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Exploring the viability of a framework for social justice-oriented digital transformation

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ABSTRACT

This paper presents an application of a framework for educational social justice-oriented digital transformation, providing an analytical examination of four case studies of community-led design and implementation of digital technology with marginalized populations. The framework is rooted in a vision of social justice and reflects the principles of equity, inclusivity, participation and empowerment and ethical responsibility for marginalized populations. Through its five pillars - accessibility and infrastructure, inclusive pedagogy and curriculum, capacity building, ethical governance, and monitoring and evaluation – it is possible to see how the framework applies to the four cases. From this analysis, the framework is relevant in both analyzing previously implemented experiences of digital transformation and guiding new initiatives undertaken in practice through an educational social justice perspective.

1. Introduction

Digital transformation refers to a process where digital technologies are integrated into systems or institutions to bring about positive change. How this might be achieved effectively to support marginalized communities is the focus of this paper, explored through a newly developed framework [39] that can enhance an important and fundamental social justice perspective. Following introductions and backgrounds to the concepts of digital transformation, marginalized communities and social justice offered in Sections 1 and 2, the new framework is presented. In Section 3, this framework is used to consider how four cases have accommodated (or not) the key factors and pillars in the framework. Similarities and weaknesses identified from these analyses are discussed in Section 4, and Section 5 concludes with a summary of the key social justice factors that are seen in the four cases to contribute to digital transformation successes for marginalized communities.

Relevant research reports [22,30,37,44] propose frameworks that highlight digital transformation (DT) as a complex and holistic process requiring many pieces and partners to move forward together. For examp [44]) frames digital transformation around a systems approach guided by purpose, priorities, and shared principles and articulated on six pillars: leadership and governance, connectivity and infrastructure, cost and sustainability, capacity and culture, content and solutions, and data and evidence. From the study of [22], findings reveal four components for effective digital implementation: robust technological infrastructure, innovative pedagogical approaches, comprehensive policy, and regulatory frameworks. These four components were carefully considered when the new framework was developed. Related backgrounds to these components, and to concepts and factors that are

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known to influence digital transformation for marginalized communities, are offered in the following sub-sections.

1.1. Digital transformation and marginalized communities

In the context of digital transformation for marginalized communities, the Organization for Economic Co-operation and Development (OECD)'s Digital Inclusion Framework emphasizes that bridging the digital divide is essential for achieving social participation, economic opportunity, and improved well-being for all citizens, especially vulnerable groups [37]. When it comes to vulnerable groups, one group in particular – People with an Intellectual Disability (PwID) - stand out. According to the American Psychological Association [1], an Intellectual Disability (ID) is defined as a neurodevelopmental disorder involving adaptive and intellectual functioning which presents as a deficit in social, practical and conceptual aptitudes. ID has 4 degrees of classification: mild, moderate, severe and profound [13] equating to intelligence quotient (IQ) scores of 50–69, 35–49, 20–35 and minus 20 respectively. Up to about 1.5% of a population may be PwID, and ages of these individuals can vary. Individuals may, for example, have delayed or impaired speech, language, motor conditions, or visuo-spatial skills. The sorts of challenges that this group might present could include low levels of reading, limited listening skills, or inabilities to engage with new or different environments. Clearly, these challenges relate to digital engagement as much as to physical or environmental forms of engagement. Whilst PwID may develop digital literacy through schooling, special education or other forms of learning support, these forms of support do not necessarily equip those individuals with the range of digital literacy that others might have. Indeed, the digital literacy enabled may often only apply to the time that those individuals are physically present within supportive institutions. Whilst individuals may have access to support programs through government initiatives, and whilst Universal Design for Learning principles and practices might address some of these challenges, the available extent of support mechanisms is not always found to fully address the challenges that they face.

Using this group as a focus in which to explore digital inequalities and transformation sheds some useful light on the extent to which digital inequalities exist when it comes to designing inclusive education platforms that cater for the needs of marginalized communities [6] highlight that people with intellectual disabilities lack access to computer training opportunities and therefore do not have the chance to develop digital skills throughout their life. Yet in an era when PwID, like most young people today, have access to personal mobile telephones and iPads, and particularly since the Covid-19 pandemic [10] forced most PwID and their support workers/carers to interact online, there is a growing need to address the digital literacy (DL) skills gap that PwID experience, which is critical to achieving digital transformation.

According to [43], DL involves the practical ability to operate digital tools and platforms in addition to the cognitive competence to interpret and apply digital content in meaningful and contextually relevant ways. DL can facilitate PwID to overcome the digital divide by promoting skill development and enhancing their online communication and social interaction capabilities. Thus, DL can be a valuable enabler for PwID to bridge the digital divide as it can support their skill development and enhance their communication and social interaction abilities. However, they face specific challenges when it comes to accessing and using digital technologies, which include receiving appropriate support and training to ensure they have the necessary skills and knowledge to use technology, the Internet and social media effectively and safely, as well as overcoming curtailment of Internet access imposed by well-intentioned support workers and carers based on safety concerns and a perceived need to protect PwID from online dangers. DL for PwID may include logging into a website, using a web browser, understanding appropriate cyber-language and etiquette [9], in-built assistance facilities and how to stay safe online. Through appropriately designed DL educational programs, PwID can be empowered to increase their technology and internet use and learn how to navigate online risks and safely handle potential dangers encountered in virtual settings [19].

