services effectively and efficiently [32].

The demand for digital transformation is driven not only by the shifts of the digital era but also by the evolving behaviours of individuals. This is deemed crucial for enhancing service quality and performance. A particular aspect of digitalisation influences the preparedness of organisational members to confront this period [31]. Numerous issues associated with digitalisation emerge, including the complexity of performance evaluation due to the necessity of considering multiple measures, such as reaction time, customer satisfaction, and operational efficiency [54].

Consequently, the impact of digitalisation transforms the conventional service paradigm into digital services, necessitating a comprehensive alteration of all operational components inside the organisation. The study found that digitalisation in public services has a significant impact on organisations, as evident in their service delivery and societal interactions. Government digital services significantly impact individuals' ability to access services tailored to their specific needs. An illustrative example is online licencing and tax payment services, which diminish lineups and waiting periods, hence enhancing service quality.

Gong et al. [55] assert that a critical aspect of the successful digital transformation of public services within government institutions is the organisation's dynamic response to change. The paramount component of the ongoing digitalisation of public services is the potential for interaction between users and the institutions that deliver these services. The correlation between service quality and performance through self-reported assessments by employees, neglecting the perspective of the service recipient, demonstrated that service quality, as perceived by the provider, led to a significant enhancement in service quality ratings.

The influence of digital services on organisations presents several benefits; yet, the implications of the digital service strategy for human resources remain under-explored. A smart digital service integrates technology into its operations. Smart digital service represents a transformation in service delivery through the integration of the Internet of things (IoT) with artificial intelligence [56]. Smart digital service is a novel variable created by creative technology to facilitate access to services for individuals [57]. This project aimed to provide an empirical analysis on smart digital services inside public sector organisations.

The findings from this study indicate that components of smart digital services, such as cooperation, are anticipated to influence the attainment of superior service quality and performance. Enhancing collaboration will further augment facets of staff performance. The study examines the mediating function of intelligent digital services in promoting employee performance outcomes. This aligns with the diffusion of innovation thesis, which posits that enhancing employee performance in the digital age offers critical insights into the use and acceptance of technology innovations by employees.

9.1 Capacity development and policy interventions

Effective capacity-building tactics encompass focused training initiatives, mentorship, and the incorporation of digital competencies into professional development

frameworks. Global best practices indicate that effective digital literacy efforts are context-specific, inclusive, and bolstered by robust leadership and policy coherence [58]. In South Africa, initiatives such as the National School of Government's digital skills programs have potential but require wider implementation and assessment.

Improving digital literacy in the public sector requires a cohesive, strategic framework that integrates policy, institutional support, and continuous education, rather than depending exclusively on isolated training programs. In South Africa, several initiatives have been launched to address digital skills deficits; however, their effectiveness is variable due to implementation challenges, resource constraints, and contextual variations.

9.2 National strategies and frameworks

South Africa has developed many policy frameworks aimed at enhancing digital capabilities.

- The National Digital and Future Skills Strategy (2020–2025) outlines a plan to provide citizens and public officials with the necessary skills for the digital economy. It emphasises inclusivity, ongoing education, and adherence to international digital competency standards.
- The Public Service Digitalisation Strategy aims to modernise government operations and enhance service delivery through the use of digital tools. It includes provisions for digital education, infrastructure improvement, and institutional reform.

The effectiveness of these projects depends on effective interdepartmental collaboration, enough funding, and strong political commitment. The digitisation of the workplace necessitates personnel who are digitally proficient and measures to ensure that employee skills develop in tandem with technological advancements. Consequently, initiatives that foster digital literacy are essential. Burke and Hughes [59] contend that organisations who fail to adopt technological developments would lag behind their rivals and forfeit prospects for productivity, creativity, and new revenue growth presented by digitisation. A digital literacy assessment provides policymakers with a method to track the dissemination of digital competencies. The method of conducting such a test will enable policymakers to compare their country's skill level against a worldwide standard, provided that the same criteria are universally recognised [60].

In the absence of uniform and comparable assessment indicators to identify digitally illiterate segments of the population, policymakers are rendered ineffective and unable to execute digital transformation goals. Moreover, to ensure successful alignment in assessing digital literacy, policymakers should avoid prioritising a limited perspective of digital usage centred on technical skills and instead concentrate on the interdisciplinary requirements of employees and the corporate sector.

9.3 Supervision and evaluation

A notable shortcoming in current attempts is the lack of robust monitoring and evaluation (M&E) systems. In the absence of explicit indications and feedback mechanisms, evaluating the efficacy of training programs or pinpointing areas for

enhancement becomes challenging. Developing a national digital literacy assessment tool for public employees might enhance progress tracking and inform policy adjustments.

10. Summaries of case studies: Digital proficiency in South Africa's public sector

10.1 The digital transformation strategy (2024)

The South African government's Digital Transformation Roadmap delineates a national policy to modernise public services using digital platforms. The plan outlines essential projects, including digital identification systems, data sharing frameworks, and digital payment solutions, while also highlighting ongoing challenges. Numerous departments continue to function using antiquated technologies that are incompatible with modern platforms. Residents and frontline personnel in remote regions face challenges in accessing digital services due to inadequate infrastructure and limited digital competencies. Disjointed cooperation across departments hinders implementation and training initiatives.

