

1. Introduction

The intersection of digitalization and employment inequalities in older age represents one of the most pressing challenges of today's labor markets and aging societies. As digital technologies increasingly shape work practices, older workers navigate a complex environment where digitalization simultaneously offers opportunities for extended working lives and creates new forms of exclusion and inequality (Pak, Renkema, & van der Kruijssen, 2023; Reimann & Tisch, 2021). This working group focuses on the need to develop robust conceptual frameworks that can explain how digitalization affects work experiences, employment outcomes, and patterns of inequality among older workers, while bridging the persistent gap between research and policy (Finsel, Wöhrmann, & Deller, 2023). The rapid development of digital transformation has fundamentally changed the nature of work across sectors, introducing new forms of automation, platform employment, digital monitoring systems, and communication technologies that are changing the quality of work, skill requirements, and working relationships (Reimann & Tisch, 2021; van Dijk, 2012). For older workers, these changes are taking place in the context of pre-existing age-related inequalities, including discrimination, concerns about skill obsolescence, and limited access to training and development (Wang, Zhang, & Feng, 2024). The convergence of these digital and demographic trends creates a unique set of challenges that current theoretical frameworks fail to adequately capture and address.

The Importance of a Conceptual Framework

Understanding the intersection of digitalization and job inequalities in older age requires a sophisticated conceptual framework that can capture the multifaceted nature of both phenomena and their dynamic interactions. Current research shows that digitalization is not a single process, but encompasses a variety of technological interventions with different impacts on different groups of workers and work contexts (Pak, Renkema, & van der Kruijssen, 2023; Reimann & Tisch, 2021). For older workers, digital technologies can simultaneously act as tools for successful aging at work—through task redesign, knowledge-sharing platforms, and flexible work schedules—and as sources of new inequalities through digital divides, technostress, and age-related algorithmic systems (Halford, Kukarenko, Lotherington, & Obstfelder, 2015; "Getting Ready for the Future," 2022). The development of robust conceptual frameworks is important not only for academic understanding but also for practical policy and organizational interventions. The persistent gap between research and policy stems in part from the lack of integrated theoretical models that can translate complex empirical findings into concrete recommendations (OECD, 2019; Finsel, Wöhrmann, & Deller, 2023). Existing frameworks often operate within narrowly defined disciplines, which limits their ability to address the multi-level and intersectional nature of the impact of digitalization on older workers. A comprehensive conceptual framework is necessary to:

- Link interdisciplinary perspectives: Integrate insights from gerontology, organizational psychology, labor economics, science and technology studies, and public policy for a holistic understanding.
- Support evidence-based interventions: Provide a theoretical basis for work practices, training programs, and policy measures that can effectively address digital inequalities.
- Guiding future research: Identifying key research questions and methodological approaches needed to advance knowledge in this rapidly changing field.
- Supporting policymaking: Providing conceptual tools for the design and evaluation of policies aimed at promoting digital inclusion and reducing employment inequalities in older age.

2. Key concepts and definitions

Digitalization refers to the comprehensive integration of digital technologies into work processes, organizational structures, and work relationships, fundamentally changing the way work is designed, performed, and managed (Pak, Renkema, & van der Kruijssen, 2023; Reimann & Tisch, 2021). This process is understood as coevolutionary, where technological capabilities and social practices interact (Trist & Bamforth, 1951) and is not neutral; technologies can either support or constrain the participation of older workers (Wang, Zhang, & Feng, 2024). Digitalization manifests itself in process, communication, monitoring, and platform dimensions (Parker & Gerbasi, 2022). Work inequalities in older age include systematic differences in opportunities, job quality, career development, and treatment in the workplace, influenced by age discrimination, structural ageism, and institutional practices (Phillipson, 2019; Calasanti & Slevin, 2001). The cumulative disadvantage perspective shows how these inequalities accumulate over the life course (Dannefer, 2003), and intersectionality theory explains their interconnectedness (Crenshaw, 1991). Social capital represents the networks, relationships, and shared norms that enable older workers to access information, resources, and opportunities, and includes bonding and bridging capital and intergenerational relationships (Coleman, 1988; Putnam, 2000; Ryan & Bauman, 2016). Technostress is the psychological and physiological strain arising from the inability to master digital technologies, exacerbated by age-related changes, limited experience, and cultural assumptions of universal digital competence (Tarafdar et al., 2007; Tisch, 2022). Intergenerational learning involves the two-way exchange of knowledge between workers of different ages, supported by formal programs or informal interactions (Kaplan, Henkin & Kusano, 2002; Choi & Kim, 2021). Digital literacy, adaptability and workforce inclusion are key related concepts: digital literacy encompasses technical, cognitive and social skills for the effective use of technology (van Deursen, Helsper & Eynon, 2016), adaptability enables older workers to adapt to change (Pulakos et al., 2000), and workforce inclusion ensures equal access and support in a digitally transformed environment (Shore et al., 2011; WHO, 2017). Other relevant concepts include the digital divide, age-friendly work design, successful ageing at work and generativity, which together influence older workers' experiences of digitalised work (van Dijk & Hacker, 2003; Truxillo et al., 2012; Kooij et al., 2010; Erikson, 1950; Wang, Zhang & Feng, 2024).