1.2. Digital transformation, marginalized communities and GenAI

As learners with cognitive challenges like PwID often encounter significant barriers within traditional learning environments [26], the use of Generative Artificial Intelligence (GenAI) in education may help address these even though it may equally exacerbate and amplify existing inequalities [21] predict that Artificial Intelligence (AI) tools which encompass adaptive learning systems, intelligent tutoring, natural language processing, and advanced analytics, will dramatically transform educational landscapes. Adaptive learning systems employing predictive analytics and personalized diagnostic tools can facilitate tailored educational experiences, leading to significant improvements in student engagement [26]. Some early research studies indicate that individuals living with disabilities have been among the earliest to adopt interactive GenAI in their daily routine and that GenAI-enhanced assistive technology can be a significant factor in the participation of students with cognitive disabilities in mainstream schools [32]. This would suggest that when it comes to accessibility and inclusion, GenAI has untapped potential, and arguably we are only at the start of what this technology has to offer when it comes to addressing educational inequities, fostering inclusive learning environments, and ultimately enhancing academic performance and student engagement across disciplines [27].

Nonetheless, the downside risks of GenAI for vulnerable and marginalized groups are substantial. Designing GenAI tools and systems for educational purposes raises privacy, ethical and algorithmic bias concerns. As GenAI systems make decisions based on datasets and algorithms, the information used to construct them is crucial. There is a very real danger that the datasets on which GenAI platforms are built may lack information from marginalized and vulnerable groups as well as non-English speaking cultures, which will perpetuate discrimination against those who already experience digital exclusion, leading to what [45] calls a deepening digital divide. In this respect, regulatory frameworks such as the European Union (EU)'s Regulation on Artificial Intelligence, which aims to ensure that GenAI systems uphold fundamental rights, are non-discriminatory and transparent [24], representing a much-needed and welcome development.

Considering AI at a broader level than GenAI, with regard to basic AI literacy (which would apply equally to all marginalized or excluded groups) [25] have proposed that the stages of educator proficiency developed and refined for the realm of digital technology integration over the past 25 years could be adapted and used as a self-classification tool for educator professional development in the realm of AI. In this context, AI literacy is defined as competences concerned with critically evaluating AI technologies, effectively communicating and collaborating with AI, and using AI tools in different situations for specific purposes. Specifically, a simple survey such as the one provided in Table 1 could quickly place educators in groups of peers at the same stage and comfort level, for the purpose of targeting small sessions of professional development designed to move each member to the next stage.

The stages and levels shown in Table 1 concern a widening of understanding and application as the individual moves from Stage 1 to Stage 6, and those stages and levels also relate to the definition of AI literacy that has been stated earlier. Awareness, learning the process, applying the process, familiarity and confidence, adaptation to other contexts and creative application align with effectively communicating and collaborating with AI, and using AI tools in different situations for specific purposes. The third element from the definition - critically evaluating AI technologies - could be specifically stated with the stages, but is perhaps inferred within the early stages, Stages 1 and 2.

Table 1
Stages of adoption of AI in education.

Stage	Stage Description
Stage 1: Awareness	I am aware that AI exists, but have not used it - perhaps I'm even avoiding it. I am anxious about the prospect of using AI.
Stage 2: Learning the process.	I am currently trying to learn the basics. I am sometimes frustrated using AI. I lack confidence when using AI.
Stage 3: Understanding and application of the process	I am beginning to understand the process of using AI and can think of specific tasks in which it might be useful.
Stage 4: Familiarity and confidence	I am gaining a sense of confidence in using AI for specific tasks. I am starting to feel comfortable using AI.
Stage 5: Adaptation to other contexts	I think about AI as a tool to help me and am no longer concerned about it. I can use AI in many applications and as an instructional aid.
Stage 6: Creative application to new contexts	I can apply what I know about AI in the classroom. I am able to use it as an instructional tool and integrate it into the curriculum.

Source: Adapted from [11] Stages of Adoption of Technology.

1.3. Digital inequity and digital transformation

Similar digital inequity to that observed with PwID can be observed in other contexts, such as in digital health services. Research has found that racial and ethnic minority groups use health-related technologies at lower rates than their white counterparts due to sociocultural barriers such as language, education, and familiarity, underscoring the need to understand these usage patterns and adapt to diverse cultural norms. Such cultural adaptations can broaden reach and engagement, helping reduce digital divides in health contexts [34,35]. Indeed, to date, the most frequent use of co-design for accessibility purposes has taken place in healthcare environments, aiming to improve the quality of patients' experience and care by including them in the process of designing equipment for their use.

2. Digital transformation, marginalized communities and social justice

As indicated in the previous text, digital education ecosystems (whether supporting and involving marginalized communities or not) are not only technological infrastructures — they are **socio-technical systems** involving people, institutions, policies, platforms, data, and power relations. When the goal is **social justice**, sustainability and resilience must be redefined beyond simple technological durability.

For effective digital transformation, social justice becomes an important concept and factor to consider. Background theories that have framed the concept of social justice relate strongly to the focus of digital transformation in this paper, especially where governance and management aspects are concerned. Considering a social justice background in this context, from the 1980s to the early 1990s, a range of new approaches began to challenge the liberal assumption of a neutral, abstract subject of justice. *Communitarianism* [28,41,46] argued that justice is inseparable from cultural memberships and shared histories that shape communities, revealing how formal equality can obscure substantive differences. *Feminist standpoint theory* [12,18] and later situated knowledge theory [17] highlighted the epistemic dimensions of marginalization, asserting that oppressed groups generate situated knowledges capable of revealing aspects of injustice imperceptible from dominant perspectives. These insights interacted with *Marxist feminism* and early *queer theory*, where figures such as [16] and [8] brought questions of economic redistribution into dialogue with the cultural norms that regulate identity and belonging. *Critical Race Theory*, advanced by [4,47], and [29], further demonstrated that racism is embedded in legal and institutional structures, challenging liberal claims of neutrality. Parallel to these developments, *postcolonial scholarship* offered a further and crucial challenge to universalist models of justice. Thinkers such as [15] and [40] revealed how colonial domination, racial hierarchies, and Eurocentric epistemologies shaped not only the lived experience of oppression but also the very categories through which justice had been theorized.

