

Ecologies of knowledge and the drifts of learning: a pedagogical reading between organism, technique and institution

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Abstract: This study explores the evolution of university pedagogical models in response to the transformations introduced by digital technologies, focusing on the co-evolution among man, the environment, and technology. Starting from the premise that cognition emerges from the dynamic interaction between biological agents and technical artefacts, the research investigates how technologies, particularly Artificial Intelligence, affect learning. The aim is to challenge the isolationist vision of the mind and to propose a reading of learning as a distributed and embodied process that transcends traditional models of information transmission. The survey is based on a systematic review of the literature indexed in Scopus and on an empirical survey conducted through a questionnaire administered to students from different European universities. The results highlight widespread acceptance of technologies as cognitive mediators, but also raise concerns about standardisation and the loss of agency, underscoring the need for a conscious, regulated pedagogical orientation. The conclusions suggest that higher education needs to design ecologically extended learning environments that integrate smart technologies, inclusive methodologies such as flipped learning, and UDL design principles. This approach implies a pedagogy that recognises the tensions between technological substrates and teaching practices, creating spaces in which learning is embodied and co-evolves with socio-technical networks.

Keywords: ecological cognition; technical mediation; educational institutions.

1. Introduction

University teaching operates in hybrid networks in which bodies, material environments, platforms and intelligent devices contribute to the production of knowledge. This configuration weakens models that reduce cognition to the individual mind and learning to the transmission of content. Research on embodied and enactive cognition has shown the situated genesis of knowing, linked to action and perception (Varela et al., 1991; Kopcha & Ocak, 2024), while the ecological approach has clarified how the environment offers possibilities for action that direct attention and conduct (Gibson, 1979). In the pedagogical debate, the centrality of the body as an operational condition of learning finds convergent formulations in the neurophenomenological readings of movement (Berthoz, 1997; Sibilio, 2002) and in didactic elaborations on embodied learning and on the variability of contexts. The distribution of agency between human and non-human actors has been made analytically visible by actor-network theory (Latour, 2005), while critical analyses of dig-



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ital education have traced innovation back to the theme of governance and the asymmetries produced by platforms (Selwyn, 2019).

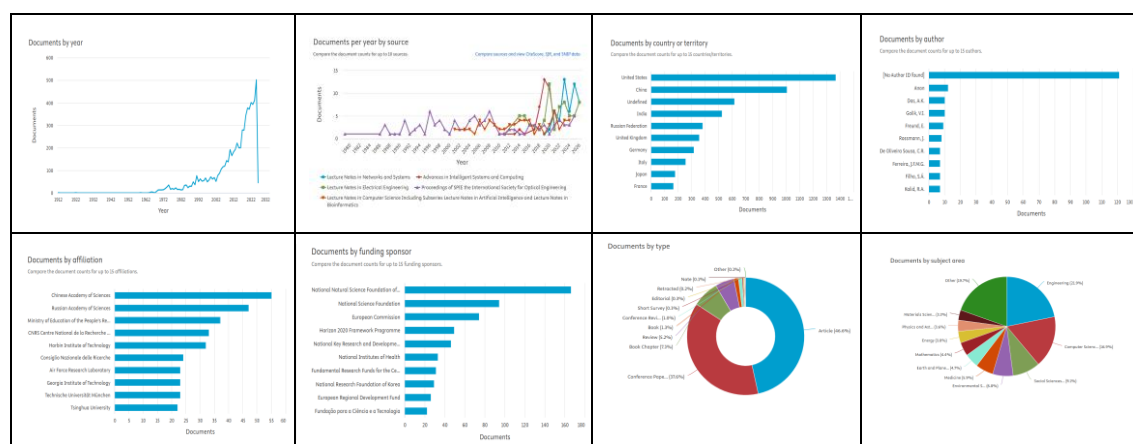
These acquisitions dialogue with a genealogy that connects experience, technique and institution. Dewey (1938) interprets education as a reconstruction of experience in the relationship with the environment; Simondon (1958) reads the technical object as part of individuation processes and transindividual dynamics; Stiegler (2008) focuses on the risk of cognitive delegation when technical outsourcing does not meet a culture of care and institutional responsibility. In Italy, reflections on the ecologies of education and digital cultures have thematised the co-evolution between educational practices and media (Rivoltella, 2024), while research on embodied education offers operational models for thinking of corporeality as a didactic and inclusive resource (Gomez Paloma et al., 2016).