Framework Objectives

This conceptual framework aims to achieve three main objectives that will support theoretical understanding and practical applications in addressing the impact of digitalization on employment inequalities in older age.

Define key concepts

The framework seeks to create clear, operationally applicable definitions of key concepts that have been inconsistently defined in the literature to date:

- Digitalization in work contexts: It goes beyond simple models of technology adoption and understands digitalization as a multi-layered process involving automation technologies, digital platforms, communication tools, monitoring systems, and algorithmic management that are changing work design, work processes, and workplace relationships (Reimann & Tisch, 2021; Phillipson, 2019).
- Employment inequalities in older age: Inequalities are understood as a multidimensional phenomenon encompassing differences in access to employment, job quality, career

development, workplace treatment, and job security of older workers (Wang, Zhang, & Feng, 2024; Street & Ní Léime, 2019).

- **Older workers:** This population cannot be defined solely by chronological age, but through the intersection of age-related workplace experiences, career stages, and societal age norms that shape employment opportunities and constraints (Fernández-Ardèvol, Rosales, & Morey, 2020).
- **Digital divide and digital inclusion:** Goes beyond access-based definitions to encompass the full spectrum of digital inequalities, including motivation, physical access, digital skills, and usage patterns that affect older workers' ability to benefit from digitalization (van Deursen & van Dijk, 2019; van Dijk, 2012).

Establish relationships between concepts

The framework maps the complex relationships and pathways through which digitalization affects employment inequalities in older age:

- **Mediating mechanisms:** Identifying how digitalization affects older workers through changes in job design, skill requirements, social relationships, and labor market demand (Pak, Renkema, & van der Kruijssen, 2023; OECD, 2019).
- **Moderating factors:** Examining how individual characteristics (digital skills, health status, education), organizational factors (digital leadership, inclusive practices, training), and societal contexts (policy frameworks, cultural age norms, labor market conditions) influence the relationship between digitalization and employment outcomes (Halford et al., 2015; Finsel, Wöhrmann, & Deller, 2023).
- **Feedback:** Recognizing that the relationship between digitalization and employment inequalities is dynamic, with digital workplace practices both responding to and reinforcing existing age inequalities (Pfeil, Arjan, & Zaphiris, 2009; Tisch, 2022).
- **Intersectional dynamics:** Understanding how the impact of digitalization on employment inequalities varies across subgroups of older workers, particularly in terms of gender, class, race, and employment status (Halford et al., 2015; Neves, Silva, Martins, Neve, & Bem-Haja, 2022).

Identify gaps in current knowledge

The framework systematically identifies critical gaps limiting current understanding and effective interventions:

- **Theoretical gaps:** Research is often isolated across disciplines, with limited integration of technological, organizational, economic, and gerontological perspectives (Finsel, Wöhrmann, & Deller, 2023; Hedge, Borman, & Lammlein, 2006).
- **Methodological limitations:** Predominance of cross-sectional studies, exclusion of digitally disadvantaged groups, and insufficient measurement of multidimensional phenomena (Fernández-Ardèvol, Rosales, & Morey, 2020; Czaja et al., 2006).
- **Lack of longitudinal data:** Limited research tracking the impact of digitalization on career trajectories and long-term work outcomes (Barth, 2023; Tisch, 2022).

- Challenges in policy translation: Lack of frameworks linking individual findings to organizational and policy interventions (OECD, 2019; Finsel, Wöhrmann, & Deller, 2023).
- Intersectional gaps: Insufficient attention to differences between subgroups defined by gender, race, class, or occupational status (Halford et al., 2015; Neves et al., 2022).
- Global and cultural contexts: Research predominantly in advanced Western economies, limited applicability in other contexts (WHO, 2017; ILO, 2016).