2.1. Dimensions of a digital social justice-oriented framework and its representation

A previous and related paper [39] develops a digital social justice-oriented framework based upon contemporary knowledge of social justice theory, challenges and issues presented by current digital technologies and their development, and an understanding of key needs to support social inclusion of marginalized communities. It differs from other frameworks by drawing out strategic pillars that highlight key social justice needs; other frameworks have not drawn out this dimension to the same extent. What it is offering that is novel and helpful for practitioners, researchers, policy makers and developers is a means to consider the extent to which each of these pillars has been accommodated within any particular initiative or development for the digital transformation of marginalized communities.

The framework (see Fig. 1) is rooted in a vision of social justice and reflects the principles of equity, inclusivity, participation and empowerment and ethical responsibility for marginalized populations. The framework is based on five 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 to reduce digital inequalities.
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.). The curriculum must integrate critical digital literacy and social justice education, leading to digital agency.
c) Capacity building: Teachers need to be well trained for inclusive digital practices, and the community should be well engaged to ensure participatory governance.
d) Ethical governance: Transparent algorithms, bias-free artificial intelligence and strong data privacy protections must be guaranteed. Policies need to be put in place to prevent surveillance and discrimination.
e) Monitoring and evaluation: These imply the presence of indicators for equity in access, participation and learning outcomes. There needs also to be a regular and continuous evaluation to ensure justice-oriented goals are met.

To make full and effective use of appropriate tools for learning, it is helpful to reference successful instructional practices, yet such examples remain limited. In this context, the following section shows how educational key stakeholders were involved in the design processes and decision-making related to educational technologies and digital transformation designs in four case studies. In each case, the relationship of practices and outcomes to the presented framework will be identified.

3. Case studies of community-led design and implementation of digital technology related to the social justice-oriented framework

The methodological approach adopted for and applied to this section of the paper is to explore how the framework developed and presented in another paper [39] applies to four case studies. Provided by authors within this paper, the four case studies were selected as examples of digital transformation for marginalized communities that appeared to

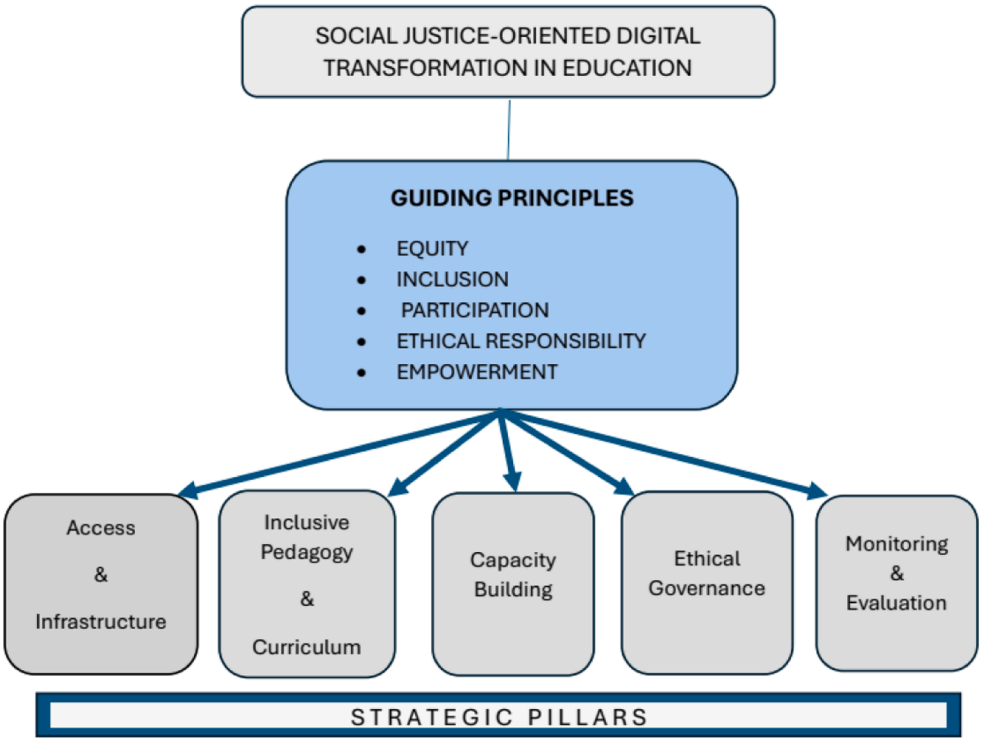

Fig. 1. Strategic pillars and guiding principles for a social justice-oriented digital transformation framework.

present features aligned with the pillars and principles within the social justice-oriented framework. The extent to which these pillars and their underlying principles had been met by the cases was identified through what [7] refer to as 'searching for themes' in the process of thematic analysis. This analysis, therefore, was undertaken through a deductive approach, using the pillars and principles as the theoretical base.