Starting from these premises, the study analyses the transformation of the ecologies of learning through a systematic-exploratory review of the literature indexed in Scopus and a questionnaire addressed to European university students. The first reconstructs recent trends on the relationship between man, environment and technology in training; the second intercepts expectations and ambivalences related to agency, inclusion, standardisation and quality of experience. The results converge on a crucial point: technology is recognised as a cognitive mediator, while the demand for educational direction, transparency and institutional responsibility is growing, which guides the discussion on learning drifts and inclusive design criteria.

2. Materials and Methods

The study adopts an integrated two-phase design that combines a systematic-exploratory review of the literature indexed in Scopus with an empirical survey via an online questionnaire addressed to university students from several European countries, in line with mixed-methods and interpretative credibility criteria typical of qualitative research (Creswell & Plano Clark, 2018). The bibliographic search was conducted in Scopus using the string “man AND environment AND technologies”, applied to title, abstract and keywords, which returned about 6,800 records (Fig. 1).

Figure 1. Bibliometric overview of the Scopus corpus.



The application of the Social Sciences and Arts and Humanities disciplinary filters produced a corpus of 1,334 contributions, which was further reduced to 540 records under the 2020-2026 time limitation, including articles in press and early access. The selection has maintained studies with explicit educational relevance on learning in socio-technical environments, on technical mediation and on agency, anchored to frameworks of embodied and ecological cognition and to socio-ethical readings of the relationship between man, environment and technology (Varela et al., 1991; Gibson, 1979; Latour, 2005; Selwyn, 2019). The synthesis of the literature was obtained through thematic coding of the field's conceptual nuclei and omissions, in dialogue with the Dewey-Simondon-Stiegler genealogy and with reviews and meta-analyses on AI in education (Zawacki-Richter et al., 2019; Chen et al., 2020; Bond et al., 2024). In parallel, the empirical investigation used a questionnaire consisting of five-modality Likert items and open-ended questions on flipped learning, UDL, educational AI and inclusion, accompanied by a socio-academic section; the tool, built based on established literature (Bergmann & Sams, 2012; Meyer et al., 2014; CAST, 2018, 2024; Zawacki-Richter et al., 2019), has undergone content validation through expert review (DeVellis & Thorpe, 2021). The online administration, anonymous and voluntary, produced 79 complete responses. Descriptive statistics analysed quantitative data, while open-ended responses were examined by thematic analysis (Braun & Clarke, 2006); the final integration systematically compared Scopus trajectories and questionnaire results, interpreting consonances and deviations as clues of repositioning of the subject in technically mediated and institutionally regulated learning environments (Simondon, 1958; Stiegler, 2008; Selwyn, 2019).

3. Results

3.1. Results from Scopus: emerging trends and thematic cores

The reading of the records indexed in Scopus recomposes a convergent picture: technology enters training as a factor in the configuration of experience, redistributing roles, legitimising criteria for knowledge, forms of participation, and attention regimes. This orientation crosses heterogeneous contributions and thickens along some recurring lines.

A first axis concerns digital and media competence as a training issue that goes beyond instrumental training and assumes the profile of cultural, reflective, and responsible competence. In initial language teacher training, digital competence is linked to European frameworks centred on security, criticality, and the responsibility of use (Retelj, 2022). A similar trajectory emerges in studies on “media competence” in pedagogical universities, which describe informational, interpretative, and safety components and highlight the role of organisational and teaching conditions in structuring skills that remain inhomogeneous (Shamigulova & Vasilina, 2023). In the background is the issue of the digital gender gap between university students, in which formal and informal practices of the network are intertwined with self-perception and security skills, suggesting a direct link between competence and agency (Pérez-Escoda et al., 2021).

A second axis thematises the transformation of educational devices through immersive environments and interaction technologies, with increasing attention to experience design and participatory involvement. The use of location-based virtual reality in cultural heritage education demonstrates how immersion and navigability

can intensify engagement and deepen the experience, offering operational guidance for educational applications and teaching strategies (Wei et al., 2025). In the contiguous area, experiments on “technology comprehension” in the visual arts enhance educational prototypes that integrate programming, co-construction and digital design, assigning technology a dual status as a means of expression and an object of critical reflection on human-machine relationships (Buhl & Skov, 2020).

