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Technology-enhanced inclusivity for educational ecosystems: Developing a framework for social justice-oriented digital transformation

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ABSTRACT

This paper develops a framework for social justice-oriented digital transformation in educational ecosystems for marginalized populations. Following explanations of the concepts of digital transformation, justice-oriented transformation and digital ecosystems in education, challenges faced by marginalized populations are outlined. Two main components of the framework are highlighted: five core principles – equity, inclusion, participation by engaging marginalized communities in design processes, ethical responsibility guaranteeing transparency and accountability, and digital competence fostering empowerment and agency; and five pillars - accessibility and infrastructure, inclusive pedagogy and curriculum, capacity building, ethical governance, and monitoring and evaluation.

1. Introduction

This paper develops a framework for social justice-oriented digital transformation (DT) in educational ecosystems for marginalized populations through an analysis of existing literature sources describing key factors and features where DT for marginalized populations is sought and implemented. The study is evidence-based, using deductive analysis to develop a framework structure defining key elements and pillars.

1.1. Digital transformation in education and marginalized communities

In the contemporary context, digital technologies penetrate domains of human activity [1]; DT is seen as an indispensable way for educational systems seeking to address multifaceted challenges engendered by profound and ongoing changes [2,3]. The necessity of DT in education was amplified during the COVID-19 pandemic [4,5] when educational institutions were forced to shift to online learning abruptly [6].

According to McCarthy et al. [[5], p.3]:

> "DT in education can be defined as a realignment of education models utilizing digital technology to engage students, teachers, parents, and leaders more effectively at every point in the students' schooling journey with new student information systems, personalized experiences and data analytics."

Whilst frameworks presented in different research reports give broad, overarching perspectives. these may not fully capture or respond to specific social justice challenges experienced by marginalized populations. Digital inequalities, brought to the forefront by the COVID-19 pandemic, mostly affected marginalized populations [7] and are expected to intensify with the advent of artificial intelligence (AI). Therefore, it is urgent to establish a framework for DT but rooted in the values of social justice and incorporating voices of marginalized

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populations, which is a key aim of this paper.

As digital technologies have become an increasingly integral part of daily living, adaptive skills required to understand and effectively use them have become essential for participating in modern society. However, not everyone has the same equality of opportunity to fully utilize digital technologies due to social and cultural factors in addition to lack of interest and confidence [8]. Socioeconomic inequities, based on economic status, gender, culture, language, education and abilities, for example, can restrict access to and utilization of digital technologies by different groups of people and minorities worldwide. Often referred to as the "digital divide" [7,9], early research on this phenomenon focused on lack of access to devices as well as infrastructural deficiencies, but in more recent times the use of the term has expanded to include access to specific interface design, usability and overall user experience. Even from this short introduction, it is clear that, for developing a framework, there is a need to consider principles of equity and inclusion, focusing on concerns for access and infrastructure.

1.2. How educational technologies are designed

Educational technologies, like all technological systems, are not neutral artifacts. Their design reflects values, assumptions, and power relations of those who conceive, develop, and deploy them. This critique of neutrality resonates with Haraway's concept of *situated knowledges* (1988). Haraway argues that all knowledge is produced from specific embodied, social, and historical positions, even when it claims to be neutral or value-free. When extended to the field of technological design, this insight reveals how design process assumptions are embedded in educational technologies, about learners, learning processes, and desirable outcomes, shaped by social positions, institutional contexts, and epistemic frameworks of their designers. Design decisions are therefore not merely technical choices, but epistemic acts that privilege certain ways of knowing, learning, and being, while marginalizing others.

Critical design scholarship has long challenged the idea that design is a purely technical or problem-solving activity, emphasizing instead its deeply political and normative nature. As Costanza-Chock argues [10], design processes tend to reproduce existing social hierarchies when led by dominant groups and oriented toward market-driven or efficiency-based logics rather than toward the needs and knowledges of marginalized communities. What is designed, for whom, and by whom are therefore fundamentally political questions. Educational technology interfaces, data models, assessment mechanisms, and assumptions about learners embed specific conceptions of ability, intelligence, productivity, and normality. Keshavarz's work [11] on the *politics of design* further highlights how design practices stabilize particular worldviews and institutional arrangements, often rendering alternative ways of being, learning, or knowing invisible. Even when design decisions appear minor or purely functional, they participate in shaping how subjects are classified, governed and evaluated within sociotechnical systems.

