# Toward Ubiquitous Learning for Adults: Opportunities Enabled by Artificial Intelligence

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**Abstract**

*Adult learning and continuous upskilling throughout the life course are essential conditions for active citizenship and workforce adaptability. Within the European Education strategic framework, a target has been set for at least 60% of adults aged 25–64 to have participated in learning activities during the previous 12 months by 2030. However, according to the European Commission's Education and Training Monitor 2025, adult participation in learning stood at only 39.5% in 2022. Against this backdrop, this paper explores how digital technologies in general and artificial intelligence in particular, may prefigure a ubiquitous and engaging learning experience for adult learners, provided that effective strategies for orientation and personalization are implemented and that a multidimensional interpretative pedagogical paradigm is adopted.*

**Keywords:** *personalization, IA, ubiquitous learning, complex learning, adult learning*

## Introduction

The European Pillar of Social Rights Action Plan increased its ambition by setting a target of 60% of adults aged 25–64 participating in learning within the previous 12 months by 2030, up from 47%. However, the *Education and Training Monitor 2025* [14] reports that participation reached only 39.5% in 2022. Similarly, the *Survey of Adult Skills (PIAAC) 2023* [40] shows an average rate of 40.8% across 20 EU Member States, broadly consistent with 2022.

The OECD report *Trends in Adult Learning 2025* [39] identifies key barriers to participation. The main obstacle is lack of time due to work and family responsibilities (48%), followed by limited suitable training (14%) and financial costs (13%). These constraints reduce motivation and willingness to engage. Negative experiences in formal education also discourage many adults.

A recent literature review [44], based on data from 2000–2025 across multiple Countries, groups barriers into three categories: situational, institutional and personal. Situational barriers include work–study conflicts, life–work balance issues, time limits, and financial constraints. Institutional barriers involve organisational inflexibility, limited interaction or social isolation, and technological or access difficulties. Personal barriers mainly concern low self-confidence and fear of failure.

Additionally, adults often experience confusion when navigating training opportunities. Many have established careers and routines shaped by specific life trajectories, habits and learning strategies, which can limit access to standardised or rigid pathways.

Against this backdrop, this paper explores how digital technologies, particularly artificial intelligence, can support more ubiquitous, flexible and engaging learning for adults. This potential depends on effective orientation and personalisation strategies, as well as a multidimensional pedagogical paradigm capable of addressing the complexity of adult learning trajectories.

## 1. Adult Learning Personalization Requirements

To increase adult participation in formal and non-formal learning, a shift in prevailing educational paradigms is needed. One response is adopting a framework that promotes ubiquitous, flexible, and engaging learning experiences. Such a framework should rely on personalization strategies and a multidimensional pedagogical approach capable of addressing the complexity of adult learning trajectories. This perspective can better align provision with learners' needs while supporting target achievement.

Personalizing learning is challenging, as it requires adapting pathways to learners' characteristics, needs, and dispositions. Drawing on the andragogic framework [28], this implies a learner-centred approach based on adult learners' key traits:

- need to understand why they must learn something;
- see themselves as self-directed and responsible for their choices;
- use prior experience as a resource;

- become ready to learn when facing real-life demands;
- face task-oriented and problem-centred assignments;
- are are primarily motivated by internal factors such as self-esteem, professional fulfilment and quality of life.

Accordingly, learning environments should help adults recognize and valorize prior experiences and actively co-design their pathways. Practical relevance and applicability should guide training, connecting it to everyday contexts, integrating informal learning and reducing disengagement [41].
Despite its complexity, a personalized approach produces positive outcomes, especially for learners with interrupted or negative educational experiences, enhancing accessibility and inclusion. However, it is time-consuming, requiring data collection, assessments and skilled trainers able to design learner profiles and tailored pathways, an even greater challenge in group settings.
Today, AI-driven solutions significantly ease this process [46] [63]. AI tutoring applications combine flexibility, adaptability and learner agency through dialogic interaction, aligning with personalized learning principles. Algorithms enable customization based on individual needs, preferences, and pace [1] [34]. Unlike general chatbots, AI tutoring systems dynamically generate and adapt study plans, functioning as learning contracts within a dialogic framework [45]. They adjust task difficulty to learner performance, guiding practice through reinforcement while identifying errors formatively [3].
Rather than replacing human guidance, AI-based personalization amplifies the Zone of Proximal Development theorized by Vygotsky [61], traditionally supported by tutors or peers. Unlike human instructors, it operates without fatigue. These solutions, often freely available, range from simple tools to advanced systems, making learning more inclusive, accessible and effective while enabling learners to fully develop their potential.