A third axis, centred on AI, brings human-machine collaboration to the fore as a matter of teaching organisation and professional governance. The chapter on conversational AI proposes a significant reversal: the conversational agent is read as an opportunity to reactivate conversation, emotions, and class climate, while technology takes on a support function, making the educational relationship more habitable (Iannella et al., 2021). This line dialogues with contributions that describe AI as an infrastructure of services and educational analytics, capable of affecting the effectiveness and variety of classroom actions, bringing teaching supervision back to the centre of design and responsibility.

A fourth axis focuses on inclusion, gender and participation, with particular evidence in STEM contexts (Steffen et al., 2023). A qualitative study dedicated to students with minority gender identity and sexuality describes a pervasive “dude/bro culture”, with effects on invisibilisation, devaluation and objectification, and with direct repercussions on the learning climate and university practices (Miller et al., 2021). Alongside this diagnosis, retention-oriented interventions are emerging, including mentorship programs with top management figures, which are associated with strengthening motivation and persistence in STEM trajectories.

A fifth, transversal axis thematises the ethical, political and institutional dimensions of technical innovation, also through lateral contexts that are instructive for the pedagogical reading of the university. Studies on smart cities and the Internet of Things report gender differences in trust and acceptance criteria related to safety, sustainability, and environmental awareness, and provide indications for public policies and targeted educational campaigns (Walczak et al., 2025). A similar approach, oriented towards gender-responsive social innovation, insists on community preparedness and social learning frameworks to support participation in smart cities (Asteria et al., 2020). In the domain of digital communication, a bibliometric analysis of the relationship between AI and the spread of fake news highlights the importance of standards, regulations, and fact-checking practices, with direct implications for public truth education and the social responsibility of information (Burcă-Voicu et al., 2025).

3.1.1. Research gaps that emerged from the Scopus documents

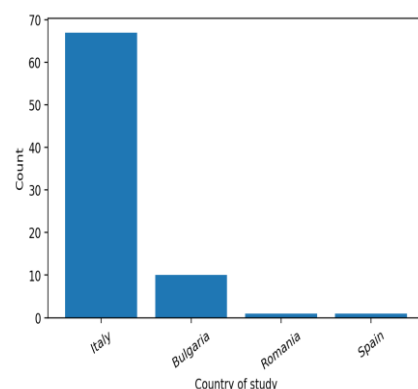
From the reconstructed trends, three gaps emerge that directly intersect the research questions. The first concerns the epistemological status of technology in educational contexts: numerous studies focus on skills, environmental design, and metrics of acceptance or teaching effectiveness, while technology is treated more rarely as a principle that reconfigures knowledge and participation, with effects on agency, attention, and forms of institutional mediation. The second gap concerns the relationship between data and experiences: a significant share of production favours declarative, performance or organisational indicators, while student representations are remarkably informative when they are read as signals of subjective positioning within socio-technical devices, as shown by the work on STEM climates and retention

and mentorship strategies (Miller et al., 2021). The third gap concerns design translation: the literature proposes interventions and operational frameworks, from media competence (Shamigulova & Vasilina, 2023) to European frameworks of digital competence in teacher training (Retelj, 2022), from immersive experiences (Wei et al., 2025) to TechArt prototypes (Buhl & Skov, 2020), while the question of overall coherence remains open, because inclusive design and institutional governance require a lexicon capable of keeping together equity, responsibility, quality of the relationship and forms of knowledge.

3.2. Results – Questionnaire (N = 79)

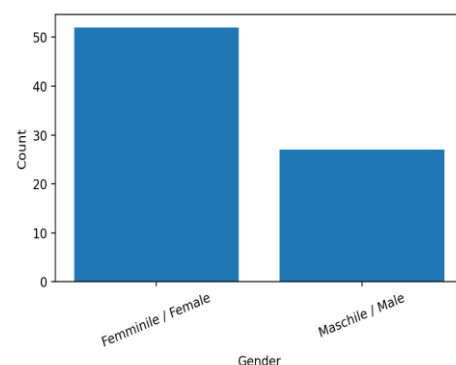
The sample comes mainly from Italian universities (67), with a substantial share from Bulgaria (10) and a residual share from other countries (2) (Fig. 2).

Figure 2. Country of study reported by respondents (N = 79).