11. Concluding remarks

Digital literacy has evolved from a peripheral ability to a fundamental competency essential for efficient government, public service delivery, and citizen engagement in the twenty-first century. This study has emphasised the complex nature of digital literacy and the substantial deficiencies present in South Africa's public sector. A confluence of structural inequities, socio-demographic variables, institutional constraints, and policy implementation challenges influences these disparities.

Despite the presence of advanced national plans and training programs, the disparate allocation of digital competencies among departments and regions continues to obstruct the achievement of a digitally inclusive public service. Rural and under-resourced communities face numerous obstacles that hinder employee growth and access to essential services.

Confronting these issues requires a comprehensive and enduring strategy—one that incorporates digital literacy into human resource policy, fosters a culture of continuous learning, and ensures equal access to digital infrastructure and training. Commitment from leadership, interdepartmental collaboration, and strong monitoring and evaluation systems will be essential for the success of these initiatives.

Ultimately, closing the digital literacy gap in the public sector is crucial for achieving operational efficiency, promoting social equality, fostering democratic engagement, and driving national advancement. By enhancing the digital competencies of its public officials, South Africa can establish a more responsive, transparent, and future-oriented government.

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Digital Transformation in Mexico: Evolution and Trends

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Abstract

This book chapter analyzes the progress and trajectories of the availability, use, appropriation, and dissemination of digital technologies in Mexico, aiming to promote the development of productive and technological capabilities as enablers of the current transformation process geared toward socioeconomic development and social well-being. The central research question is to determine how the digital transformation has evolved in the production of goods and services in the country and what is the state of the digital divides, both external and internal. The research results allow us to gauge the magnitude of the challenges and opportunities of the digital agenda. At the same time, these aspects allow for an accurate diagnosis of digital transformation in the country, with the aim of contributing to the discussion on the design and implementation of public policies in this area, to promote socioeconomic development and the well-being of the population.

Keywords: digital transformation, digital technologies, digital divides, digital economy, Mexican economy, socioeconomic development

1. Introduction

Throughout the historical development, evolution, and progress of modern societies, science, technology, and knowledge have emerged as key forces shaping patterns of production, distribution, marketing, and consumption of goods and services. In the current phase of the development process of Latin American economies, several components determine the degree of progress in growth, economic development, and social well-being in Latin American countries. One of these factors is the capacity to adopt, adapt, and deploy information and communication technologies (ICTs) within their productive structures and in organizations in the public, business, and academic sectors, as well as in social organizations. This is due to the transversal nature of digital technologies, which makes them present in virtually all economic, social, political, educational, and cultural activities, as well as to the rapid progress experienced in knowledge and research disciplines related to the various areas of digital technologies [1–3].

The digital paradigm of ICT is reaching its maturation phase and constitutes the pillar on which the new molecular paradigm (biotechnology, nanotechnology, genetics) is being configured, which together with the advances in artificial intelligence (AI), quantum computing, and the fourth technological revolution in progress

(industry 4.0) are shaping, in prospective terms, the new center of gravity of the socioeconomic progress of humanity toward the future [4, 5].

Since the trajectories of technological progress, its adoption and deployment in societies are not linear or automatic, for developing countries, such as Mexico¹, the effective use of digital technologies in the economic system, the institutional structure, and social organization represents a route of opportunities to advance toward the goals and objectives in its transformation process, but at the same time it implies challenges if the need to implement public policies aimed at promoting digital transformation is not assumed as a priority, which could become a critical factor that prevents effectively facing and overcoming national problems in the areas of the economy and society.

In this context, the central objective of this chapter is to analyze the evolution and possible trajectories of the path toward digital transformation in Mexico in order to provide an accurate diagnosis and, at the same time, contribute analytical elements to the discussion related to the design and implementation of public policies on the matter.

To address the topic at hand, this chapter is structured into five sections, in addition to this introductory section. The second section constructs a brief analytical framework associated with the importance of reflecting on the development and future trajectories of the digital technology ecosystem. The third section analyzes the recent adoption and deployment of digital technologies (goods and services), which will be useful for gaining insight into the behavior of the digital economy in the country. The fourth section assesses the state of digital transformation, using as a parameter the existing digital gaps with respect to the most advanced countries of the Organization for Economic Cooperation and Development (OECD), as well as with the group of countries in Latin America with the best performance in digital areas. Subsequently, the possibility is raised that Plan Mexico could serve as a trigger for greater use of digital technologies in the country. The conclusions highlight that while there has been relative progress in digital transformation, there are still significant areas of opportunity to leverage the potential for positive impact that new technologies must drive the current Fourth Transformation process, as well as Mexico's socioeconomic development and social well-being.