3.1. Case study 1: community-led design

Participatory design research as elaborated by [3] represents a reimagining of how educational interventions are designed, moving beyond simply providing access to existing educational resources, towards fostering authentic participation in the educational design process, that centers the multiple ways of being and knowing (epistemic heterogeneity) of marginalized communities including PwID. Their research approach challenges traditional power dynamics in research and design, focusing attention on what forms of knowledge are generated, how, why, where and by whom, with a goal of generating new theories of sustainable and transformative social change based on critical historicity, power and relationality. Rather than treating participants as passive recipients of predetermined solutions, community-led design positions them as experts who possess critical insights about their own experiences and contexts, often critically needed to support applications for PwID. This orientation is also especially crucial when working with historically minoritized populations who have been systematically excluded from certain disciplines. Central to this approach is supporting participants in developing transformative agency — the capacity and commitment to transform the contexts of their activity for personal, academic, and civic purposes as discussed by [14]. This development occurs through gradual sense-making as participants

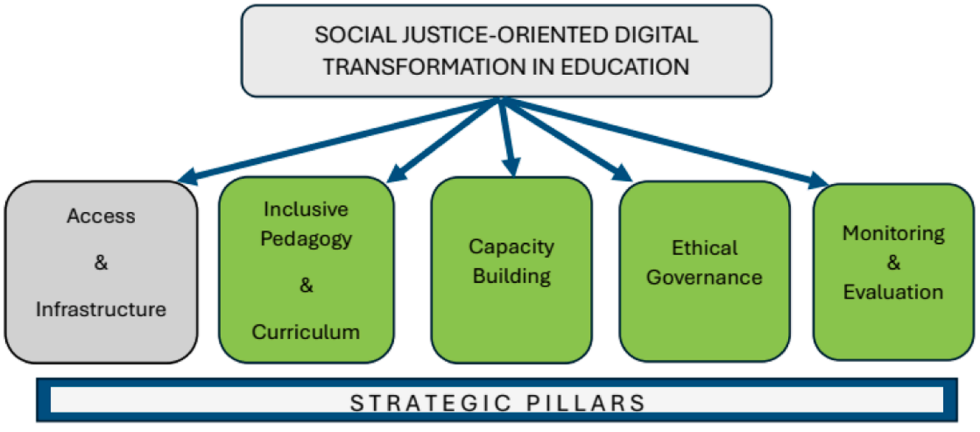

Fig. 2. Relationship of Case Study 1 to the strategic pillars of the social justice-oriented digital transformation framework.

engage in cycles of reconceptualization and re-design.

Fig. 2 shows that four of the key pillars are addressed in this case study example (highlighted in green background): the curriculum and pedagogy are informed by representative individuals; they build capacity; they have responsibility for ethical governance; and the process is monitored and evaluated by them. Access and infrastructure, however, are not specifically addressed in this case. In this case, the framework analysis highlights that the community-led design focuses more on social and governance aspects, whereas technological aspects, which could lead to wider and more prolonged use, are not clearly evidenced.

3.2. Case study 2: co-designing game-based learning for culturally responsive computing

Arastoopour Irgens et al. [2] conducted a participatory design-based research project with elementary school children (aged 7–12 years) to co-design a digital game-based learning environment called S.P.O.T. (Solving Problems of Tomorrow) that would engage children in computational thinking through culturally responsive-sustaining approaches. The research team worked with seven children from diverse backgrounds over five years through iterative cycles, beginning by building relationships and spending several weeks volunteering at centers, assisting with homework and playing games with children to build rapport and trust before beginning participatory design activities. The team explicitly addressed historical inequities in computing education, recognizing that Black, Latino, and Native American children, as well as those living in poverty or with disabilities (PwID), typically face adversity in participating in computer science, including lack of resources, non-relevant curriculum, and social barriers from belonging to marginalized groups. The project grounded its work in culturally responsive-sustaining computer science education frameworks (exemplified by, for example [5,23]) that embrace and validate students' interests, identities, and cultures while facilitating computing knowledge and sociopolitical critique about technology's impact.

The project applied participatory design principles through several key approaches. Children's roles evolved over three design cycles from testers and informants to co-designers, allowing them to engage in learning and design simultaneously even as they became familiar with AI computing content and practices they had not previously encountered. In initial co-ideation sessions, children reviewed digital visuals and mockups of game environments, drew their visions for game elements and functionality, provided names for the agency and chose agent names, and created drawings about harmful versus helpful technologies. These activities positioned children as genuine collaborators whose cultural knowledge and creative visions shaped the game's development. The team implemented micro-ethics practices including attention to turn-taking, building authentic relationships while maintaining boundaries, and negotiating multiple agendas between adults and children.

The resulting game design incorporated children's suggestions for animated characters, customizable avatars, narrative-driven gameplay set in future cities, and systems for earning badges. Importantly, the game featured characters with intersectional identities and counternarratives that made visible stories of marginalized populations often excluded from computing spaces. This design approach demonstrated the power of community-led design for digital social justice. User experience testing revealed children's positive responses to characters with counternarratives and visible intersectional identities in computing, with girls responding particularly enthusiastically to diverse presentations of agent profiles and interests, finding them "inspiring". For example, one character, Captain Storm, was a Black woman in a leadership role with a Nigerian accent, which one child, Agent Life, expressed excitement about because she could see herself and her family's heritage reflected in the character. The game allowed children to develop projective identities, that is creating virtual characters onto which they projected their values and desires while viewing them as aspirational identities. For instance, one child considered multiple agent names reflecting different aspects of her identity before selecting "Agent Indy" based on her prior positive experience with Sphero Indi robots, demonstrating how the design supported reflection on personal technology experiences.