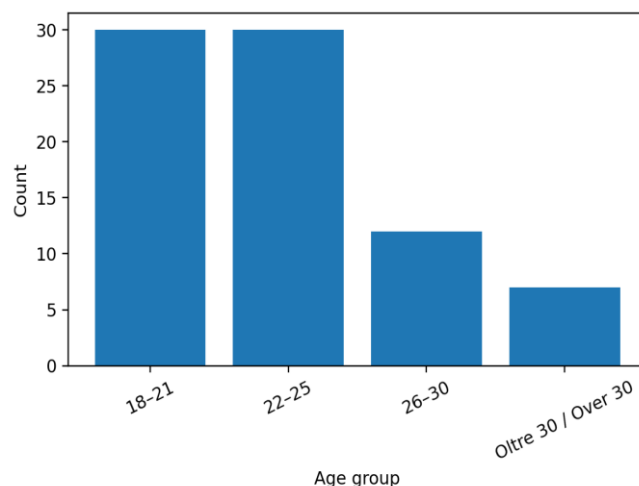
The gender distribution recorded 52 female respondents and 27 male respondents (Fig. 3).

Figure 3. Gender distribution of the respondents (N = 79).



Age is concentrated in the 18-21 (30) and 22-25 (30) age groups, with presence in the 26-30 (12) and >30 (7) age groups (Fig. 4).

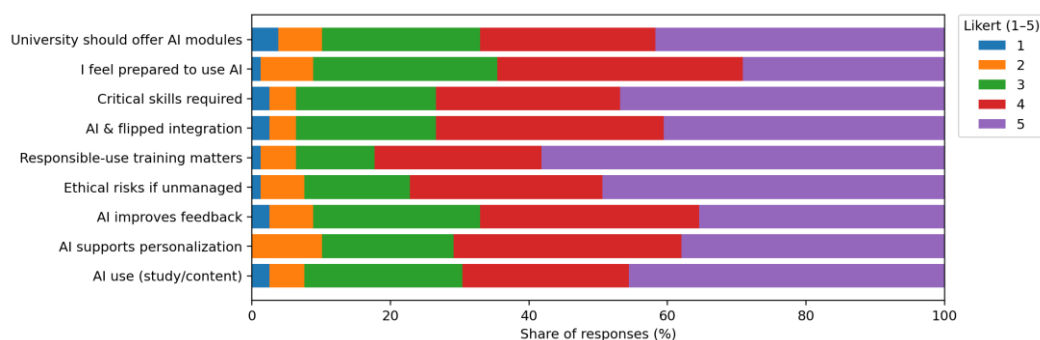
Figure 4. Age distribution of the respondents (N = 79).



3.2.1. Descriptive channel: AI, flipped learning, UDL and inclusion

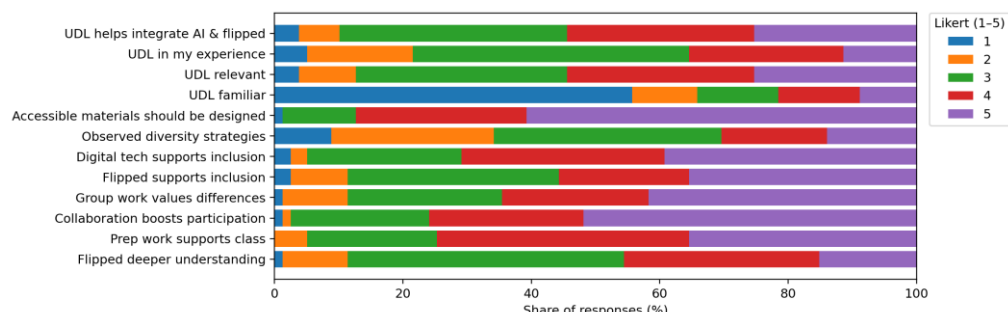
The items on AI describe a frequent use to support the study and production of content, associated with an explicit request for training and criteria for responsible use, with particular sensitivity to the ethical implications and the quality of institutional mediation (Fig. 5).

Figure 5. AI-related perceptions and practices (Likert 1–5; shares in %).