2. Maturity and trends of the digital technology ecosystem

In the last two decades, we have witnessed the accelerated advance in innovations experienced around the areas that make up the ecosystem of digital technologies, and that due to their transversality characteristic in most areas of the economy and society, the traditional forms of lifestyles, work, education, culture, recreation, organization, and social interaction are being modified. Likewise, the ongoing technological revolution has implications in various areas of society; for example, in academia and

¹ Mexico is currently immersed in a transformation, as the Fourth Transformation of public life began on December 1, 2018, led by the presidency of Andrés Manuel López Obrador, with a government model called “Mexican Humanism,” considered an alternative to the neoliberal model. During the 1980–2018 period, neoliberal policies had negative results in the economic and social spheres, increasing rates of poverty, inequality, insecurity, and social disintegration. Currently, “the second stage” of the Fourth Transformation is advancing under the leadership of President Claudia Sheinbaum Pardo, who is promoting Plan Mexico to advance the country's socioeconomic growth and development in the post-neoliberal era.

research it implies a responsibility to generate knowledge that allows an explanation and understanding of the complexity of its determining factors and the prospective analysis related to its behavior, evolution, and future trajectories, in such a way that it allows to take advantage of the potential of its benefits, as well as help mitigate the uncertainty of the negative impacts on the economy and society [4, 2].

Indeed, for developing countries like Mexico, the challenges are enormous, given that, due to their material conditions of underdevelopment, catching up with the development of technological capabilities represents a “moving target” [6, 7]. The development of productive and technological capabilities plays a strategic role in overcoming the productivity, income, well-being, technological and digital gaps with respect to more advanced countries.

The digital technologies paradigm is considered the fifth phase of the science and technology paradigm, which has had a fundamental impact on the economic development and technical progress of countries [8, 9]. The increased generation of data, circulation of information, and the advance in technological innovations shift the frontier of knowledge, which is constantly moving due to the process of knowledge generation itself as a permanent activity of creation, construction, and deconstruction that turns it into an “endless frontier” for the progress of humanity [3, 10].

From this perspective, the digital paradigm has changed global production trends, work methods, business models, consumption patterns, and the life cycle of products (goods and services). The changes associated with the digital technology system, which are evident in companies and their relationships with partners, customers, and suppliers, can contribute to significant improvements in productivity and competitiveness. The transformations in global business models, production relationships, and knowledge generation suggest that full utilization of digital technologies is only possible if substantial changes are made within companies, as well as in the productive structure and social and institutional organization [5, 7].

Therefore, the effective use of digital technologies represents a path of opportunity for developing economies like Mexico, to the extent that their use, adaptation, and deployment can significantly stimulate the development of productive and technological capabilities to overcome economic backwardness and social inequality. However, due to the accelerated dynamics of technological innovation, such opportunities can become critical factors if the effective appropriation of such technologies is not assumed as an unavoidable priority in relevant public policies. In this sense, the pressing structural problems of developing economies can worsen, resulting in a widening of the productive, technological, and digital gaps compared to more advanced countries.

The literature highlights that the magnitude of the impact of digital transformation on organizations and institutions in the regional, national and local maps is not yet fully understood, and simultaneously new technological advances are emerging [5]. These are manifested in the ubiquity of the Internet, which is transitioning from 3G and 4G networks to high-speed 5G, big data analysis, cloud computing (IaaS (infrastructure as a service), PaaS (platform as a service), SaaS (software as a service)), the Internet of Things (IoT), robotics, 3D (three-dimensional) and 4D (four-dimensional) printing, artificial intelligence (such as recent innovations in generative AI, ChatGPT, DeepSeek, among others), blockchain and its application in nonfinancial areas, industry 4.0, which are being leveraged in the configuration of digital platforms in the global economy.

At the same time, it is recognized that in the evolution and trends of digital technologies, the positive impact is observed to be limited over the time horizon,

due to the maturation of the digital paradigm and the gestation of a new phase of technical progress that is being configured with the paradigm of molecular technologies (biotechnology, nanotechnology, genetics), at the base of which digital technologies are located. This represents a greater challenge, due to the complexity and breadth of the social and institutional learning processes for the appropriation, adaptation, use, and deployment of applications of new technologies for the full use of their potential benefits in the various areas of the economy, government, and society [11].

3. Performance of the digital economy in Mexico

From a supply-side perspective, the industries that comprise the digital technology universe have the capacity to impact the entire economy across multiple sectors, sub-sectors, and productive branches of the economy, potentially enhancing their positive impact on productivity, competitiveness, and growth. Therefore, it is considered important that ICTs be disseminated to the largest number of sectors, subsectors, and productive branches of the economy.

The prevailing lag in the use of digital technologies in Mexico compared to more advanced countries is explained by multiple factors, including social inequality in terms of income and education, which constitute an obstacle to the use, adaptation, and dissemination of ICTs. Likewise, the specificities of the national innovation system, human resource training, and the development of technological capabilities in the productive system explain the country's potential to absorb and disseminate ICTs throughout the economic system.

The analysis presented below is carried out based on the available information to construct a narrative about the behavior and dynamics related to the production of goods and services in the sectors, subsectors, and branches that make up the digital economy, for the period from 1994 to 2024. During this time, the Mexican economy has experienced a series of transformations in its productive structure, which are manifested in the composition and trends of the Gross Domestic Product (total gross domestic product (GDP_T)) generated in the different sectors and industries that comprise it.