This conceptual framework provides a foundation for a comprehensive understanding of how digitalization shapes employment inequalities in older age. By clearly defining key concepts, mapping their relationships, and identifying critical gaps, the framework paves the way for the development of theoretical understanding and practical interventions. Emphasizing multi-level analysis, intersectional perspectives, and policy translation allows us to bridge the research-policy gap that has so far limited addressing the digital inequalities of older workers.

3. Analytical dimensions

The analytical dimensions represent key areas to explore to understand how digitalisation impacts on labour inequalities in older age, focusing on policy interventions and digital literacy initiatives as key mechanisms for addressing the identified inequalities (OECD, 2019; Finsel, Wöhrmann & Deller, 2023). The framework is structured around five interrelated dimensions operating at the individual, organisational, sectoral and societal levels, with their interactions revealing the complex pathways through which inequalities arise, persist or can be reduced. The first dimension – policy responses and governance frameworks – includes government, institutional and regulatory interventions aimed at the employment of older workers in a digitally transformed environment, including active labour market policies, digital skills development programmes, job search services, financial incentives for employers, lifelong learning policies, social protection, adaptations of pension systems, unemployment support, health and labour policies, legal protection against discrimination and ensuring digital rights, work arrangements and data protection, as well as regulation of digital platforms, algorithmic liability, accessibility and quality standards for digital training (European Commission, 2020; ILO, 2019; Age Platform Europe, 2021; European Union, 2022; Phillipson, 2019). The second dimension – digital literacy initiatives and skills development – includes formal and informal educational programs, training, mentoring, peer learning, community learning, independent study, on-the-job training, job rotation, collaborative projects, and personalized approaches with individual plans, multimodal methods, culturally sensitive approaches, and training for the different abilities of older workers (van Deursen, Helsper, & Eynon, 2016; Czaja & Sharit, 2009; UNESCO, 2018; Kaplan, Henkin, & Kusano, 2002; Pak, Renkema, & van der Kruijssen, 2023; Rogers, Fisk, McLaughlin, & Pak, 2005; van Dijk, 2012). The third dimension – organizational practices and workplace culture – includes HR practices with age-inclusive recruitment, performance appraisal, career development, employee retention strategies, participatory technology design, user-friendly interface, gradual technology introduction, technical support, organizational climate supporting learning, error tolerance, knowledge sharing, innovation, intergenerational team composition, communication, social support and management training (Kunze, Böhm & Bruch, 2011; Shore et al., 2011; Kooij et al., 2010; Tisch, 2022; Wang, Zhang & Feng, 2024; Choi & Kim, 2021). The fourth dimension – individual characteristics and resources – includes demographic and educational aspects, work history, cognitive and physical abilities, health status, learning preferences, motivation, attitudes towards technology, self-efficacy, career goals, work values, social capital, economic resources, family and community support, and previous experience with technology (Dannefer, 2003; Baltes & Baltes, 1990; Calasanti & Slevin,

2001; Czaja et al., 2006; PsyArXiv, 2022; Ryan & Bauman, 2016). The fifth dimension – sectoral and economic context – takes into account sector specificities and market conditions, including the digitalization of manufacturing, services, knowledge work, platform work, demand and supply of skills, job creation and destruction, job quality and wages, regional disparities, availability of digital infrastructure, innovation ecosystems, investment in human capital, economic stability, competitive and regulatory environment, sectoral standards and global economic forces (Barth, 2023; Reimann & Tisch, 2021; Parker & Gerbasi, 2022; OECD, 2019; World Bank, 2019; ILO, 2019). Interactions between dimensions create feedback loops and multiplier effects, where policy responses influence individual experiences through the provision of resources, opportunities, and norm-setting, while individual characteristics influence policy effectiveness, organizational practices are shaped by sectoral context, and successful development initiatives change workplace culture (Pfeil, Arjan & Zaphiris, 2009; Hedge, Borman & Lammlein, 2006; Halford et al., 2015). Critical patterns of interactions include cycles of reinforcing advantage, compensatory mechanisms, threshold effects, and the importance of timing and sequencing of interventions (Marmot, 2005; Truxillo et al., 2012; WHO, 2017; Neves et al., 2022). Policy responses are a central lever for addressing inequalities, as they influence all other dimensions, shape organisational behaviour, enhance individual capacities, influence sectoral transformations and coordinate multi-level activities (OECD, 2019; Finsel, Wöhrmann & Deller, 2023). Digital literacy is a key building block as it addresses the primary mechanisms by which digitalisation creates disadvantage and is most effective when it links skills development to work outcomes, takes into account the heterogeneous needs of older workers, is integrated with organisational support and is aligned with the policy framework (van Deursen, Helsper & Eynon, 2016; UNESCO, 2018; van Dijk, 2012; G. van Dijk, 2012; European Commission, 2021). This multidimensional approach provides a systematic framework for identifying key intervention points, uncovering interaction effects, guiding empirical data collection, designing comprehensive interventions, and evaluating the effectiveness of policies to create fairer working conditions for older workers in the digital era.