Critical scholarship has shown how bias and exclusion can become structurally embedded within digital technology design. Rather than resulting from isolated errors or unintended consequences, forms of harm are often produced through routine design decisions, data selection practices, and institutional priorities. Research on algorithmic systems has demonstrated how technologies developed under claims of objectivity and efficiency can systematically disadvantage racialized and gendered groups. Use of facial recognition systems is a case in point. Similarly, Buolamwini's work [12] underscores how homogeneous design teams and biased datasets contribute to technologies that misrecognize or exclude those who fall outside dominant normative categories. When such systems are designed without attention to intersectional differences in race, gender, abilities, and socioeconomic positions, they risk reproducing deficit-based models of learners and reinforcing existing educational inequalities. In this way, the politics of design materialize not only in technological artifacts themselves but also in social consequences they generate, shaping who is recognized as a legitimate learner and whose knowledge is rendered visible or invisible.

Taken together, these perspectives suggest consequences of design extend well beyond issues of technical performance, representation, or bias mitigation. Designed artifacts and infrastructures, in turn, configure how humans think, act, and relate to the world. Through this recursive dynamic, technologies participate in producing particular forms of agency, normativity, and social order.

Applied to educational technologies, ontological design highlights how platforms, interfaces, and algorithmic systems do not merely support existing learning practices but contribute to redefining what learning is understood to be, who is recognized as a successful learner, and which forms of knowledge are legitimized. Educational technologies can gradually reshape pedagogical relations and learners' self-understandings, normalizing specific modes of participation while marginalizing others. But educational technologies hold significant potential to facilitate learning processes, expand access to educational resources, and address concrete pedagogical and organizational challenges. When thoughtfully designed and contextually implemented, they can support inclusion, flexibility, and new forms of participation in education. Precisely because of this transformative potential, however, design of educational technologies constitutes a complex and deeply responsible practice. Design choices shape not only how technologies function, but also how learners are represented, assessed, and governed within educational systems.

Without critical reflection, educational technologies may become powerful vectors of oppression, reproducing marginalization through exclusionary design choices, surveillance-oriented infrastructures, or deficit-based models of learners. Design decisions determine whose needs are prioritized, which forms of knowledge are valued, and who benefits from technological innovation while others are placed at risk of exclusion or harm. For this reason, design of educational technologies is inseparable from questions of social justice. A critical review of design practices reveals that equity, inclusion, and justice are not secondary considerations to be addressed after deployment, but foundational concerns that must inform design processes from the outset. Situating educational technology design within social justice frameworks enables a clearer understanding of how design choices are implicated in the reproduction or addressing of existing inequalities. When developing a framework, there is a clear need to consider fundamental principles of equity, inclusion, participation, ethical responsibility and empowerment, focusing on concerns for inclusive pedagogy, and ethical governance.

1.3. Why social justice matters

Critical analysis of educational technology design highlights the complexity of the processes through which technologies are produced and the far-reaching consequences they generate. As design choices are shown to be situated, political, and ontologically productive, questions of inequality, power, and responsibility become inseparable from the design of educational technologies themselves.

Social justice enables an understanding of how seemingly technical decisions are embedded in broader social, cultural, and institutional arrangements, and how these arrangements indicate who is included, excluded, or differentially affected by educational technologies. Rather than reducing inequality to a problem of access or implementation, a social justice perspective foregrounds structural dimensions through which educational technologies are implicated in the reproduction or transformation of social relations.

At the same time, social justice supports an analysis of how educational technologies operate once deployed, through infrastructures that mediate learning, assessment, and governance. Because these technologies increasingly structure educational participation, they can shape norms of success, legitimacy, and belonging. A social justice framework makes it possible to examine how these norms are unevenly distributed

and how their effects intersect with existing social hierarchies related to race, gender, disabilities, and socioeconomic positions.

Social justice thus functions as a connective framework that links design processes to their social consequences, without presuming technologies to be either inherently emancipatory or inherently oppressive. However, social justice is not a singular or unified concept, but a field composed of multiple theories and approaches that have developed over time in response to different historical, social, and political contexts, as discussed in Section 2.