A first result to highlight is that, during this long period, the production of goods and services of the ICT industries (ICT_GDP) registered a higher growth rate compared to the dynamics of the Mexican economy, since the ICT_GDP went from a sum of 366,870 million pesos, at 2018 prices, in 1994 to 933,690 million pesos in 2024. This represents an average annual growth rate (AAGR) of 3.2%, above the growth registered in the total GDP of the Mexican economy, which was 1.9% average annual in the period from 1994 to 2024, equivalent to 1.2 percentage points more in the growth rate of the ICT industries.

The importance of these industries' potential impact on the Mexican economy can be seen from a long-term perspective. In this regard, a growing share of ICT industries in total GDP is observed, as they reached a relative share of 2.2% in the first quarter of 1994 and reached a weighting of 3.7% in the fourth quarter of 2024. At the same time, the relative share of ICT industries in gross value added (GVA) for the same quarters increased from 2.4 to 3.9%, respectively. (**Figure 1**).

A disaggregated analysis of available statistical information shows that the production of goods and services in the ICT industry averaged 579,883 million pesos at 2018 prices over the long period from 1994 to 2024, equivalent to 3.2% of the Mexican

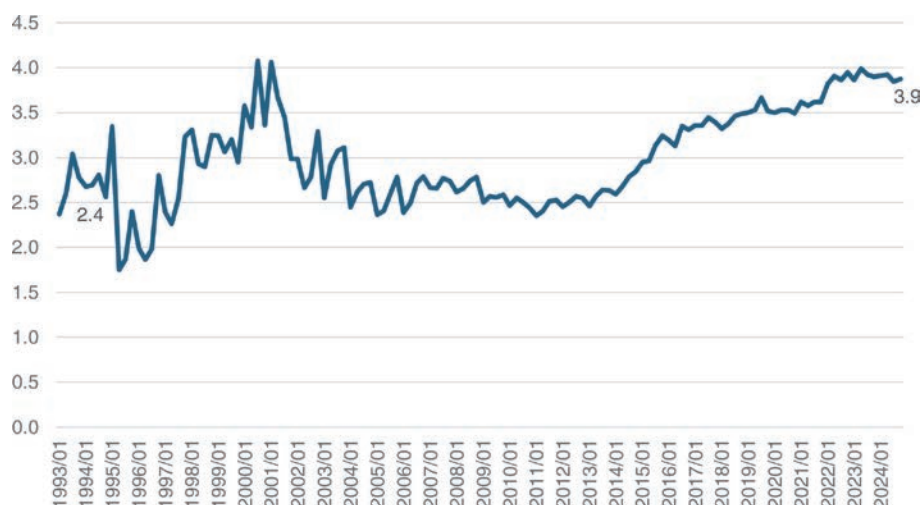


Figure 1. Gross domestic product ICT/gross value added (share in percentage). Source: Prepared by the authors based on the National Institute of Statistics and Geography (INEGI), 2024. Economic Information Bank.

economy's total GDP. During this period, the goods industry² accounted for 63.0% of the ICT sector's GDP, while the services industry³ accounted for 37.0%.

It should be noted that the relative share of both industries in ICT_GDP is not uniform throughout the study period. The production of ICT goods had a greater weighting, equivalent to 79.5% of sectoral GDP in 1994; thus, 20.5% corresponds to services industries. This situation is gradually changing, and both industries had a share of 60.0 and 40.0%, respectively, in 2009. Subsequently, they reached an almost identical proportion in 2024: 50.3 and 49.7%, in the same order (**Figure 2**).

These changes in the composition of the structure in percentage of sectoral production are explained by sectoral transformations within the ICT industries, as well as by external factors associated with geographic mobility in the global value chains of these industries. In this regard, if we focus on the global figures for the period 1994–2024, we can see that during this period, the GDP of the ICT industries averaged 579,883 million pesos, at 2018 prices. The goods industries “Manufacture of computing, communications, measurement, and other electronic equipment, components, and accessories” accounted for a relative share of 63.0%, and the services industries “Mass media information” accounted for 37%. Throughout this period, the goods industries showed a decrease in their weight in the ICT_GDP equivalent to 29.2 percentage points, since it decreased from 79.5% in 1994 to 50.3% in 2024. Of the six branches that made up the ICT goods industries, the “communications equipment manufacturing” branch registered a drastic reduction in its relative participation in

² In the nomenclature of the North American Industry Classification System (NAICS), used by INEGI to compile the Mexican System of National Accounts (SCNM), subsector 334 is called “Manufacture of computing, communications, measurement, and other electronic equipment, components, and accessories.” This subsector is made up of the six (four-digit) branches described in **Table 1**. Total Gross Domestic Product and Digital Technologies, 1994–2024.

³ In the SCIAN (International Standard Industrial Classification of All Economic Activities) nomenclature, sector 51 is called “Information in mass media” and is made up of the six (three-digit) subsectors described in **Table 1**. Total Gross Domestic Product and Digital Technologies, 1994–2024.