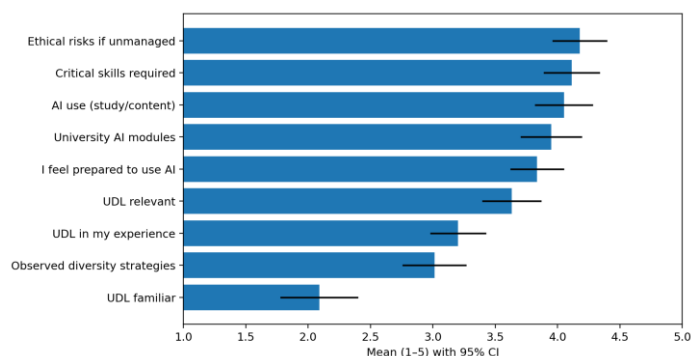
The answers on flipped learning and inclusion indicate a favourable orientation towards active methodologies and inclusive frameworks; however, there is an information gap between recognition of relevance and familiarity with and operational implementation of UDL, with signs of inhomogeneity in the university practices reported (Fig. 6).

Figure 6. Flipped learning, inclusion, and UDL perceptions (Likert 1–5; shares in %)



The synthesis by means and confidence intervals makes visible the distance between “UDL relevant” and “UDL familiar,” which helps interpret the relationship between declared innovation and actual training conditions (Fig. 7).

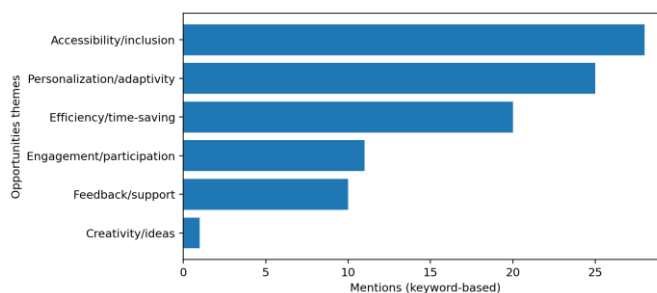
Figure 7. Selected items: mean (1-5) with 95% confidence intervals.



3.2.2. Thematic channel: open-ended opportunities and risks

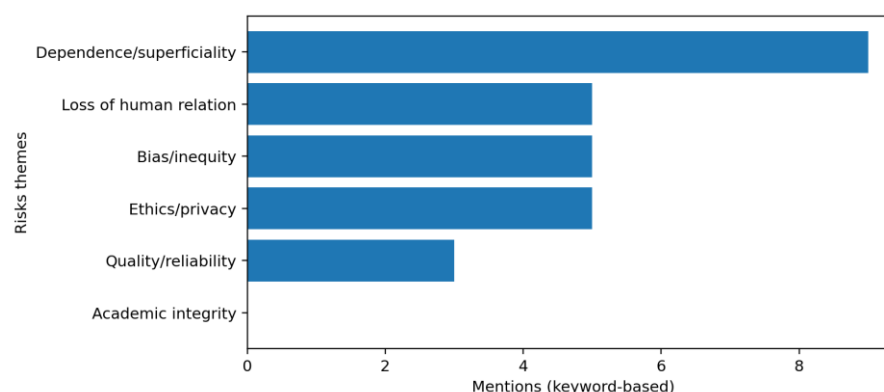
In the open-ended questions, opportunities converge on accessibility, inclusion, personalisation, and time savings, with technology enhancing participation and the quality of academic work (Fig. 8).

Figure 8. Open-ended responses: opportunities themes (keyword-based mentions).



The critical issues are concentrated around dependence and superficiality, ethical issues and privacy, reliability of outputs and academic integrity; the theme of the didactic relationship also recurs as a condition that guides its use and stabilises its educational quality (Fig. 9).

Figure 9. Open-ended responses: risk themes (keyword-based mentions).



4. Discussion

The comparison between Scopus reconnaissance and questionnaire describes a transition governed by the intertwining of technique as a cognitive mediator, institution as a regulatory device and subjectivity as a space of agency and ambivalence. Indexed literature consolidates a lexicon centred on digital competence, AI, equity, and accountability, while empirical data show widespread adoption accompanied by a persistent demand for educational direction and institutional transparency.