Ultimately, the project demonstrated how community-led design can create computing education that goes beyond providing access to existing tools. The approach created spaces for marginalized elementary school-aged children to participate in computing in personally meaningful ways that made their cultures more visible in computing education environments, directly addressing inequities that have historically excluded these populations from computer science fields.

Fig. 3 shows that four of the key pillars are addressed in this case study example (highlighted in green background): access and infrastructure are supported as required in classroom sessions; the curriculum and pedagogy are matched to the interests and cultural concerns of the users; teachers have responsibility for ethical governance; and the process is monitored and evaluated by teachers and users. Evidence of outcomes of the pillar concerned with capacity building is not known at this stage; however, this suggests that further and longer-term research and evidence gathering would be worthwhile in such cases. In this case, the framework analysis highlights that long-term concerns associated with developing local capacity are not fully and clearly accommodated, meaning that continued use and engagement might be limited without an ongoing local focus.

3.3. Case study 3: user-centred design of an educational cybersafety application for users with an intellectual disability

McDonnell [31] conducted a user centered design (UCD) PhD research study on cybersafety for young adults with an intellectual disability. Although UCD involving PwID is not common practice, a limited number of studies have been conducted with mild ID participants. Uniquely, the bulk of McDonell's research work was conducted with moderate ID participants, as she was keen to explore the experience of risk and cyberbullying among more vulnerable PwID, and how best to address the gap in limited educational resources available to them, their support workers and carers. Her research also examined the question of whether an e-learning application can be designed to be sufficiently inclusive in meeting the needs of young people with an ID.

The impetus for McDonnell's research was inspired by calls for the need for more research on how to teach safe Internet skills to PwID who are increasingly using technology such as mobile telephones and iPads, and who are twice as likely to be the victims of cyberbullying compared to neurotypicals [20,36]. This led McDonnell, working with PwID as co-designers, to design a digital prototype, known as *CyberSafe* (https://weathered-cell-5036.animaapp.io/homepage), consisting of 6 interactive modules comprising Cybersafety, Trust, Personal Information, Respect, Safety and Privacy (see Fig. 4).

While the application (app) is very much a prototype, the significance of McDonnell's work lies more in the process, expertly documented in her thesis [31], of how she managed to involve users, expert stakeholders and designers in the process; the UCD tools and techniques she deployed such as paper prototyping in advance of high fidelity prototyping, empathy maps, persona development and brainstorming tools like Figma (https://www.figma.com/) and Miro (https://miro.com/) which enabled her to engage PwID in the design of *Cybersafe* which might otherwise have been difficult to achieve; and finally the production of a best practice "Toolkit for User Centered Design with PwID" broken down into four quadrants encompassing research, methods, tools and content design (see Fig. 5), that other researchers and designers keen to use UCD with PwID can constructively deploy.

Fig. 6 shows that four of the key pillars are addressed in this case study example (highlighted in green background): the curriculum and pedagogy are informed by representative individuals; they build

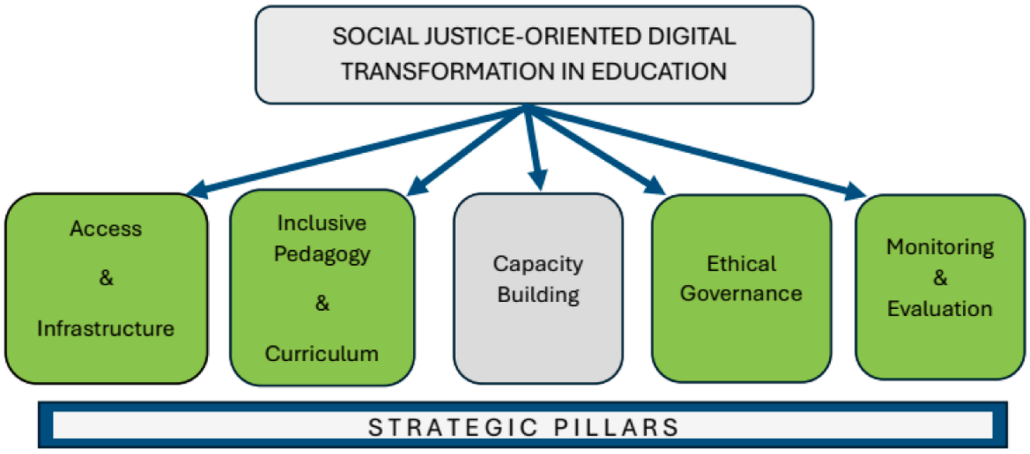

Fig. 3. Relationship of Case Study 2 to the strategic pillars and guiding principles for a social justice-oriented digital transformation framework.

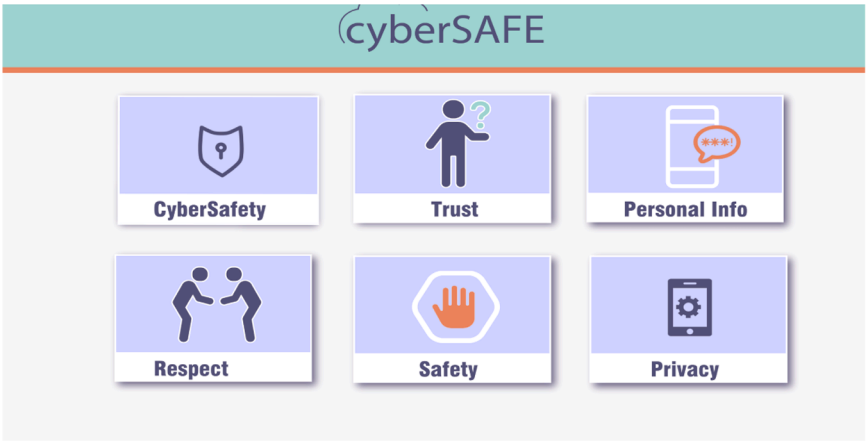

Fig. 4. Cybersafe application modules (Source: https://weathered-cell-5036.animaapp.io/homepage).