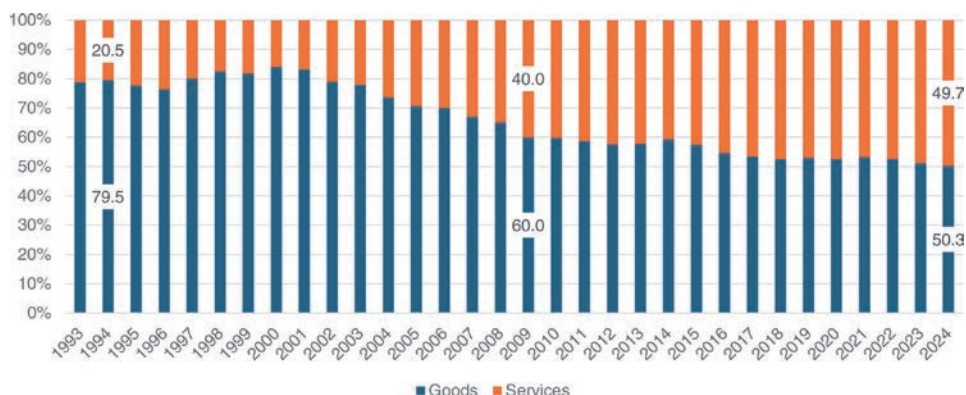


Figure 2.

Gross domestic product ICT (structure in percentage). Source: Prepared by the authors based on INEGI, 2024.

the sectorial production of 42.6 percentage points, going from a weight of 50.4% in 1994 to 7.8% in 2024. In contrast, in the same period, the services industries registered an increase in their relative participation in the ICT_GDP of 29.2 percentage points, since its weight increased from 4.8% in 1994 to 49.7% in 2024. Of the six subsectors that made up the ICT services industries, the “Telecommunications” branch showed an extraordinary growth in its weighting in ICT_GDP, as it increased from 4.3% in 1994 to 38.0% in 2024, equivalent to 33.7 percentage points. These changes reflect the transformations within the productive structure of digital technologies during the period 1994–2024 (Table 1).

Now, in terms of the dynamics of the production of ICT goods and services, the ICT_GDP registers an average annual growth rate of 3.2% over the period 1994–2024, higher than the total GDP of the Mexican economy: 1.9%. However, in both cases, this indicator shows a downward trend. For ICT goods industries, the growth rate is 1.6% over the same period, and their production also shows a downward trend, registering negative growth of 0.45 and 0.20% in the last two quarters of 2024, respectively. In the case of ICT service-generated industries, they register an average annual growth rate of 6.3%, well above the global GDP and double the sector’s GDP, with an upward trend over the study period. In the goods industries, the best performance in terms of growth is presented in the “Computer and peripheral equipment manufacturing” branch (7.6%), and in the ICT service-generated industries in the “Telecommunications” subsector (10.9%).

It is striking that, given the accelerated pace of innovation and convergence experienced in the digital technology ecosystem worldwide, in Mexico’s case, the technological solutions industries in the software and electronic information processing sectors are experiencing a downward growth trend and a precarious weighting in this sector’s production account throughout the study period. This situation represents an opportunity for public policy actions that should be geared toward further boosting these sectors.

In summary, the previous analysis of the productive performance of the ICT goods and services industries offers a general overview of the relative progress of digital transformation in Mexico. Additionally, it shows the transformation in both the structure of production and its composition, dynamics, and trends, which is explained by internal factors associated with changes in production business models at the national and regional levels, as well as by the transformation and trends in the value

Denomination	Average	Percentage	AAGR*
Total gross domestic product (GDP_T)	20,153,334		1.89
ICT_GDP	579,883	100.00	3.16
Manufacturing of computing, communications, measurement, and other electronic equipment, components, and accessories	365,619	63.05	1.60
Manufacturing of computers and peripheral equipment	69,859	12.05	7.65
Manufacturing of communication equipment	101,226	17.46	−3.06
Manufacturing of audio- and video equipment	73,268	12.63	3.43
Manufacturing of electronic components	100,993	17.42	3.24
Manufacturing of measuring, control, navigation instruments, and electronic medical equipment	17,299	2.98	4.09
Manufacturing and reproduction of magnetic and optical media	2975	0.51	2.70
Information in mass media	214,264	36.95	6.26
Publishing of newspapers, magazines, books, software and other materials, and publishing of these publications integrated with printing	15,932	2.75	−1.01
Film and video industry, and sound industry	20,848	3.60	3.46
Radio and television	34,733	5.99	2.93
Telecommunications	132,571	22.86	10.96
Electronic data processing, hosting, and other related services	8053	1.39	2.18
Other information services	2126	0.37	−1.61

*Average annual growth rate.

(Millions of pesos at 2018 prices, percentage share, and growth rate). Source: Prepared by the authors based on the National Institute of Statistics and Geography (INEGI), 2024.