2. Conceptual foundations

2.1. Social justice theories

The evolution of social justice theories reflects an expanding effort to understand how power operates across intersecting social, cultural, and material relations. Early normative theories, such as Rawls's Justice as Fairness [13], framed justice in terms of rights, opportunities, and protections for the least advantaged. Scholars soon argued that such universalist models overlooked how individuals experience inequality differently, depending on their social position. Sen's capability approach [14,15] marked a significant shift by emphasizing what people are actually able to be and do, drawing attention to lived conditions shaping freedom. Honneth [16] further expanded this focus by conceptualizing justice as a struggle for recognition, grounding social equality in the relational dynamics of dignity and esteem.

This landscape set the stage for Crenshaw's articulation of the *intersectionality* concept (1991), which showed how race, gender, class and other identity markers intersect to produce compounded forms of marginalization that expose the limitations of single-axis justice models. More recently, *critical and feminist posthumanist theories* [17–19] have expanded the horizon of social justice by critiquing the humanist conception of a universal, rational subject and exposing how this figure historically functioned as a norm that marginalizes racialized, gender-nonconforming, disabled, and colonized bodies. By extending this critique to the boundary between human and non-human life, posthumanist scholarship decouples justice from human exceptionalism, highlighting how digital technologies, ecologies, and multispecies' relations shape contemporary forms of vulnerability, agency, and inequality.

Together, these evolving frameworks show that social justice is historically dynamic, in continuous evolution and deeply *situated* within diverse cultural and geographical contexts. These theories remind us that, for developing a framework, there is need to consider social justice principles of equity, inclusion, participation, ethical responsibility and empowerment.

2.2. Understanding justice-oriented transformation

Building on the idea that social justice is historically dynamic and deeply situated, the digital sphere represents one of the most significant contemporary arenas in which power, marginality and opportunity are negotiated. Digital technologies are not neutral: technological systems embed cultural assumptions, institutional biases, and political choices that can either expand or restrict social participation [20–22]. Consequently, they can function both as facilitators and as barriers of inclusion. On the one hand, technologies enable people to overcome physical and social constraints by providing access to real-time information, communication, and learning opportunities [23]. On the other hand, meaningful participation in digital environments remains unevenly distributed, making digital inclusion a key dimension of modern social justice. As research shows, access alone is insufficient: inclusion requires skills, safety, and critical literacies necessary to navigate technologies in ways that support political, social, and economic participation [24,25]. Persistent disparities in connectivity, digital skills, and cultural relevance continue to deepen forms of digital exclusion, especially among vulnerable groups [26]. Moreover, these disparities produce differentiated forms of "digital capital", which reinforce and reproduce broader inequalities [27].

In this context, concepts of digital equity and digital justice refine and extend the debate. Digital equity refers not only to access but also to the fair distribution of infrastructures, opportunities, and digital literacies necessary for thriving in a technologically mediated society [28]. The broader notion of digital justice goes further: it examines how people can be adversely incorporated into digital systems through surveillance, extractive data practices, algorithmic discrimination, or precarious platform labor [29,30]. This perspective shifts attention from mere access to structural operations of power embedded in digital infrastructures, revealing how technologies can reproduce or intensify racialized, gendered, and class-based hierarchies.

These concerns are especially salient in education, where digital technologies increasingly mediate learning opportunities. Intersectionality provides a critical lens for understanding how race, gender, disabilities, and socioeconomic status shape differentiated access not only to devices and connectivity, but also to design, functionality, and pedagogical appropriateness of educational technologies [31,32]. Disabled students face barriers related to accessibility, interface design, and alignment of educational platforms with their learning needs [23]. Furthermore, racialized groups, such as Black and Hispanic women, are discriminated by digital technologies [4], illustrating how digital inequalities mirror and reinforce wider social hierarchies.

In school contexts, technology can support inclusive practices when infrastructures, teacher training, and pedagogical approaches are effectively aligned. Studies indicate that in low-income schools, targeted digital initiatives can enhance learning equity and support lower-social economic status (SES) students when embedded in supportive institutional ecosystems [33]. But even so, such interventions are most successful when they address not only access but also social, cultural, and political dimensions of digital participation.

Together, these insights suggest that justice-oriented DT cannot be separated from broader social justice frameworks. Both require contextualized, intersectional approaches that recognize how power, identity, and material conditions shape access, use, and exposure to technology. Ultimately, understanding digital justice means interrogating not only who gains access to technology, but also *who designs it, who benefits from it,* and *who is placed at risk by its infrastructures.* For developing a framework, there is clearly need to consider principles of equity, inclusion, participation, ethical responsibility and empowerment, focusing on concerns for access and infrastructure, and inclusive pedagogy and curriculum.