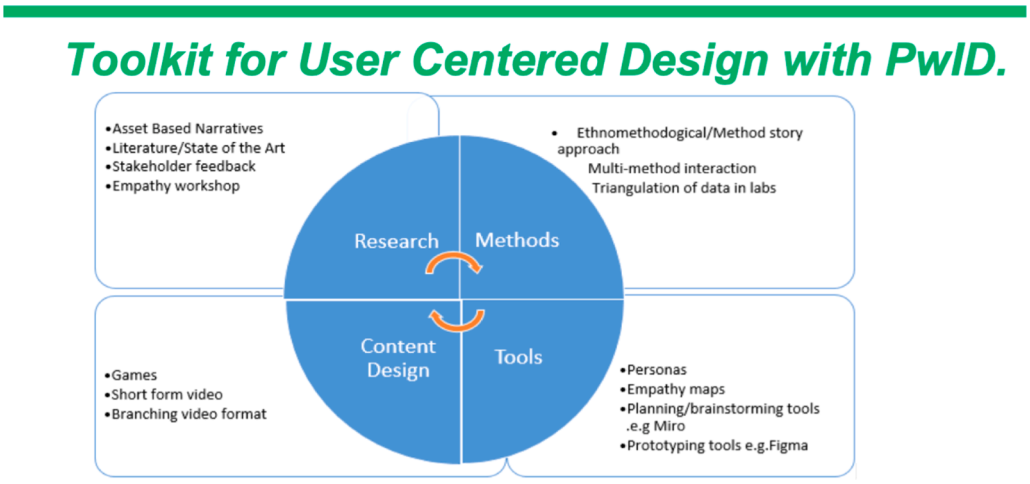

Fig. 5. Cybersafe's toolkit for user centered design with PwID (Source: [31], p.249).

capacity; researchers have responsibility for ethical governance; and the process is monitored and evaluated by researchers and users. In this case, the pillar concerned with access and infrastructure is not directly addressed for those beyond the involved group. In this case, the framework analysis highlights that technological concerns have not been clearly addressed to the same extent as social and governance concerns, which could limit longer-term engagement and use. This finding aligns with the finding from Case Study 1.

3.4. Case study 4: supporting young people with special needs

From the perspective of learning analytics (LA) research [42], which aims to provide personalized support based on data generated from individual learners, a field study was designed in special needs classes

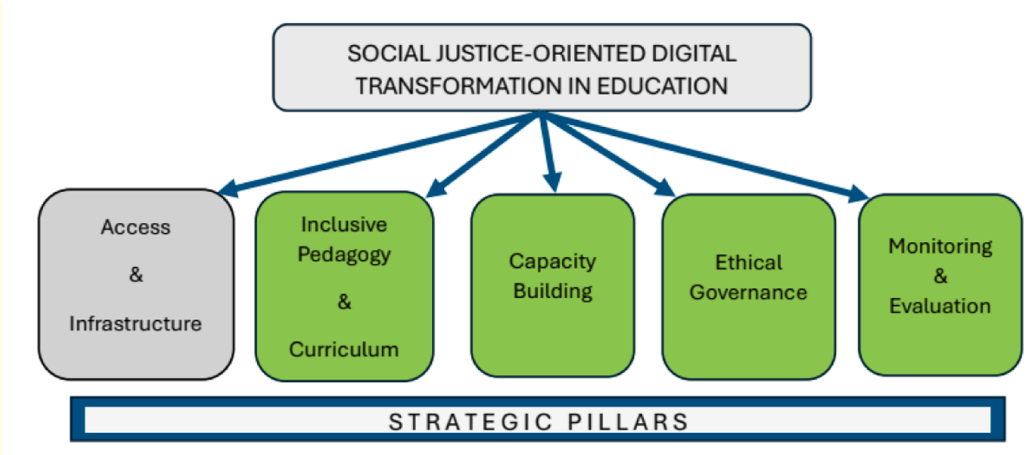

Fig. 6. Relationship of Case Study 3 to the strategic pillars and guiding principles for a social justice-oriented digital transformation framework.

using the Learning and Evidence Analytics Framework (LEAF) system. LEAF is a platform that collects and analyzes learning logs (e.g., memos, markers, browsing pages) to facilitate individualized learning and instructional improvement [38]. The ongoing field study involved two elementary schools and one lower secondary school in Japan. Their special needs classes differed in structure: some combined multiple grade levels in one class, while others organized classes by type of difficulty such as autism/emotional disorders or intellectual disabilities, typically with 5 to 10 students per class with flexible arrangements that allowed students to move between special needs classes and regular classrooms as needed. A class usually has more than one teacher present. In one lesson, teachers may teach different subjects simultaneously—for example, 1st-grade Japanese and 4th-grade mathematics.