Table 1.
Total gross domestic product and digital technologies, 1994–2024.

chains of ICT industries in the global economy. In this regard, it is important to note that, in the case of ICT goods, a large part of their production is carried out under the export-oriented maquila format, so learning processes are restricted to the technology transfer conditioned by the large transnational corporations that drive the value chains on a global scale. Therefore, the leakage of added value to the external market derives from the temporary import programs required by the production processes of these industries. This represents a limiting factor for endogenous technological updating, as well as for an effective sectoral productive transformation with a greater positive impact on national production.

4. Current situation of digital gaps in Mexico

The assessment of the state of the digital gaps is carried out from two perspectives: i) the analysis of information related to the ICT Development Index (IDI) on the world map, to evaluate the country's relative progress compared to the group of member countries of the Organization for Economic Cooperation and Development (OECD), as well as its progress compared to the Latin American and Caribbean (LAC) economies with the highest scores in this index; and ii) the internal progress

in the use of ICTs by households and users. In the first case, statistical information from the report prepared by the International Telecommunication Union (ITU, 2024) [12] is used; in the second, the source of the information is the data published in the National Survey on the Availability and Use of Information Technologies in Households (ENDUTIH) [13], prepared by the National Institute of Statistics and Geography (INEGI) of Mexico.

4.1 ICT development index-ITU (IDI-ITU)

The International Telecommunication Union (ITU) constructs the ICT Development Index (IDI) to measure the extent to which societies leverage and have access to these technologies. The IDI's main objective is to measure the level and evolution of ICT development in high-, middle-, and low-income countries, by country groups and regions; the digital divides according to their levels of ICT development; and the potential for ICT development and utilization to enable countries to foster their growth and development. By assessing aspects, such as ICT access, use, and skills, it helps to identify gaps between countries and regions. Additionally, it is very useful for guiding policies that promote digital inclusion and universal connectivity [12].

Starting in 2023, changes were made to the index construction methodology, which was previously based on three categories: i) access and infrastructure; ii) use and intensity; iii) capacity for effective use of ICTs. The IDI 2024 is based on the dual concept of Universal and meaningful connectivity (UMC). This concept defines digital connectivity as the ability for all people to enjoy a safe, satisfying, enriching, and productive online experience at an affordable cost. The IDI methodology is designed to measure the extent to which countries have achieved this level of connectivity [12]. Thus, the index is structured around two main pillars that reflect aspects of connectivity:

- *Universal connectivity*: It measures the availability and access to digital infrastructure (Internet access and mobile coverage).
- *Meaningful connectivity*: It evaluates the effective and relevant use of technologies, considering indicators, such as subscription traffic, affordability, and adoption of digital services.

The ITU's annual report, The ICT Development Index 2024 (IDI 2024), covering 170 economies, indicates that scores for the *universal connectivity pillar* ranged from 6.7 to 100 points, with an average of 69.6, reflecting the rate of adoption and actual use of the Internet by people. This result constitutes a persistent challenge in effective access, since many people still do not use the Internet, despite the availability of infrastructure.

In contrast, scores in the meaningful connectivity pillar are higher, ranging from 30.6 to 99.9, and averaging 80.0 points. This indicates that while infrastructure and enabling factors are in good condition in many regions, full and universal use has not yet been achieved. Meaningful connectivity is dominated by indicators related to infrastructure and availability, which are easier to achieve in the short term compared to adoption and use.

As expected, the digital divides between countries, groups of countries, and regions are primarily determined by income levels. This situation poses critical

challenges for low- and middle-income countries to make progress in the indicators of both pillars of connectivity.

In this regard, in the IDI 2024, as in previous years, developed countries with higher income levels occupy the top spots in the evaluation. The top 10 OECD countries are ranked as follows: Finland (98.1), Estonia (97.9), Denmark (97.1), the United States (96.7), Iceland (95.9), Poland (95.8), Sweden (95.3), Australia (95.1), South Korea (94.4), and Austria (94.3). Mexico recorded a score of 80.7 in the IDI 2024, representing a 3% increase compared to its 2023 score of 78.0. Despite the relative progress in the IDI score, significant digital gaps remain for Mexico compared to the average IDI score recorded by OECD member countries (**Figure 3**). This means that, considering the country's relative progress recorded in 2024, Mexico requires, all else being equal, a time horizon of around 4 years to achieve a score equivalent to the average IDI score for the group of OECD member countries.

Now, when comparing the country's progress in the IDI score with respect to the countries of the Latin America and the Caribbean (LAC) region, it is observed that Mexico is ranked 9th among the 10 main countries in the region in the IDI 2024 ranking, in which Chile occupies the first place with a score equivalent to 91.7, followed by Uruguay (89.9), Bahamas (89.3), Saint Kitts and Nevis (84.9), Costa Rica (84.8), Argentina (83.4), Suriname (82.5), Brazil (82.0), Mexico (80.7), and Trinidad and Tobago (78.8).