## 2. Learning in the Ecosystem

The extraordinary potential of AI-based technologies in enhancing personalized learning nonetheless faces a structural limitation: it remains confined within the interactional boundaries of the device through which it operates. AI-driven learning applications often become self-contained systems, reproducing, albeit in new forms, the traditional boundaries of the classroom. This limits their ability to support truly lifelong learning grounded in adult needs, fostering self-direction, integrating informal and non-formal dimensions, and aligning with learners' biographies and daily lives. Even with advanced AI, the "rear-view mirror syndrome" described by McLuhan [36] reappears, without breaking the "fourth wall" theorized by Pirandello: a necessary condition for making learning genuinely interactive. This requires overcoming fixed roles and structures, to reflect the fluid nature of adult learning.
The concept of a learning ecosystem, as framed by Bronfenbrenner [10], is crucial to reach this aim: technology is only one component of a broader system shaped by interactions among institutions, contexts (formal, non-formal, informal) and the relationships between subjects, objects, times, and places of learning [30]. Within this system, AI tutoring applications act as active agents alongside human participants.
Transforming learning into a personalized, adaptive lifelong process within a ubiquitous ecosystem requires rethinking these categories and their relationships. The goal is to map and connect learning environments, physical and virtual, to design personalized pathways. Urban spaces frequented by adults become not just contexts but "learning activation devices," serving as nodes in continuous educational networks.
One could envision a distributed network of "learning dashboards," connecting diverse environments such as fast-food venues, shopping centres, archaeological sites, natural areas, libraries, schools, businesses, travel agencies, sports centres or bookstores. While once utopian, early initiatives like the ARIADNE project [15] in the 1990s explored interoperable platforms for adaptive learning, laying the groundwork for flexible, modular environments during the growth of the web.
Today, AI strengthens these connections, enabling not only interconnected resources, but integrated ecosystems and personalized pathways. Interoperability expands beyond technology to include experiential and contextual dimensions, forming dynamic systems that adapt to individual needs.
The sense of disruption that this vision can create reflects the scale of the paradigm shift driven by AI. Overcoming the "rear-view mirror syndrome" means moving from accumulation-based models to those based on distribution and flow. In this sense, Serres, in *C'était mieux avant!* [49], captures this transformation: what was once concentrated is now diffused and circulating.
Within this framework, learning may begin in informal or non-formal contexts and later be formalized within institutions, creating a virtuous circular relationship among diverse learning environments.

### *2.1 Breaking the "Fourth Wall": A Possible Application*

Widespread museum initiatives embody the concept of a ubiquitous learning ecosystem, connecting diverse cultural environments, physical and virtual, and fostering synergies among formal, non-formal, and informal actors in urban and rural contexts, integrating learning into spaces frequented by adults [16] [32].

Consider a daily commute. In a city like Rome, even a short journey reveals rich historical stratification: passing the Pyramid of Cestius, skirting Porta San Paolo, once part of the city walls (275 AD) and later a site of resistance, and walking alongside the Non-Catholic Cemetery, resting place of poets and intellectuals. One might also encounter an early "Casa dei Bambini" founded by Maria Montessori. This brief route encapsulates multiple eras, showing how urban space can act as a pervasive cultural environment and learning device. Similar dynamics exist also in rural contexts, offering rich links between space, memory and education.

The widespread museum provides diverse stimuli within an ecosystem enabling informal and non-formal learning across cultural, naturalistic and recreational domains. However, the relevance of each stimulus depends on the learner's biography, experiences and dispositions. For this reason, connections among environments and stimuli should extend across broader urban spaces.