The objective of the study was to use log data collected through the LEAF system to objectively visualize learning processes and to evaluate its effectiveness in improving instruction and support in special needs (PwID) settings. Researchers designed the study based on existing theories and past research, and worked with the board of education, principals, teachers, and parents to explore possible ICT-, AI-, and data-supported assistance and to coordinate and execute learning plans. They refined the plan through repeated discussions and conducted the implementation collaboratively. Special needs (PwID) settings require additional reasonable accommodations — for example, registering learning materials in accessible formats (e.g., larger text, easy-to-find file layouts), selecting appropriate devices, and arranging physical learning environments. Explanations for obtaining parental consent were provided by teachers or school executives. Boards of education and specialists might also join the discussions from the planning stage, ensuring that national or municipal requirements, school capacities, and researchers' aims were aligned. After the broader framework was agreed upon, detailed planning continued between researchers and the teachers directly involved. Even in the preparation phase, researchers and teachers communicated with parents about classroom and home use of the system, concerns about participation, expected benefits for their child, and the appropriate level of parental involvement. Support became possible only by gathering and respecting all voices — and supplementing them with objective data allowed truly necessary support to be delivered. System developers, researchers, the board of education, principals, and teachers engaged in ongoing dialogue and visited the schools to observe classes for deliberations about appropriate support, areas for improvement, and contributing to decision-making. The overall work of each stakeholder from preparation to implementation and subsequent follow-up is summarized in Table 2.

Learning in schools was supported by a network of key stakeholders, each fulfilling distinct roles. In the context of implementation studies, researchers also joined this network. Particularly in special needs education, system implementation requires greater caution and deeper involvement from multiple actors compared with general education settings. Through repeated consultations with stakeholders during the field studies, it was possible to understand why the participation of individuals from diverse fields is indispensable.

Educational boards and local governments hold substantial authority over public schooling. They work closely with schools to ensure that curricula are developed, and instruction is delivered in accordance with

Table 2
Outlined roles and responsibilities of each stakeholder.

Stakeholders	Roles and responsibilities
Researchers and system developers	-Develop systems -Create implementation plans -Consult regarding research participation -Introduce the system and provide orientation and teacher training on system operation -Prepare consent forms -Discuss and refine implementation details -Coordinate with stakeholders -Conduct data analysis -Provide feedback -Improve the system -Coordinate subsequent implementations and iterative system enhancement
School executives	-Receive and respond to consultations -Review and adjust the school-wide structure -Explain the project to teachers and request their cooperation -Communicate with researchers and the board of education -Serve as a liaison between teachers and researchers -Explain the study to parents and distribute/collect consent forms -Report implementation progress to relevant stakeholders -Engage in decision-making
Teachers	-Participate in training -Attend meetings to plan implementation -Explain the project to parents -Cooperate in the implementation -Provide feedback to researchers -Report progress and issues to the school
Learners	-Engage in learning activities -Review and reflect on their learning -Improve their learning processes
Parents	-Participate in meetings -Provide necessary information -Support their child's learning -Explain or report the project to relevant community stakeholders (e.g., tutoring schools, developmental support centers)

the national curriculum guidelines. Schools operate under their guidance and support, conducting daily learning activities grounded in these standards. In special needs education, creating tailored individualized education plans requires accordance with national guidelines (Ministry of Education, Culture, Sports, Science and Technology [33] 2019) as well as expert insight from educational boards and related specialists and information obtained from parents. School principals play a central leadership role in establishing a cohesive support system among school staff, coordinating with external agencies, specialists, and families, and fostering environments that promote understanding of special needs and inclusive education. Families, on the other hand, collaborate with schools and teachers to develop individualized plans through formal procedures; in cases where learners have limited verbal communication abilities, parents advocate on their behalf to determine necessary support.

In Japan, one device per student is provided, and learners are expected to use the same device for instruction. Learners who struggle with device operation may receive reasonable accommodation upon request. Teachers and families — who observe learning challenges in daily practice — are typically the ones who initiate such requests. In today's educational landscape, the use of AI technologies can meaningfully strengthen abilities to provide tailored support to every learner in inclusive classrooms.

Through this study, it became clear that advancing inclusive education requires broader and deeper understanding of the inclusive concept itself. Researchers must therefore communicate research aims and their potential effects to all stakeholders, including educators, local government, and families. Emphasizing privacy and ethical considerations and enhancing AI literacy across all actors engaged in learning will be critical for future inclusive practices. Furthermore, encouraging stakeholders to take active roles in system development and implementation planning will be a key factor in successful adoption. This collaborative effort offers valuable opportunities to reflect on and develop the knowledge required to build future inclusive learning environments.

Fig. 7 shows that all five of the key pillars are addressed in this case study example (highlighted in green background): access and infrastructure are provided by the government; the curriculum and pedagogy are informed by all representative stakeholders; stakeholders and users build capacity; there is shared responsibility for ethical governance; and the process is monitored and evaluated as a shared responsibility. In this case, the framework analysis highlights that all pillars have been addressed, which indicates that it is likely that the outcomes can be more sustained over time. The analysis indicates that views and concerns from all stakeholder perspectives have been considered and integrated.

4. Comparative analysis

Across these four case studies, what emerges most explicitly is that they all share a concern – or at least the principle – of the transfer of design authority from researchers to the people most closely affected by the results in four different educational ecosystems. Also, in all four cases, the populations of the studies come from marginalized backgrounds. These two similarities are not surprising, as the case studies were selected, in part, on the basis of their possible alignment with the social justice-oriented framework.