2.3. Components of digital ecosystems in education

Digital ecosystems in education can be conceptualized as socio-technical systems in which infrastructure, pedagogy, policy, data, and stakeholders form interdependent and reinforcing layers that together produce emergent outcomes for equity and learning. From a social justice perspective, digital ecosystems are not inherently inclusive; they must be intentionally (re-)designed to address historical marginalization and contemporary algorithmic inequities.

Physical and digital infrastructure (broadband, devices, learning platforms, identity systems) constitute the backbone of the digital ecosystem; without robust, accessible infrastructure, other interventions cannot scale equitably [34]. In this regard, accessibility standards, offline contingencies, and maintenance models are essential design features that influence who can participate.

Pedagogy can shape how digital technologies are used in educational practice. Inclusive, culturally responsive instructional design leverages digital affordances (adaptive content, multimodal resources, learner control) while resisting one-size-fits-all implementations that often reproduce existing biases [25,35]. Teacher professional learning and curriculum alignment are critical to develop approaches that translate

tools into pedagogical practice. A framework such as Technological Pedagogical Content Knowledge (TPACK) provides one approach that emphasizes alignment and appropriate consideration of content, pedagogy and technology to produce meaningful learning experiences rather than seeing the need for digital technologies to be used for their own sake [36].

Policies can determine funding priorities, data governance, procurement practices, accessibility standards, and teacher professional learning requirements. Policy can set incentives, rights, and obligations that in turn can shape the digital ecosystem. Policy can also shape standards for accessibility, authorship, and openness, which affect long-term equity [34,37].

Data practices can power personalization and system monitoring but also introduce risks. Data collection, governance, and analytics pipelines determine whose learning is visible, how decisions are automated, and how privacy and power asymmetries are managed. Equitable ecosystems require transparent governance, user agency over data, and auditability of algorithms [38]. Furthermore, Indigenous data sovereignty movements argue for data governance that recognizes collective rights, cultural protocols, and community control over collection, sharing, and reuse [39].

Learners, families, educators, administrators, vendors, society, and government each have distinct incentives and agency. Inclusive ecosystems intentionally redistribute agency toward traditionally marginalized communities and users, emphasizing meaningful participation in design, procurement and governance [35,40]. The different components form an interdependent network; adaptation or transformation targeted at one component affects all others in some way, intentionally or unintentionally. Systems-level monitoring and assessment approaches such as systems-thinking and adaptive governance are essential to observe and manage unintended consequences and emergent inequalities [25,37].

Conceptualizing educational digital ecosystems as interconnected socio-technical systems reframes inclusion from a feature to a governance objective that must be engineered across infrastructure, pedagogy, policy, data, and stakeholder engagement. Technology-enhanced inclusivity demands systemic interventions that align technical design with pedagogy and policy, centering the voices and experiences of those historically marginalized in the digital ecosystem. In this regard, this section highlights the need for a developed framework to consider principles of equity, inclusion, participation, ethical responsibility and empowerment, focusing on concerns for access and infrastructure, and ethical governance.

The next section focuses on core principles identified in this section that should underlie a developing framework.

3. Core principles of a digital social justice-oriented framework

3.1. Equity and inclusion: towards digital equality and culturally responsive technologies

As the Internet began gaining popularity among high-income countries, the concept of the "digital divide" emerged. Thirty years later, the unequal access to basic digital technologies persists [41]. Instead of progressing towards equity, gaps widen as technologies develop faster than they can spread to marginalized and low-income communities [42,43].

As digital technologies can penetrate all areas of our lives, the digital divide is no longer concerned with mere access to digital technology [42,43] but also with abilities to navigate its opportunities. Economy and public services have shifted so much to the digital space that some scholars argue that access to digital technology is not a nice-to-have but a human right [41,44]. In this context, accessing online public services such as education and healthcare requires a know-how that disadvantaged groups may lack.