The average IDI 2024 score for countries in the LAC region is 76.0, placing Mexico 4.7 points above the average IDI 2024 score for countries in the region. However, when comparing Mexico's scores with those of Chile, which ranks first among LAC countries on the IDI score, the digital divides in 2023 and 2024 are 12.7 and 11.0 points, respectively. This means that it would take Mexico just over 4 years to achieve an IDI score equivalent to that of Chile, the leading country in the Latin American region.

This analysis leads us to reflect on the magnitude of the challenges that must be faced in the Fourth Transformation process, not only to close the digital gaps with respect to the most advanced countries in this area, but also to effectively achieve the appropriation and use of ICTs in all sectors of economic activity, government, and society, in order to contribute to socioeconomic development and social well-being in Mexico.

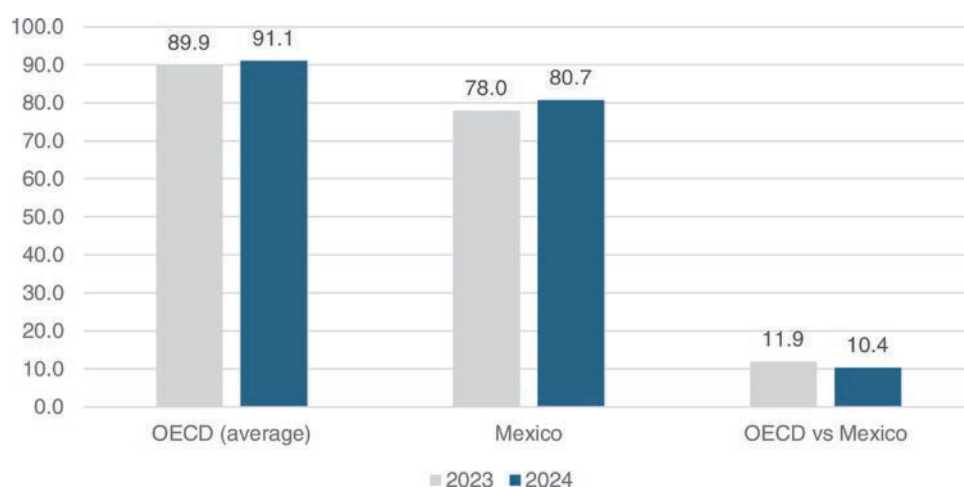


Figure 3.
 Digital divides for Mexico compared to OECD member countries. Source: Prepared by the authors based on: ITU 2024.

4.2 Indicators on the use of ICT in Mexico

The assessment of the state of connectivity, availability, and progress in ICT use among households and the population in Mexico suggests that there has been relative progress in recent years. However, there are still demand gaps that need to be closed to achieve effective adoption of ICTs by users and households in the country.

Indeed, according to ENDUTIH estimates, Internet users increased from 61.4 million in 2015 to 100.2 million in 2024. Similarly, the number of cell phone users increased from 71.4 million in 2015 to 81.7 million in 2024; while the number of computer users decreased from 54.8 million to 44.1 million during the same years. This reflects a shift in connectivity patterns from computer users to mobile devices, as well as from fixed broadband to mobile broadband, where the ubiquity of the connection becomes more important for users of digital technologies.

Considering the information universe (population aged 6 years and over) and coding the users of these technologies in percentage terms, by 2024 the following figures are obtained: Internet users accounted for 83.1%, cell phone users 81.7%, and computer users 36.6%. Therefore, it is evident that there are demand gaps in the use and availability of these technologies.

A relevant aspect to highlight regarding Internet users is the increase in the proportion of Internet use between 2015 and 2024 in the following activities: for entertainment, from 71.4 to 89.0%; for training or education, from 56.6 to 81.3%; for accessing social networks, from 71.5 to 90.4%; for e-commerce, from 9.7 to 35.8%; and for using cloud services, from 15.6% in 2017 to 20.4% in 2024.

Another important issue is that while there has been a decline in the proportion of computer users for school activities, from 51.3% in 2015 to 45.4% in 2024, there has also been an increase in the use of computers for work activities, from 36.7 to 53.2%, and as a means of training, from 24.2 to 28.3%, during the same years.

On the other hand, the examination of the information recorded in the ENDUTIH 2024, regarding households with ICT equipment, shows that the number of households with computers increased from 14.4 (44.9% proportion with respect to the total number of households) in 2015 to 17.2 million (43.9%) in 2024; with Internet from 12.6 (39.1%) to 28.8 million (73.6%); television from 30.1 (93.5%) to 35.3 million (90.2%); with telephony (wired or cellular) from 28.7 (89.3%) to 37.6 million (96.1%); and with electricity from 31.9 (99.2%) to 38.9 million (99.4%), for the same years. In contrast, pay-TV households decreased from 14.1 (43.7%) in 2015 to 13.9 million (35.7%) in 2024; and radio from 21.2 (65.9%) to 14.9 million (38.2%), respectively.

These estimates show significant progress in these areas with ICT equipment in homes; however, there are also clear gaps in demand for use and connectivity, considering the total number of households in the respective ICT areas.