In Case Study 1, community led participatory design reimagines marginalized learners less as the recipients of interventions, and more as knowledge holders, whose lived experiences influence the process and goals of educational change. Motivated in ways guided by power and historicity readings, the approach foregrounds processes of transformative agency and reflection and restructuring circularity. Case Study 2 is an approach that shares this ethos but also is more child centered and concrete, in which a small group of younger participants (aged 7 to 12 years) move forward from being the testers to developing co-designed elements of a culturally responsive computing game. These youngsters were originally excluded from computing due to racial biases. By inscribing their identities, stories and cultural references are integrated in the game's mechanics and characters; the project shows how design can become more than a site for assimilation. Although Case Study 3 was carried out with a different population and framed through user centered design rather than participatory design language, it still resonates with this same philosophy. Here, young adults with moderate intellectual disabilities are seen not as passive users but as assisted co-conspirators who create a "cybersafe" learning platform which is informed by their aspirations and challenges. In Case Study 4, young people are involved in developing support practices with digital technologies involving the wider educational eco-system. In this case, there is shared responsibility with interactions that go across and engage all stakeholders, involving appropriate actions and participation of policy makers, advisers, researchers, teachers, parents and carers, and the young people themselves.

Participation in all four is not a symbolic phenomenon but a practical, iterative exercise that defines the product, the produced knowledge and the culture. Yet, from the analysis, the variations across the cases highlight how participatory ideals need to be made context specific. The first case study is what might be regarded as the most theoretical and conceptual, focusing practice through social justice. The sociocultural and decolonial paradigm establishes the foundation for a long-term social transformation study. The second case translates those principles into a longitudinal (5 year-long), relationship-based design practice with children, focusing on how to build trust, play and

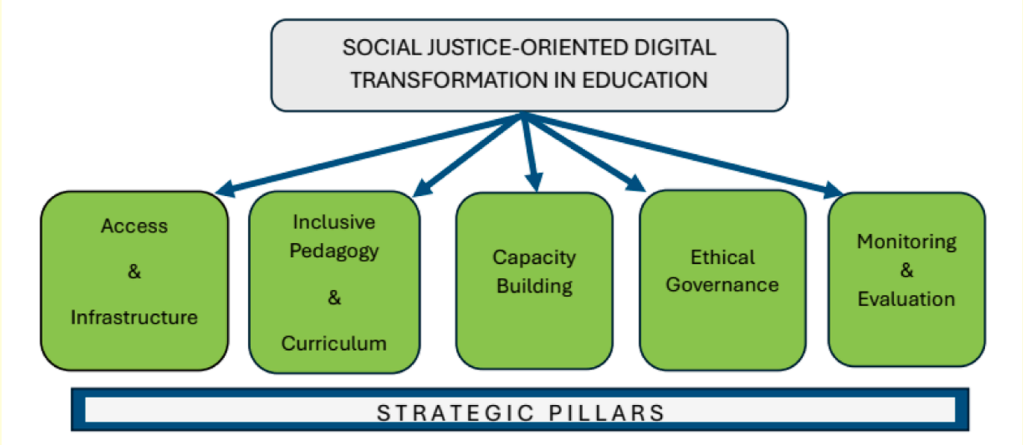

Fig. 7. Relationship of Case Study 4 to the strategic pillars and guiding principles for a social justice-oriented digital transformation framework.

iteratively prototype as the core methods. The third case has a clear focus, is more structured and includes more traditional, user centered practices including personas, empathy mapping, and staged building of learning to meet the needs of cognitive and communication flexibility. The fourth case is built on a strong social justice framework, where participation and inclusion are central to practices. Outcomes rely on the eco-system, rather than on individuals.

Read together, these cases reflect a range of participatory practice, from critical theory to classroom codesign to highly scaffolded, accessibility focused development. But the analysis indicates that they agree on the same thing: effective educational technologies become possible when the design process designers stop to consider, listen carefully, and treat communities as partners. The outcome is not just improved products, but more ethical, inclusive and socially responsible processes.

The four cases represent examples of design rooted in a social justice perspective. It is noteworthy that in all four cases, the design process places the participants' voices at the center. Their epistemic and cultural perspectives are therefore given significant importance. Rather than being treated as passive recipients of predetermined solutions developed without their involvement, their own experiences and contexts serve as the starting point and guiding thread for the entire design process.

5. Conclusions – and future focus

This paper has shown that digital transformation can both be visualized and conceptualized as a framework (see Fig. 1), but that digital transformation can also be effectively undertaken in practice when key pillars of social justice are fundamentally integrated. The message for practitioners, for policy makers and for researchers is that digital transformation to support marginalized communities needs to be developed with due respect given to context; with regard to social justice needs, these are likely to be specific to populations and communities. Additionally, however, if digital technologies are to be developed to support marginalized communities, then, as stated earlier, it is important to recognize that from the analysis presented, this becomes possible when design process designers stop to consider, listen carefully, and treat communities as partners. Design process designers, as well as all other stakeholders, need to carefully consider access, infrastructure, inclusive pedagogy, curriculum, capacity building, ethical governance, and the findings of monitoring and evaluation. Design process designers should not be set apart from the concerns of other stakeholders; they should be involved in these concerns throughout the journey.

From a research perspective, this paper has provided case study examples of effective practice that demonstrate the importance of meeting the strategic pillars of the framework developed to support digital transformation for marginalized populations. More examples of this type are needed, and, importantly, there is a need to know through longer-term research studies how effectiveness in these contexts is sustained. In essence, the challenges for researchers are not dissimilar to those for developers: stop to consider, listen carefully, and treat communities as partners.

There are limitations of this paper that should also be recognized. Taking four case examples for analysis provides a starting point rather than an end point. The outcomes should be considered as providing exploratory messages and recommendations at this stage. As with any conceptually based case study research, it is the reader and audience who should critically consider the potential value that this study and its messages might bring to support their specific contexts.

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, Visualization, Methodology, Formal analysis, Conceptualization. **Jean Gabin Ntebutse:** Writing – original draft, Project administration. **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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