4. Theoretical foundations

The digitalization of the workplace has a major impact on employment inequalities for older workers. This impact cannot be adequately analyzed by a single theoretical approach, so the working group integrates insights from gerontology, organizational psychology, sociology, economics, and science and technology studies (STS), creating a multilevel and intersectional framework (Finsel, Wöhrmann, & Deller, 2023; Halford, Kukarenko, Lotherington, & Obstfelder, 2015). Social capital theory, developed by Bourdieu (1986), Coleman (1988), and Putnam (2000), shows how relationships and networks influence older workers' experiences of digitalization. Bourdieu emphasizes the interplay of social, cultural, and economic capital that can support or hinder adaptation to digital technologies. Coleman's theory of social closure and collective efficacy explains how intergenerational collaborative work cultures support digital learning, and Putnam distinguishes between bonding and bridging capital, which is important for connecting older workers with younger colleagues (Ryan & Bauman, 2016; Wang, Zhang, & Feng, 2024; Choi & Kim, 2021). The digital divide has evolved from a focus on physical access to technology to multi-level models that include motivation, material access, digital skills, and usability (van Dijk & Hacker, 2003; van Deursen & van Dijk, 2019; van Dijk, 2012). For older workers, barriers can include technological anxiety, limited access to devices, and insufficient digital skills. The intersectional approach shows that age interacts with gender, class, education, and other categories to produce specific patterns of digital advantage and disadvantage (Crenshaw, 1991; Calasanti & Slevin, 2001). The workforce adaptation model uses life-cycle theory and the SOC model (Baltes & Baltes, 1990), which suggests that older workers adapt selection, optimization, and compensation strategies to cope with digital demands. The job demands and resources (JD-R) model shows that digital technologies can present new demands but also provide resources that support performance and

well-being (Bakker & Demerouti, 2007; Tarafdar, Tu, Ragu-Nathan, & Ragu-Nathan, 2007; Reimann & Tisch, 2021). Technology acceptance models, particularly TAM and UTAUT, identify factors influencing technology adoption, such as expected performance, ease of use, social pressure, and support (Davis, 1989; Venkatesh, Morris, Davis, & Davis, 2003; PsyArXiv, 2022). Critical gerontology argues that age is socially constructed and that stereotypes and ageism influence older workers' experiences with digitalization (Estes, Biggs, & Phillipson, 2003; Palmore, 1999). The political economy of aging analyzes the impact of market structures, organizational strategies, and policy frameworks on digital employment opportunities for older people (Estes, 1979; Phillipson, 2019; Barth, 2023; OECD, 2019). STS perspectives emphasize that technologies are not neutral but shaped by social and institutional factors, and that adaptation involves collaboration between human, nonhuman, and institutional actors (Bijker, Hughes, & Pinch, 1987; MacKenzie & Wajcman, 1999; Woolgar, 1990; Latour, 2005; Callon, 1984). The working group's integrated framework connects these theories at three levels: individual (SOC, TAM, social capital), organizational (JD-R, STS), and societal (critical gerontology, political economy, digital divide). It also includes dynamics over time (life-course perspective, historical context, future orientation) and intersectional analysis to understand how inequalities accumulate across different social categories and contexts (Kozłowski & Klein, 2000; Van de Ven & Poole, 1995; Elder, 1998; Mannheim, 1952; Neves, Silva, Martins, Neve, & Bem-Haja, 2022; Collins & Bilge, 2016; Sampson & Laub, 1997; McCall, 2005). This framework allows for the connection of empirical research with the design of interventions, supports a participatory approach and a long-term strategy to reduce the digital inequalities of older workers, both at the organizational and policy levels (WHO, 2017; Pawson & Tilley, 1997; Bjögvínsson, Ehn, & Hillgren, 2012; ILO, 2016).

5. Proposed framework

The conceptual framework for examining the impacts of digitalisation on employment inequalities for older workers is a hierarchical five-level model, where policy measures play a central role, influencing all other dimensions (Czaja et al., 2019; Van Dijk, 2020). The model integrates insights from several disciplines and allows for an understanding of the complex processes through which digitalisation affects the work experiences of older workers (OECD, 2021; Eurofound, 2020).