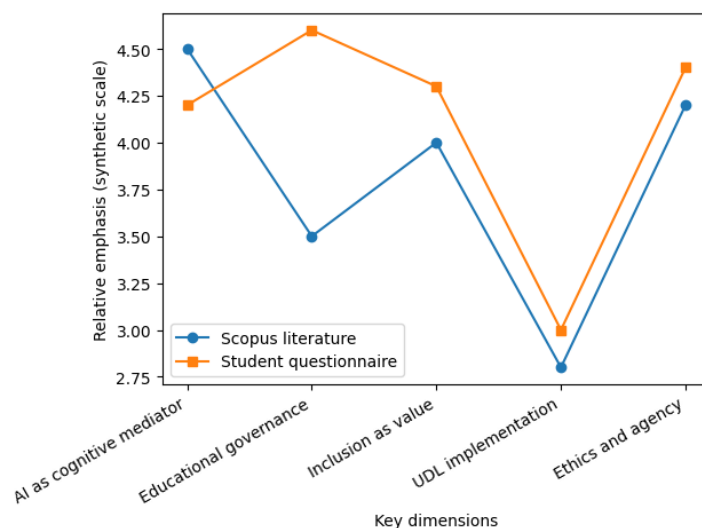
On the first axis, technology emerges as a factor of didactic and professional reorganisation, with digital competence understood in a cultural and value sense and with models of human-machine collaboration that maintain responsibility on the teacher and institutions (Retelj, 2022; Liu & Wang, 2020); students confirm openness to AI, but point out a gap between the speed of adoption and the solidity of training conditions, which makes visible a first epistemological gap on technology as a form of agency redistribution (Latour, 2005; Selwyn, 2019).

On the second axis, inclusion and equity are also curricular and institutional properties, crossed by gender asymmetries (Tsakalerou et al., 2025; Gómez Paniagua et al., 2024); the questionnaire reinforces the value of inclusion but shows a distance between UDL principles and actual practices, highlighting a second gap related to the educational governance of active methodologies and smart technologies (Meyer et al., 2014; CAST, 2018).

On the third axis, GenAI appears in the literature as a creative and ethically problematic resource (Pérez Pérez, 2024; Álvarez, 2024), while empirical data return a concrete ambivalence between opportunities and fears of standardisation and delegation; here the third gap emerges, since the representations of the students function as sensitive indicators of the quality of institutional mediation and of the processes of externalisation that invest attention and judgment (Simondon, 1958; Stiegler, 2008).

Figure 10 visualises areas of convergence and divergence, highlighting how alignment is most substantial on ethical concerns and inclusion, while gaps emerge in educational governance and UDL operationality.

Figure 10. Scopus literature and student questionnaire: convergence and divergence across pedagogical dimensions.



5. Conclusions

This study interprets university learning as a situated and technically mediated process, emerging from practices embodied within socio-technical networks (Varela et al., 1991; Gibson, 1979; Latour, 2005), taking the Dewey–Simondon–Stiegler genealogy as the key to reading digitisation as a transformation of the educational experience and individuation processes, with effects on agency and institutional mediation (Dewey, 1938; Simondon, 1958; Stiegler, 2008). The Scopus review identifies established trajectories on digital competence as a cultural competence, on AI as an educational governance infrastructure, on the use of GenAI with equity implications, on the persistence of gender asymmetries and on the expansion of ethical frameworks of responsibility (Selwyn, 2019; Zawacki-Richter et al., 2019; Bond et al., 2024). Empirical data confirm a favourable orientation towards technologies as cognitive mediators, accompanied by caution regarding standardisation and delegation, and converge on a demand for educational direction based on clear criteria, institutional responsibility, and the quality of the teaching relationship. The comparison between literature and questionnaire clarifies three critical points: the limit of outcome-only approaches compared to heterodirection experiences; the role of the institution as a regulatory agent of agency and inclusion; the centrality of embodied experience, in which attention, cognitive load and operational trust are decisive in hybrid environments integrating AI, flipped and UDL (Meyer et al., 2014; CAST, 2018; Bergmann & Sams, 2012). An essential pedagogical thesis emerges: the university is called upon to design learning environments as devices of regulated co-evolution, in which tech-

nology acts as a cultural medium, and the institution guarantees conditions of interpretation, choice and responsibility, supported by critical teacher training, inclusive design and care for attention and relationship (La Manna et al., 2024). Future lines require longitudinal, ethnographic, and design-based studies capable of connecting learning analytics and pedagogical interpretation, clarifying where automation supports individuation and where it weakens it (Creswell & Plano Clark, 2018). As Paulo Freire reminds us, the educational problem never concerns the transmission of content, but the quality of the relationships that make the meaning of experience possible: “no one educates anyone, not even himself; men are educated in communion, through the mediation of the world” (Freire, 2002, p. 69). In an increasingly dense network of organisms, environments and techniques, this affirmation retains an intact pedagogical force, recalling institutions’ responsibility to safeguard the relational, critical and generative dimension of learning.

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