Learning pathways may activate in everyday contexts such as supermarkets, theatres, libraries, bookstores and fast-food venues, as well as sport and leisure spaces. These familiar environments offer opportunities to leverage informal learning. Digital displays at bus stops or kiosks and interactive interfaces could embed access to a learning tour.

These spaces can be interconnected nodes in a hybrid, dynamic, reconfigurable network. Ecosystems inspired by the diffused museum paradigm, enhanced by digital technologies, then reflect real-world complexity. Learners play an active role in perception, interpretation, and knowledge construction, processes that unfold through cyclical and interconnected dynamics rather than linear sequences.

Such environments align with andragogic principles: experiential, meaningful, interest-driven, self-directed and oriented toward mastery [11]. However, learning in natural contexts emerges from dynamic, sometimes serendipitous interactions between learner and environment [47] and is not fully predictable. This requires moving beyond linear models; accept the unexpected, toward deeper engagement and meaning, enabling flexible, personalized trajectories.

AI-based learning systems make these transformations increasingly feasible. They support adaptive, dialogical experiences calibrated to learners' knowledge and pace, extending learning beyond classrooms and reinforcing the concept of the Personal Learning Environment [51] [62].

At the same time, such ecosystems are more complex than traditional classrooms, increasing cognitive load and requiring strong metacognitive skills. Moreover, effective learning does not arise spontaneously: a solid pedagogical framework and structured plans oriented toward clear outcomes are necessary to ground educational stimuli.

Given this complexity, learning plans should span progressively structured levels, from individual experiences to pathways and full curricula, addressing diverse needs. While AI enables personalization at the micro-level, it remains insufficient to address the systemic and contextual dimensions of adult learning, which require an ecosystemic approach and human mediation. Within this framework, the role of the Learning Personalization Trainer remains essential, alongside a coherent pedagogical paradigm.

## 3. The Human Agency. The Learning Personalization Trainer in the AI Age

Anyone who has used an AI-based learning tutor is likely to trust this powerful ally: a system that does not tire, judge or lose patience with mistakes.

However, for personalization and guidance to be truly effective, a human agent, a Learning Personalization Trainer (LPT), with a clear pedagogical vision remains essential [52]. This agent selects appropriate solutions, designs meaningful pathways, avoids generic responses, and identifies strategies suited to diverse needs, while also experimenting with new approaches and contributing to educational innovation.

Personalization indeed, even when AI-mediated, remains a means for individual development and identity construction. It enables learners to shape their trajectories, becoming co-authors of their growth while developing metacognitive skills for autonomous learning [27] [48]. These learning trajectories, in ubiquitous learning environments, emerges through continuous negotiation with context and others, reshaping what adults build across formal, non-formal, and informal experiences. This process relies on complex cognitive connections, moving beyond linear models and producing highly individualized pathways. The LPT is crucial in guiding self-assessment and, the skills assessment [13] [59] [60] in reskilling contexts. Through interaction with the LPT, assessment becomes a reflective process