The highest level includes policy and governance frameworks, which include active employment policies, social protection, anti-discrimination legal frameworks and regulation of digital technologies. Policy creates conditions for inclusion, coordinates actions across levels, addresses market failures and supports innovation (ILO, 2022; European Commission, 2021). The second level presents analytical dimensions: digital literacy initiatives, organisational practices and sectoral context. Digital literacy enhances individual capabilities, supports lifelong learning and intergenerational knowledge exchange (Ng, 2012). Organizational practices translate policy into the workplace environment, influencing technology implementation, work culture, and social integration (Morgeson & Humphrey, 2008). Sectoral context shapes the broader economic environment, determining the pace of digitalization, and infrastructure (Autor, 2015; Arntz et al., 2016). The third level includes individual characteristics and resources that mediate the influence of contexts on outcomes, including demographics, cognitive and physical abilities, motivation, attitudes, and social and economic resources (Bandura, 1997; Lifshitz et al., 2021).

The fourth level includes mediating processes: social capital, technostress, digital processes, intergenerational learning, and age-friendly work design, which influence how individuals experience digitalization (Bonsang, 2009; Tarafdar et al., 2015). At the fifth level are outcomes, including employment inequalities, successful aging at work, and digital inclusion (Ng & Feldman, 2015; Van Dijk, 2020).

Hypotheses

Policy Level

- H1: Policy Comprehensiveness – Comprehensive policies, covering multiple dimensions, reduce employment inequalities more than unilateral interventions.
- H2: Policy Coordination – The effectiveness of digital literacy depends on coordination with organizational and sectoral policies.
- H3: Policy Timing – Proactive policies before digitalization changes are more effective than reactive ones.

Digital Literacy

- H4: Multimodal Learning – Combined forms of learning (training, mentoring, internships) increase retention and transfer of skills.
- H5: Intergenerational Learning – Intergenerational learning improves the skills of older workers and the knowledge of younger ones.
- H6: Contextual Relevance – Job-relevant training increases employability more than general courses.

Organizational Level

- H7: Age-Inclusive Culture – Organizations with inclusive cultures show smaller age differences in adaptation to technology.
- H8: Participatory Design – Involving older workers in the design of technologies increases adoption and reduces technostress.
- H9: Managerial Support – Managerial support moderates the relationship between skills and performance.

Individual level

- H10: Resource Accumulation – Higher social capital, financial resources and experience increase adaptation to digitalization.
- H11: Self-Efficacy Mediation – Self-confidence in using technology mediates the effect of training on performance.
- H12: Intersectionality – The impacts of digitalization vary by the combination of age, gender, race and class.

Sector and context level

- H13: Sectoral Variation – The impact of digitalization varies across sectors according to the intensity of digitalization.
- H14: Regional Infrastructure – The quality of digital infrastructure moderates the effectiveness of inclusion interventions.
- H15: Labor Market Tightness – A tight labor market increases the effect of digital skills on employability.

Processes and mechanisms

- H16: Social Capital Mediation – Social capital mediates the effect of organizational practices on adaptation.
- H17: Technostress Moderation – Individual and organizational support mitigates the negative impacts of technostress.
- H18: Generativity Activation – Mentoring and knowledge sharing improve technology adaptation and acceptance.