Beyond access and literacy, design of digital technologies also plays a role in shaping inclusion. Software systems need to reflect various societal values, among which are language and culture, yet current software development methodologies do not explicitly address these values during design processes [45]. An example of this is AI systems for cultural heritage that inherit and amplify biases in existing historical records such as dominant narratives of colonial-era records, leading to systematical marginalization of non-dominant cultural identities [46]. This lack of design inclusivity can deter cultural minorities from understanding and benefitting from digital tools, thus widening the digital gap.

Digital divides go across multiple lines - income, gender, education, age, and rural versus urban. Culture, race and ethnicity emerge as more subtle yet defining factors of one's ability to benefit from digital technologies' diverse uses [42,43]. Moreover, digital gaps build on each other - when someone lacks basic access to infrastructure, those challenges can echo into other layers in terms of use, consumption, literacy, and skill, reinforcing digital inequities [41].

Research shows that people from more privileged backgrounds are more likely to use the Internet for learning and productivity, which further boosts their status, skillset and even wealth, as opposed to uses for entertainment only [41,42], demonstrating that as technology advances, it creates new gaps that deepen digital inequalities. This is particularly evident in education, where those who can only access the Internet via mobile telephones also have a narrower access to skills, information or content creation [47].

These social disparities are further exacerbated by algorithmic design structures of digital platforms and tools. Current research shows that algorithms often amplify existing social patterns, strengthening dominant narratives and points of view while excluding diversity [48]. This AI behavior has been called a "bias loop", where bias penetrates in all stages of data processing, showing that even carefully trained models can be infiltrated with bias [46]. These biases, alongside linguistic barriers and the lack of culturally relevant information, are shown to reduce engagement among diverse cultural groups like Indigenous communities, racial and ethnic minorities, migrants and refugees [43]. Yet digital technologies are particularly valuable for these groups, enabling participation in society, effective communication, understanding new cultural contexts, maintaining social connections, and expressing cultural identities [49]. Similarly, inclusive design, native-language lessons, subtitles, and icon-based interfaces can support learners from diverse cultural and linguistic backgrounds, helping overcome barriers in digital education [50,42,49]. A Brazilian-based initiative offers a perfect example addressing these disparities. The Artificial Intelligence in Education (AIED) unplugged project has developed AI-based educational technologies that do not rely on infrastructure, stable Internet, or advanced digital skills to support student assessments in remote schools across the country and its diverse social and cultural groups [47].

Because its impacts differ across contexts, digital equality is multifaceted rather than linear. Evidence from intervention research supports this [44]. For instance, Mervyn et al. [51] found that United Kingdom (UK) mobile-technology initiatives designed to help socially excluded citizens access government services failed to deliver meaningful benefits because they overlooked users' social and cultural contexts and diverse literacy needs. This reflects broader patterns: digital technologies alone do not guarantee inclusion. Educational, social, and historical contexts shape whether tools empower or exclude learners [42]. Ultimately, bias mitigation is not a one-time fix: scholars advocate for continuous, holistic strategies that span from the initial design phase to algorithm development and users' engagement [46], with design tailored to local norms to improve access and meaningful use [49].

This section highlights the need, when developing a framework, to consider principles of equity, inclusion, participation, ethical responsibility and empowerment, not only focusing on concerns for access and infrastructure, but also on inclusive pedagogy and curriculum, capacity building, and ethical governance.

3.2. Participation and voice: engaging in the design process

Engaging students, educators, and other key stakeholders in the design process of educational technologies and decision-making is a key factor in building inclusive learning environments in modern society to ensure that learning is optimized for each learner. Even as AI technologies advance, learning remains fundamentally human and develops through interactions among humans.

The concept of Human-Centered Learning Analytics emphasizes involving researchers, learners, educators, and other stakeholders from the design stage of a system, grounding the design in learners' needs [52]. It highlights the importance of qualitative information—such as learners' backgrounds and classroom contexts— as well as quantitative data in decision-making. By incorporating stakeholders into the design and decision-making processes of educational technologies, this approach provides core ideas for constructing inclusive learning environments.

When envisioning inclusive learning, it is crucial to deeply understand the needs of marginalized communities and learners who require different forms of support. In this context, for example, the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) states that special needs education is essential for the construction of an inclusive education system in order to form an inclusive society [53]. Considering principles of equity, inclusion, and participation highlights the need to consider access and infrastructure, but also inclusive pedagogy and curriculum.