involving professional paths, learning strategies, and emotional dimensions. The human interaction with the LPT guiding self-assessment become central to support the learner autonomy.
AI enhances these dynamics: Intelligent Tutoring Systems provide adaptive guidance, adjusting pace, offering feedback, and refining strategies. They help learners monitor progress, identify next steps, and explore solutions, gradually increasing difficulty. This reduces frustration, prevents emotional blocks, and indirectly supports trainers. At the same time, managing frustration has pedagogical value. While reducing it benefits adults, especially those with negative past experiences, it can foster resilience in adolescents. In both cases, the LPT plays a key role in balancing this dynamic.
Although AI can manage personalization, informal learning risks remaining ineffective without a meaningful framework. Here, the LPT helps position outcomes within formal structures and pathways. This framework remains provisional and evolving, with the LPT supporting interpretation, integration, and planning of future learning stages aligned with ubiquitous and personalized principles.
Another key dimension is the social nature of learning. The LPT ensures learning remains connected to broader interactions and communities. Overall, the LPT adopts a learner-centred, co-constructive approach, focusing on challenges rather than predefined goals and supporting adaptive, non-standardized pathways. The process involves collaboration in defining challenges, designing pathways, and evaluating progress, with personalization tailored to learner profiles, contexts and resources.
The LPT intervention unfolds through phases such as welcoming, interviewing, needs analysis, agreement, design, support, and evaluation. Diagnostic activities integrate interviews, self-assessment tools, and AI-supported analysis. Over time, learners take ownership of their learning, developing metacognitive and transversal skills like reflection, autonomy, collaboration, and problem solving.
The LPT can also mitigates risks related to data use, algorithmic bias, and accessibility in AI systems. Since AI may reflect human biases, human-machine interaction becomes a balancing mechanism, fostering critical awareness in learners too.
Thus, the LPT plays a pivotal role in advancing personalized adult education by integrating adaptive design, learner empowerment and continuous evaluation; promotes personalization not as a purely AI-driven adaptation, but as an intentional process aimed at strengthening adult learners' capabilities. This supports both immediate outcomes and long-term competences, while AI technologies help manage the complexity of the role in terms of data, strategies, and time.

## 4. A Theoretical Framework for Ubiquitous and AI Augmented Learning for Adults: Complex Learning

Understanding and governing a learning process shaped by non-linear, emergent and constantly evolving dynamics requires a multidimensional pedagogical paradigm capable of interpreting the complexity of knowledge construction. Such a paradigm must fit increasingly dynamic, holistic, serendipitous, ubiquitous and highly personalized learning pathways unfolding in open, interactive contexts marked by unpredictability and fluidity, typical of "liquid modernity" [6]. A paradigm addressing these features must integrate multiple educational dimensions. It implies the hybridization of physical and virtual learning spaces, where traditional classroom boundaries are transcended in favour of open, interconnected environments fostering multi-channel and multi-actor interaction. In this perspective, relationships among media are reconfigured according to remediation logic [9], highlighting new hierarchies among communication tools and languages.
Another element concerns the transformation of participants' roles. In complex, collaborative environments, adult learners move beyond passive reception, exercising situated and variable leadership, acting as experts de facto in their domains and actively contributing to shared knowledge construction. From this viewpoint, knowledge develops through authentic, situated experiences grounded in dialogue and collaboration [29]. Learning assumes a cyclical, recursive structure it unfolds through phases of reflection and reinterpretation that lead to new knowledge and deeper awareness [24]. Within this framework, importance is given to representative biographies [23] and competences developed across formal, non-formal, and informal contexts [54]. Learning is thus seen holistically, as a dynamic continuum rather than a sum of discrete modules. Metacognitive competences become essential, enabling learners to plan, monitor, and regulate their learning while engaging in self-assessment and continuous reorientation. Learning pathways rely on personalization, participation and hybridization of environments, tools and communicative codes. Learners become active users and co-producers of resources within an integrated framework.
These elements converge in the Complex Learning paradigm, which interprets dialogic, networked, multi-channel learning within digital ecosystems [47] [56]. Its emergence is linked to social media, online learning communities and the growing relevance of collective knowledge systems. Through participatory and dialogic processes [5] [35], learners achieve personalized outcomes tied to their biographies and

development. Learning becomes continuous reorganization and reinterpretation of knowledge across contexts, with competences progressively recognized within formal frameworks. Early conceptualizations trace back to Linda Harasim [27], who identified Complex Learning as distinct from traditional educational models. Morin's complexity paradigm [38], emphasizing interactions between order and disorder; the transactional perspective of Garrison and Anderson [18]; and connectivism [50], which views knowledge as distributed across networks of people, technologies, and information sources well display this educational frame. Later interpretations adopted in this paper [12] [20] [21] [22] [26] [58], have framed Complex Learning as an emerging pedagogical paradigm, capable of supporting genuinely learner-centred educational processes.
Consistent with ubiquitous, personalized, and learner centred approaches, Complex Learning interprets outcomes as temporary stages in an ongoing evolutionary trajectory, where new knowledge continually becomes the basis for further development. These dynamics, initially enabled by multiple media interactions, are now amplified by AI technologies.