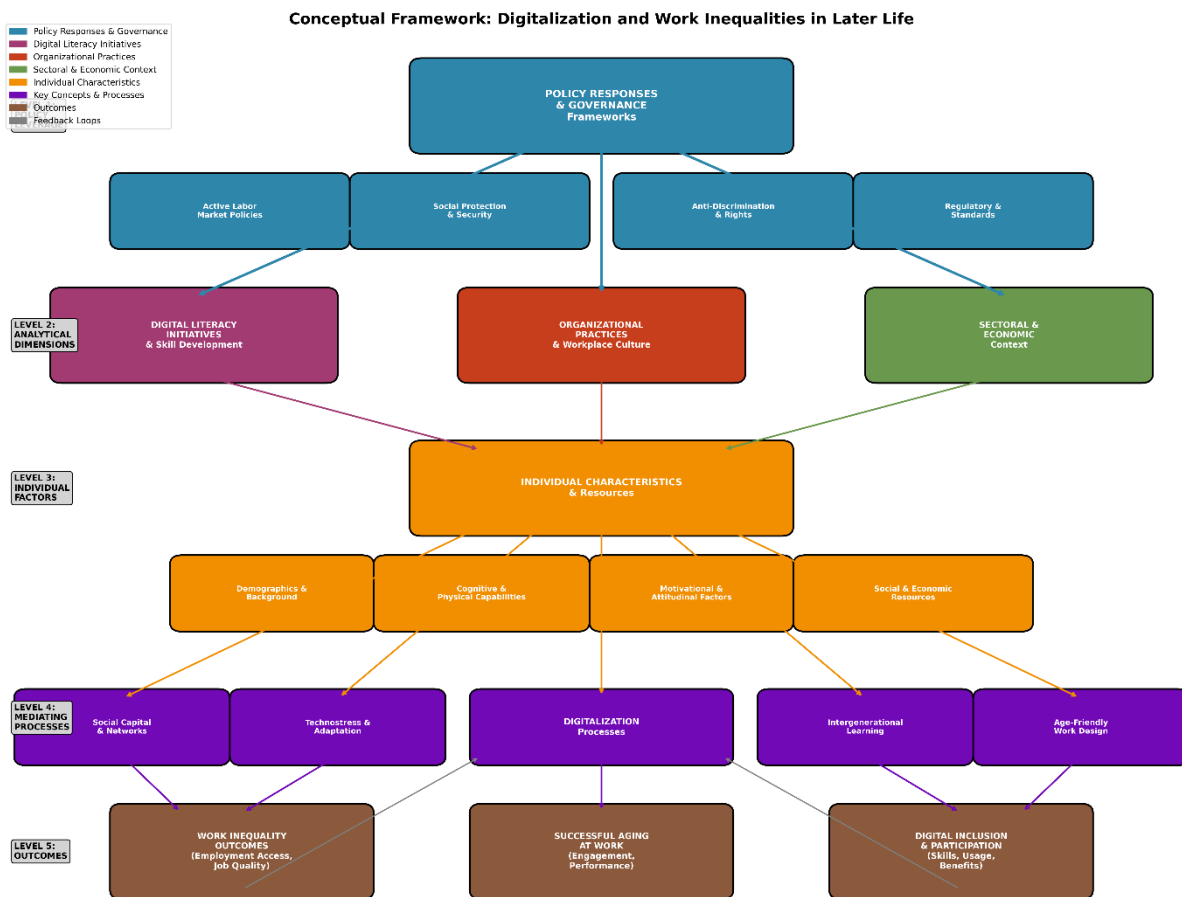
Developmental and Longitudinal Hypotheses

- H19: Adaptation Trajectory – Adaptation to digitalization follows predictable trajectories that can be influenced by interventions.

- H20: Cumulative Advantage – Initial advantages in digital adaptation accumulate, widening inequalities.

Methodology and Applications

The framework requires multi-level, longitudinal and mixed methods to test hypotheses and capture complex interactions (Bryman, 2016). It provides practical guidance for the design of digital literacy policies, organizational strategies and programs with an emphasis on participatory and long-term sustainable approaches (European Commission, 2021; OECD, 2021).



Source: WG 4 members based on literature review

6. Methodological approach

The development of this conceptual framework for understanding the impacts of digitalization on employment inequalities for older workers used a comprehensive multi-methodological approach that integrates different research methodologies across disciplines. This methodological pluralism was necessary given the complexity of the phenomenon under study and the need to connect theoretical insights from different fields with empirical evidence from different contexts. The approach was guided by the principles of systematic integration of evidence, interdisciplinary synthesis, multi-level analysis, international scope, and linking theory with practical applications in