3.3. Accessibility: inclusive design for learners with disabilities or different languages

Digital accessibility is essential in today's technology-driven world. Under the human rights framework, access to ICT is a basic human right, and as argued by others, digital inclusion is a key social justice concern in the 21st Century [54]. According to the World Health Organization, approximately 1.3 billion people globally have a significant disability, be it physical, cognitive or both [55]. This figure underscores the important role that inclusive design plays, ensuring that people with disabilities are not excluded from participating in today's digital society. By prioritizing accessibility in the design and development of learning tools, environments and systems, stakeholders can foster a more inclusive technological world [56] as inclusive design is not just about accessibility - it is also about empowerment, participation, and agency [57].

The OECD's Digital Inclusion Framework emphasises that bridging what has become known as the "digital divide" [58] is essential for achieving social participation, economic opportunity, and improved well-being for all citizens, especially vulnerable groups [2]. Yet recent research has shown that not everyone can easily access digital content, particularly people with intellectual disabilities [59]. Denying people with intellectual disabilities (PwID) access to digital tools can be seen as a denial of their rights to learn, express themselves, and participate fully in society. Even when accessibility is actually considered in the design and development process, the emphasis tends to be on users with a visual or listening impairment [60].

In recent years, digital tools, learning applications, and AI have been widely used in special support settings. The Japanese government highlights the potential of ICT, data, and other promotional technologies such as AI when considering inclusive learning for a diverse mix of learners [61]. Although there are challenges associated with digital inclusion for individuals with intellectual disabilities, including access to hardware, sensorimotor and cognitive requirements, and comprehension of codes and conventions [62], from a social justice perspective they have a right to participate fully in digital society. This means that society has a responsibility to ensure that future technology development encompassing devices, applications, digital artefacts and resources including advances in AI embrace an inclusive approach to designing for diversity [63].

To this end, User-Centred Design [64] emerged as a recommended approach when designing for users with intellectual disabilities [65]. User-Centred Design (UCD) is an iterative design approach promoting the active involvement of users in the process of design to improve the understanding of their needs and requirements [66]. This approach describes a design process that involves the potential user at all stages, encompassing requirements, prototyping, testing and evaluation [67].

Within the broad context of UCD research, the concept of co-design has emerged as an important component. Co-design which aims to give a voice in the design process to the future users of technology has been defined as a creative problem-solving process involving multiple stakeholders [68]. Involving the collaboration of diverse experts (researchers, designers or developers) and crucially the end-users (untrained in design) throughout the design and development process [69,70] would be of particular value. Co-creation is viewed as an emancipatory process where the historic power imbalance of experts shifts to a more collective, equal ownership model [71]. In this respect, co-design forms the basis of inclusive practices where equal participation and shared creativity are central, which relates to and aligns with the discussion in Section 3.2.

This section highlights the need, when developing a framework, to strongly consider principles of equity, inclusion, participation, ethical responsibility and empowerment, focusing on concerns for access and infrastructure, inclusive pedagogy and curriculum, capacity building, ethical governance, and monitoring and evaluation.

3.4. Transparency and accountability: ethical uses of data and AI

In terms of technology-enhanced inclusivity, it is clear that generative artificial intelligence (GenAI) is being seen as raising both challenges and opportunities. Many 21st Century scholars who have addressed the topic of AI in education agree that an important first step is educating teachers, students, parents, policy makers and the general public about potential benefits and pitfalls of AI for enhancing teaching and learning [72–75]. Most of these sources agree that "making sense of what is happening" ([75], p.1) with the end goal of helping humans flourish as members of society [76,77] should always be kept in sight.

With regard to transparency and accountability, it is crucial to include stakeholders in the design and implementation of AI in education; for example, First Nation language speakers and others underrepresented in the core training corpus of a large language model need to be the 'humans in the loop' as AI is developed and deployed. Engagement is also required for users of specialized vocabulary, such as science, technology, engineering and mathematics (STEM), and to include people knowledgeable about adaptations required for various levels of education of the user. In addition, transparency and accountability extend to authors and developers.

A multi-year study sponsored by UNESCO [77] cautioned against the potential dangers of marginalization and isolation for humans as individuals, due to digitalization of learning in general. In this category, emerging digital technologies such as GenAI can be included. Therefore, "governments should focus on how digital technology can support the most marginalized so that all can benefit from its potential, irrespective of background, identity or ability" ([77], p.25).