## 5. Future Perspectives

From an operational standpoint, the National Lifelong Learning System represents a relevant application scenario for a distributed, adaptive AI-based learning ecosystem. In Italy, the ITS Academy system [33], a higher vocational pathway parallel to higher education, offers a suitable context. An Edutech District within ITS Academies could exemplify such an ecosystem, where educational environments act as interconnected nodes linking schools, start-ups, enterprises, and regional innovation hubs. A formal cooperation among educational stakeholders, in synergy with local industries and communities, extended into urban spaces via AI-enhanced digital displays in everyday settings, could implement this educational network.
An initial step would involve designing and validating a prototype of a dynamic, holistic, serendipitous, and ubiquitous learning ecosystem, highly personalized and applied to the ITS Academy system. An AI-augmented map could embed this model in urban environments, accessible through interactive infrastructures. Many underlying components of the complex learning ecosystem have already been tested in European projects and educational initiatives (e.g., PEAPEDA FSE/OB3/C4, EQUAL Project ComuNet IT-S2-MDL-374, LLP-LDV- TOI/2009/IT/0447 DEEPER, LEADLAB - Leading Elderly and Adult Development – LAB Reference: 502057-LLP-1-2009-1-IT-GRUNDTVIG-GMP 2011 [23][25][43][20]). A new pilot phase would enable empirical validation of the framework and refinement of its methodological and technological architecture, integrating AI technologies.
To ensure feasibility and sustainability of the proposed model, human mediation remains essential. The LPT plays a key role in supporting personalized adult education, also through AI technologies. Formal recognition and institutionalization of the LPT within the professional domain of educators is needed, ensuring standardized competencies, clear roles and effective integration into existing education and training systems. In Italy, this perspective aligns with recent policy developments, such as Ministry Decree No. 328 (December 22, 2022) [37], which introduces roles like the learning personalization tutor and guidance tutor. Building on this framework, the proposed approach is well suited for scalability, adaptation, and extension to other sectors and target groups, including learners with diverse needs such as NEETs or early school leavers.
Finally, mapping environments and generating curricula within a distributed learning ecosystem can support orientation functions, integrating professional outcomes into educational design and aligning with labour market demands. The resulting model, as an adaptive educational infrastructure, could interact with social and economic systems, strengthening the link between education, employability and territorial development.

## 6. Conclusions

Despite the policy ambition of the European Pillar of Social Rights Action Plan, adult participation in learning remains well below the 60% target for 2030. As highlighted by OECD and European Commission reports, adults still face multiple barriers, including time constraints, limited access to training, financial costs and dispositional factors such as low self-confidence or negative past educational experiences. These challenges are often compounded by difficulties in navigating complex training systems, especially for adults with already established careers and life routines.
In this context, lifelong learning can no longer be seen as a phase preceding professional life but as a continuous process spanning the entire life course [55]. Educational provision must therefore align with key OECD principles [42]: a systemic vision integrating formal, non-formal, and informal learning; learner

centrality; development of learning-to-learn competences and a multi-objective conception of education evolving over time.
From this perspective, a multidimensional pedagogical approach becomes essential. The Complex Learning paradigm offers a coherent framework to interpret dialogical, adaptive, and interconnected learning processes distributed across diverse environments typical of digital ecosystems.
Overall, the framework proposed contributes to the debate on AI-supported lifelong learning ecosystems by integrating ubiquitous environments, personalized strategies and human mediation through the Learning Personalization Trainer. This approach can support more inclusive and adaptive learning infrastructures, addressing structural barriers that still limit adult participation. At the same time, it emphasizes that the primary "technology" to enhance is the human mind itself, in line with the educational vision of John Dewey and, earlier, Aristide Gabelli [17], who promoted the "*strumento testa*" as the foundation of education. Since the early reforms of the Italian school system, this perspective has aimed to foster conscious, responsible citizens capable of autonomous decisions, an objective that remains highly relevant today.

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