policy and organizations. The literature search used the principles of systematic review to identify, evaluate, and synthesize existing research on digitalization and older workers across disciplines and contexts. The searches were conducted in the databases PubMed, PsycINFO, Web of Science, Scopus, EconLit, and Sociological Abstracts, including grey literature and specialized gerontological and technology resources. Combinations of keywords related to digitalization, older workers, and employment inequalities were used. Inclusion criteria included publications between 2010–2025, empirical and theoretical studies focusing on workers aged 50+, peer-reviewed articles and government reports, while studies without a workplace focus or prior to digitalization trends were excluded. Due to the interdisciplinary nature of the topic, a scoping review was also used to map the breadth of approaches and identify conceptual gaps according to the framework of Arksey and O'Malley (2005). A meta-narrative review allowed us to understand how different disciplines – gerontology, organizational psychology, labor economics, sociology and science and technology studies – are investigating the topic and how their findings can be integrated (Pawson et al., 2005). For emerging topics with limited literature, in particular policy initiatives, the impacts of COVID-19, the platform economy and new technologies, rapid evidence assessment techniques were used with quality assessment using CASP, Newcastle-Ottawa Scale, ROBIS and GRADE. The empirical part included the analysis of secondary data from ESS, SHARE, HRS and ISSP, as well as administrative data on labour force, training participation and social protection, using analytical methods such as multilevel modelling, longitudinal analysis, propensity score matching and decomposition analysis. Primary data were collected through qualitative methods, including interviews, focus groups, case studies and interviews with policymakers, and quantitative methods, such as questionnaires and training evaluations, with the integration of mixed methods through triangulation, sequential explanatory design and a transformational framework with an emphasis on inequality and power relations. Advanced analytical techniques included machine learning, text mining, cluster analysis, predictive modelling, network analysis and causal inference methods, including instrumental variables, regression discontinuity and difference-in-differences. The international comparison used comparative case studies of selected countries with different levels of digitalization, policies for older workers and institutional and cultural contexts, complemented by institutional analysis according to the Varieties of Capitalism and welfare state typologies (Hall & Soskice, 2001; Esping-Andersen, 1990) and policy diffusion analysis (Dolowitz & Marsh, 2000), taking into account multi-level governance at EU, national and regional levels (Hooghe & Marks, 2001). Interdisciplinary methods included theoretical integration across paradigms, conceptual mapping and synthesis, linking quantitative and qualitative data, participatory methods including advisory panels, co-design workshops and validation with participants, and a systems approach, including systems mapping, feedback identification and agent-based modelling. Quality assurance was achieved through protocol registration, transparency, reproducibility and inter-rater reliability testing, with validation through triangulation, member checking, peer review and replication, while ethical principles including IRB approval, informed consent, GDPR and protection of vulnerable populations were adhered to. Limitations and challenges included data limitations (geographic, sector and time biases), methodological difficulties in interdisciplinary integration, language barriers and issues with causal inference, as well as practical constraints including limited resources, time pressures and access to data. Methodological innovations consisted of an integrated framework with multi-level integration and dynamic process modelling, meta-narrative integration, theory linkage, use of digital methods, machine learning, simulations and participatory methods, with practical benefits including rapid evidence synthesis, implementation science, capacity building and international collaboration. This comprehensive methodological approach has enabled the connection of theory with practice and provides a model for researching complex phenomena that require integration across disciplines and levels of analysis.

7. Implications and applications

The conceptual framework for understanding the impacts of digitalisation on employment inequalities for older workers provides practical guidance for different areas of practice and policy and can be used to address real-world problems, with an emphasis on the benefits for policy-making, organisational strategies and public awareness-raising initiatives. The multi-level and integrated approach of the framework offers concrete solutions to the complex challenges identified in the reports of Working Group 4. In the area of policy-making, the framework enables the systematic development of comprehensive policies that simultaneously address the impacts of digitalisation on older workers across multiple domains, for example by mapping existing policies, planning integrated packages of measures and aligning stakeholders at EU, national, regional and local levels. The testable hypotheses of the framework provide a basis for evidence-based policy prioritisation, for example by identifying high-impact interventions, interventions with cascading positive effects and targeted measures in places with under-coverage. The framework also supports the coordination of policy implementation across levels and sectors, including vertical and horizontal integration and the timing of interventions, and provides tools such as implementation maps, coordination protocols and performance indicators. Stakeholder engagement is systematic and includes key actors such as older workers, employers, unions and training providers, as well as secondary and political stakeholders, using co-policy making processes, partnership approaches and feedback. In policy evaluation and adaptation, the framework enables the design of evaluations based on a theory of change, the measurement of outcomes across all dimensions of the framework and the monitoring of implementation processes, using methods ranging from randomised controlled trials to natural experiments and longitudinal follow-up. The dynamic approach of the framework supports adaptive policy management, continuous learning, flexible implementation and support for innovation, including networks for sharing experiences, evidence synthesis and international benchmarking. In the area of organisational strategy, organisations can use the framework to develop age-inclusive digital strategies that take into account the needs of older workers and exploit their benefits, for example through age-specific impact assessments, inclusive technology design, mentoring, multimodal training and support for lifelong learning. The framework also provides a basis for building a business case for age-inclusive digital practices, including improving innovation, preserving knowledge, gaining competitive advantage and mitigating risks. In the area of HR, the framework supports inclusive recruitment, selection, training, development and performance appraisal systems, including intergenerational learning programmes, reverse mentoring and fair remuneration. Transforming organisational culture according to the framework includes developing leadership that supports older workers, reducing age bias, participatory implementation of change and supporting innovation and knowledge management through cross-generational teams and systematic knowledge transfer. To raise public awareness, the framework provides a basis for creating counter-narratives and campaigns that reduce stereotypes, promote lifelong learning, digital inclusion and intergenerational understanding, targeting various groups from the public to employers and older and younger workers, and recommends strategic media and communication approaches. The framework also addresses specific challenges identified by Working Group 4, including the lack of research-policy linkages, fragmented responses, limited evidence of policy effectiveness, insufficient consideration of the implementation context and limited stakeholder engagement, and offers a systemic solution through context-sensitive policy design, multi-level governance mechanisms, implementation science, stakeholder engagement and participatory development. The implementation of the framework is divided into phases: building foundations, piloting and scaling up and refining, with success measured using indicators at the policy, organisational, individual and societal levels, including policy complexity, coordination, digital skills of older workers, inclusive working practices, intergenerational collaboration, job satisfaction and public awareness. The practical application of the framework lies in connecting theory and practice, coordinating comprehensive