This section reinforces the need for a developing framework to consider principles of equity, inclusion, participation, ethical responsibility and empowerment, ensuring concerns for access and infrastructure, inclusive pedagogy and curriculum, capacity building, and ethical governance are adequately accommodated.

3.5. Empowerment: fostering agency and digital competence

Many forms of civic, social, and economic participation have become digital. For the average citizen to benefit from and contribute to society, the economy, and public affairs, they need to engage with the digital

world. Such participation is not easy and straightforward; it is a complex combination of access, competence, and confidence to navigate technology, as well as personal responsibility and accountability for one's digital behavior and the consequences of digital actions. Passey et al. [78] have brought all these elements together to define the term digital agency (DA) that explains the individual's abilities to control and adapt to a digital world. Digital agency is dynamic and arises through the interaction among digital tools, institutional structures, and professional judgment. It involves not only access and skills but also intentional decision-making and purposeful, critical, and responsible behavior within digitally mediated environments.

A lack of digital agency hinders ethical participation, critical engagement, and informed decision-making, which leads to disempowerment within the increasingly digital landscape of social, economic, and other essential services. Governments must promote agency and digital skills by addressing all aspects, not just providing hardware and access. Digital agency involves building cultural capital, confidence, and skills for digital creation, participation, and collaboration, grounded in lifelong learning as technology and systems continually change [78].

Empowering digital agency can begin during school years through the cultivation of teachers' professional digital competence (PDC) and transformative agency to critically evaluate and reshape digital practices in response to pedagogical goals and demands. PDC empowers teachers for effective and responsible digital practice, including collaboration, problem-solving, innovation, and lifelong professional development in increasingly digitized contexts. As a result, teachers can encourage learners' proactive civic participation, critical engagement, and leadership initiative in digital contexts.

This section further reinforces the need for developing a framework to consider principles of equity, inclusion, participation, ethical responsibility and empowerment, with adequate accommodation of concerns for access and infrastructure, inclusive pedagogy and curriculum, capacity building, ethical governance, and monitoring and evaluation.

4. Deductively developing a digital social justice-oriented framework

Attempting to create a digital social justice-oriented framework needs to accommodate the detail and dimensions highlighted in the previous text. Such a framework needs to be rooted in a vision of social justice and reflect the principles of equity, inclusivity, participation and empowerment and ethical responsibility for marginalized populations. Taken from the features highlighted at the end of previous sections in this paper, Fig. 1 illustrates this, showing how a digital social justice-oriented framework should be considered through five guiding principles, and how these lead to strategic pillars that should be embedded within plans and actions for digital social justice-oriented transformation for marginalized populations. Considering each of the five strategic pillars:

a) Access and infrastructure: all learners from marginalized populations—regardless of socioeconomic status, ability, gender, ethnicity, or geography—need access to connectivity, devices and digital resources. There should be clear policies aimed at reducing digital access inequalities, accommodating guiding principles of equity, inclusion, participation, ethical responsibility, and empowerment.
b) Inclusive pedagogy and curriculum: Digital tools should be designed with the participation of voices of marginalized populations, discussing and describing their diverse learning needs (different languages, disabilities, etc.), accommodating guiding principles of equity, inclusion, participation, ethical responsibility, and empowerment. Additionally, the curriculum must integrate critical digital literacy and social justice education, leading to digital agency.