5. The plan Mexico: An opportunity to advance digital transformation

Plan Mexico represents the long-term vision for economic development and social well-being. The plan recognizes that the country's integration into global value chains took place during the neoliberal period through assembly and low-value-added activities. Therefore, it proposes a new industrialization strategy to boost the country's growth and socioeconomic development. In this sense, it is expected that with the implementation of this plan, progress will be made in the digital transformation, since among its goals is to increase the national content in value chains in strategic

sectors, including electromobility, electronics, aerospace, and semiconductors [14]. These activities are closely linked to the digital technology ecosystem.

Additionally, with the creation of the Digital Transformation and Telecommunications Agency, the Fourth Transformation government is promoting a series of programs that can become catalysts to drive digital transformation in Mexico [15], among which is Nube Mx (Nube Michoacán), a government technological infrastructure, which aims to provide the federal public administration with capabilities in computing processing, storage, and information management to streamline online procedures and services. The Digital Government program aims to reduce procedures by 50% through a simplification and digitalization process, in addition to becoming a digital option in 80% of the most frequent procedures and services in the country. Likewise, the creation of the National Center for Public Technologies has been established as a priority project to promote capacity development, and together with the creation of the Software Factory, technological projects will be promoted to advance national technological sovereignty. The Government Cybersecurity Center project aims to advance the integration of cybersecurity as a cross-cutting theme in the definition and execution of government policies, projects, and processes. The central objective of the project, known as Data Intelligence, is for the Mexican Government to adopt evidence-based analytical tools for statistical inference and artificial intelligence to optimize strategic public policy decisions. The Mexican Space Program aims to address the satellite communications service needs of national security agencies, as well as foster the development of local industrial capabilities and technical and scientific human capacity through technology transfer. Finally, the new Telecommunications and Broadcasting Law, currently under discussion for approval by Congress, aims to connect 15 million Mexicans without Internet access, among other goals.

It is hoped that these programs and projects will be comprehensively incorporated into a base document for the Digital Agenda, which will serve as a road map for streamlining the country's Fourth Transformation process. This will include goals, objectives, policies, and strategies, as well as financial and material resources for the medium and long term, with short-term actions, and will be of a multiyear nature. In other words, the digital transformation will transcend the cycles of change in the federal public administration and the country's government.

6. Conclusions

For developing countries, digital technologies are a fundamental enabler of socioeconomic development, due to their transversality, which makes them present in almost all areas of the economy, government, and society. In the case of Mexico, the appropriation, use, adaptation, and deployment of digital technologies represent challenges and opportunities for driving the Fourth Transformation process, as well as the goals and objectives of the current administration's government program.

Over the past three decades, industries generating ICT goods and services have undergone a series of changes in their productive structure. These industries currently account for a significant relative share of approximately 3.0% of total GDP and recorded an average annual growth rate of 3.2%, higher than the Mexican economy's growth rate (1.9%) during the study period. The transformation in the productive structure of ICT goods and services is also reflected in the decrease in the weighting of the former and the increase in the relative share of the latter in the sectoral structure of ICT_GDP.

Although Mexico has made relative progress in digital transformation, there are still areas of opportunity to harness the potential benefits of digital technologies in multiple areas of the economy, government, and society. In particular, the digital gaps with respect to the average ICT Development Index of OECD member countries remain significant (10.4 points in 2024). At the same time, internal digital gaps persist, reflected in indicators of equipment, availability, and use of digital technologies in households and among the country's population.

Finally, it is important to note that Plan Mexico represents an important opportunity not only to continue advancing toward the goals and objectives of the 2025–2030 National Development Plan of the Fourth Transformation Government, but also for the integration and implementation of the Digital Agenda that the country requires to trigger growth and advance socioeconomic development, as well as to achieve the social well-being of the Mexican population.

Note

This book chapter is part of the research project “Industrial Policy and Digital Technologies for Development: Perspectives for Mexico.” Registration number: 20250372, Secretariat of Research and Graduate Studies of the National Polytechnic Institute (SIP-IPN).

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Edited by Sandro Serpa and Ana Isabel Santos

Digital transformation is an unavoidable force that is redefining society. However, beneath a surface of technological optimism, deep inequalities can be observed. How can we ensure that all share the benefits of digitisation? The book *Digital Equity and Literacy* is a valuable contribution that addresses these critical questions, serving as a reference for navigating the complex intersection between technology, society, and justice. This work presents a compilation of global perspectives from international experts who study the concept of digital divide. Based on an in-depth analysis, frameworks are proposed that consider digital literacy a human right, expanding its definition to include artificial intelligence. This work explores the experienced dimensions of digital inclusion and pedagogical strategies for empowering citizens with critical thinking and ethical skills. The analysis of high-level challenges, including governance and ethical dilemmas in sectors such as health, as well as the risks associated with financial transformation, is complemented by the presentation of concrete case studies on policies and strategies implemented in diverse countries and contexts. This work provides conceptual tools and practical evidence, offering policymakers, educators, researchers, and citizens a roadmap for fostering a more equitable, fair, and inclusive digital future.

*Usha Iyer-Raniga,
Sustainable Development Series Editor*

Published in London, UK

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ISSN 2753-6580