interventions, supporting evidence-based decision-making and enabling continuous learning and adaptation, thereby contributing to the creation of more inclusive and equitable digital workplaces that fully exploit the potential of workers of all ages.

8. Limitations and areas for further research

Although the conceptual framework for understanding the impacts of digitalization on employment inequalities in older age represents a significant advance in theoretical integration and practical application, its current limitations need to be acknowledged and areas for further research identified. The framework is still heavily focused on Western contexts, formal employment and current technological trends, which limits its applicability in different cultural, institutional and economic settings, including developing countries, the informal economy, platform and flexible forms of work and remote locations. Current empirical evidence is often based on cross-sectional studies, which makes it difficult to identify causal relationships and monitor dynamic processes, and some groups, such as migrants, people with disabilities, low-skilled workers, minorities or workers in sectors with unique characteristics, are underrepresented. Theoretically, the framework integrates different paradigmatic approaches, which can lead to internal tensions, complications in connecting the micro- and macro-levels, and its relative complexity, which makes it difficult to implement, communicate, and empirically test all relationships. Future research should therefore systematically focus on expanding the geographical and cultural scope, adapting the framework for development and informal contexts, longitudinal and causal studies, intersectional and diversity analyses, research on the impacts of new technologies, innovations in policy and organizational approaches, methodological development, and strengthening interdisciplinary collaboration. At the same time, it is necessary to build a robust infrastructure for long-term data, support for researcher capacity, ethically involve older workers in research, and a participatory approach to ensure that the results correspond to real needs. The aim is to gradually develop a more sophisticated, culturally sensitive and practically relevant understanding of how to promote a more equal and inclusive digital work environment for workers of all ages, with active collaboration between researchers, policymakers, organisations and older workers themselves being key to ensuring effective and sustainable interventions that take into account the dynamics of digitalisation, demographic changes and the specificities of individual work and cultural contexts.

9. Conclusion

The conceptual framework for understanding the impacts of digitalisation on employment inequalities in older age represents a significant step forward in addressing the complex challenges identified by Working Group 4 in the area of digital literacy policy measures and initiatives. Its main contribution lies in integrating hitherto fragmented theoretical perspectives from gerontology, organisational psychology, labour economics, sociology and science and technology studies into a coherent, multi-level model that allows for an understanding of the complex interactions between the individual, the organisation, the sector and policy, and the dynamics of the co-evolution of technologies and social systems. The framework supports evidence-based policy-making by systematically synthesising empirical data from different contexts, identifying knowledge gaps, formulating testable hypotheses and proposing practical interventions that are sensitive to the cultural, institutional and economic context. It also enables coordinated collaboration between multiple actors – from older workers, employers and trainers to policy makers – and supports partnership and participatory approaches in developing and implementing solutions. The framework also supports innovation in digital inclusion and the development of digital literacy, in particular through intergenerational learning and the integration of training into real work processes. A key value is the ability to deliver targeted, adaptive and personalised interventions that take into account the heterogeneity of the older workforce, identify at-risk groups, optimise the timing and intensity of measures and enable continuous improvement through feedback. The

strategic imperatives of the framework include immediate actions in policy and organisational practice, medium-term system building, scaling innovation and a long-term vision of transformation towards an age-inclusive digital society, supporting intergenerational collaboration, lifelong learning and sustainable development. The framework is not a static tool but a living guide, the effectiveness of which depends on the collaboration, creativity and engagement of all actors involved, and provides a path towards digital workplaces that enhance equality, inclusion and meaningful participation of workers of all ages.

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