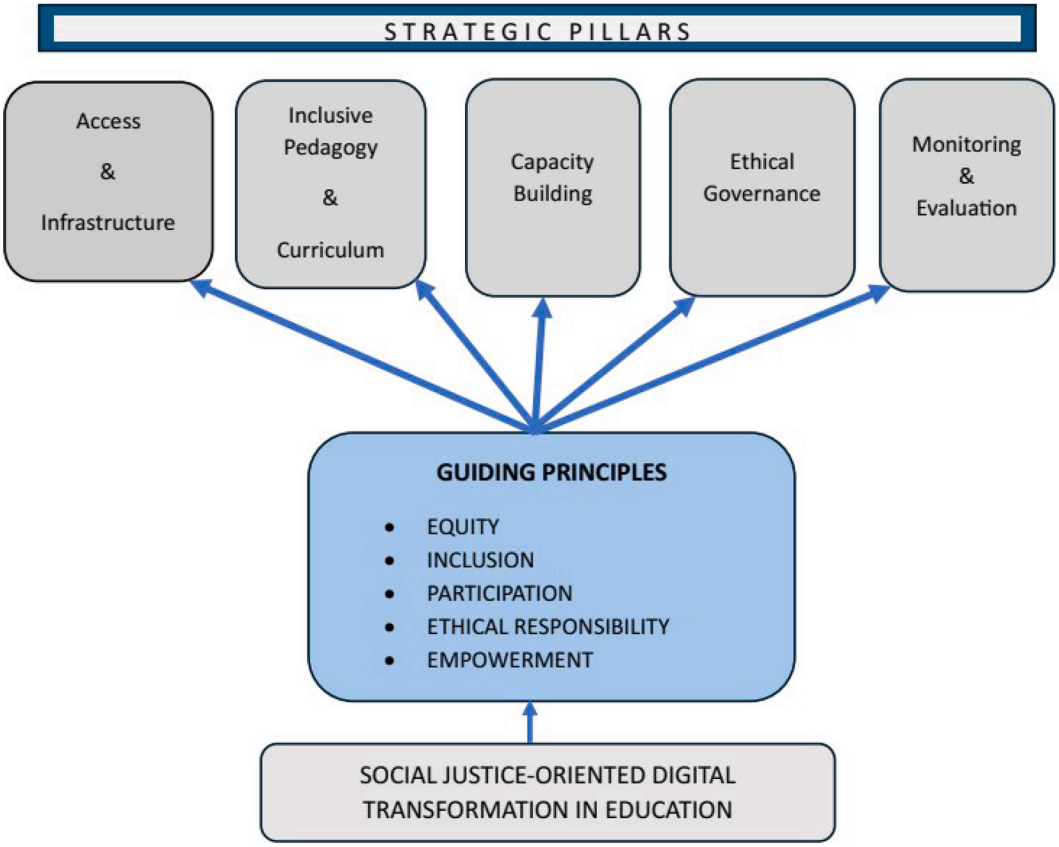

Fig. 1. Strategic pillars and guiding principles for a social justice-oriented digital transformation framework.

c) Capacity building: Teachers need to be well trained for inclusive digital practices, with training based on guiding principles of equity, inclusion, participation, ethical responsibility, and empowerment, and the community needs to be well engaged to ensure participatory governance.
d) Ethical governance: Transparent algorithms, bias-free AI and strong data privacy protections must be guaranteed. Policies should be put in place to prevent surveillance and discrimination, at the same time accommodating guiding principles of equity, inclusion, participation, ethical responsibility, and empowerment.
e) Monitoring and evaluation: This implies the presence of indicators for equity in access, participation and learning outcomes. There must also be a regular and continuous evaluation to ensure justice-oriented goals are met, accommodating guiding principles of equity, inclusion, participation, ethical responsibility, and empowerment.

5. Conclusion

The digital social justice-oriented framework is deductively derived from relevant existing literature and theories. The framework speaks to all stakeholders, but as practices sought can emerge from interactions with teachers and supporters, there is a place for those concerned with creating learning activities (teachers and teacher educators) to consider how the strategic pillars can be best addressed in their specific contexts.

Considering the viability of this proposed framework and how it aligns to some current case study marginalization practices is explored in a further paper [79]. Although this paper offers a view of the framework's viability, limitations should also be noted. Deductive analysis depends on how features are interpreted, and the texts analyzed could be interpreted by other researchers in alternative ways. Also, as digital technologies are developing rapidly, with tools including GenAI being introduced recently for educational purposes, this could affect viability of this framework. It is recommended that future research monitors and reviews contemporary contexts of DT for marginalized populations and amends the framework accordingly.

Note

Integrated forms of AI were used to generate some initial text, to translate from Japanese to English and to revise English writing. All text was checked and reworked prior to submission.

CRediT authorship contribution statement

Don Passey: Writing – review & editing, Project administration. **Jean Gabin Ntebutse:** Writing – original draft, Project administration, Formal analysis, Conceptualization. **Miriam Judge:** Resources, Data curation. **Gerald Knezek:** Resources, Data curation. **Aditi Kothiyal:** Resources, Data curation. **Valeria Piras:** Resources, Data curation. **Miri Shonfeld:** Resources, Data curation. **Thomas Tomas:** Resources, Data curation. **Miki Tomita Okamoto:** Resources, Data curation. **Yuko Toyokawa:** Resources, Data curation.

Declaration of competing interest

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

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