Revista Latinoamericana de Tecnología Educativa, 25(2)
https://doi.org/10.17398/1695-288X.25.2.53

RELATEC
Revista Latinoamericana de Tecnología Educativa

Received: June 1, 2026
Accepted: June 29, 2026

Corresponding authors' address:

Facultad de Educación. Departamento de Pedagogía Aplicada y Psicología de la Educación. Universitat de les Illes Balears Cra. de Valldemossa, km 7.5. 07122 Palma (Spain)

E-mail / ORCID

jesus.salinas@uib.es

https://orcid.org/0000-0002-3043-8455

juan.moreno@uib.es

https://orcid.org/0000-0001-7381-8370

jacoba.munar@uib.cat

https://orcid.org/0000-0001-5933-1929

ARTICLE / ARTÍCULO

Personalized Learning Supported by Digital Technologies: Trends, challenges and perspectives

Aprendizaje personalizado facilitado por tecnologías digitales. Tendencias, retos y perspectivas

Jesús Salinas, Juan Moreno-García & Jacoba Munar-Garau

Resumen: Since the establishment of compulsory education, the personalisation of learning has been a recurring concern in educational research and practice, in which educational technology has always played a part. This paper analyses the state of the art on personalized learning supported by digital technologies, identifying trends, challenges and perspectives from Educational Technology as a discipline. It adopts the form of a theoretical essay based on a narrative review of literature, focused on review articles and conceptual frameworks published in specialised journals. The analysis identifies two main strands of personalisation, articulated around the continuum proposed by Cuban (2018): one centred on technological adaptation through algorithms, learning analytics and intelligent tutoring systems, and another oriented towards curricular flexibility and student agency through personal learning environments, flexible pathways and co-design processes. Generative artificial intelligence acts as an accelerator for both strands yet intensifies the risk that the appearance of personalisation may replace genuine learning. Conceptual, institutional, psychological, technological and pedagogical barriers to implementation are identified. The paper concludes that personalisation is not essentially a technological problem but a pedagogical one, and that it must attend both to the evolution of technologies and to human supervision in the construction of learning.

Keywords: Personalized Learning, Artificial Intelligence, Self Regulated Learning, Learner Autonomy, Educational Technology, Adaptive Instruction.

Abstract: Desde la generalización de la educación obligatoria, la personalización del aprendizaje ha constituido una preocupación recurrente en la investigación y en la práctica pedagógica, en la que la tecnología educativa ha estado siempre presente. Este trabajo analiza el estado de la cuestión sobre la personalización del aprendizaje facilitada por tecnologías digitales, identificando tendencias, retos y perspectivas desde la Tecnología Educativa. Para ello, adopta la forma de ensayo teórico basado en una revisión narrativa de literatura, centrada en trabajos de revisión y marcos conceptuales publicados en revistas especializadas. El análisis identifica dos grandes vertientes de la personalización, articuladas en torno al continuo propuesto por Cuban (2018): una centrada en la adaptación tecnológica, mediante algoritmos, analíticas de aprendizaje y sistemas de tutoría inteligente, y otra orientada a la flexibilización curricular y a la agencia del estudiante, mediante entornos personales, itinerarios flexibles y procesos de codiseño. La inteligencia artificial generativa actúa como acelerador de ambas vertientes, pero intensifica el riesgo de que la apariencia de personalización sustituya al aprendizaje real. Se identifican barreras conceptuales, institucionales, psicológicas, tecnológicas y pedagógicas que dificultan su implementación. Se concluye que la personalización no es esencialmente un problema tecnológico, sino pedagógico, y que debe atender tanto a la evolución de las tecnologías como a la supervisión humana en los procesos de construcción del aprendizaje.

Palabras-clave: Aprendizaje personalizado, Inteligencia artificial, Aprendizaje autorregulado, Autonomía del aprendiz, itinerarios flexibles de aprendizaje, Tecnología educativa, Instrucción adaptativa.

1. Introduction

Personalized learning has been one of the key areas of research and pedagogical practice associated with the evolution of educational technology since the early 20th century. In a context of universal, public, and compulsory education, the inability to address diverse needs, interests, abilities, family cultures, and cognitive styles makes personalization one of the key areas of pedagogical research.

Personalized learning is essentially an extension of an earlier solution to a persistent problem: there are far more students than teachers. Therefore, instruction must be one-to-many, but students arrive with different levels of preparation and require different amounts of practice to master schoolwork, making it unlikely that a single curriculum will be effective for everyone. Chan and Gastelum (2016, p. 85) note that

> «the personalization of learning is an old movement pedagogically speaking; technologically, it is relatively new, and it is 'yet to come' in terms of curriculum organisation and, above all, the didactic or instructional design of online courses»

The concept of personalized learning (understood as addressing students' individual needs) finds in the application of digital technologies, the possibilities of artificial intelligence, and other emerging technologies a means to develop tools, approaches, and practices that seek to adapt the teaching-learning process to individual characteristics, itineraries, and motivations (Salinas and Lizana, 2025).

There have always been attempts to rely on technology to contribute to this personalization. The first teaching machines were purely mechanical. Sidney Pressey was the first to use "intelligent" machines for educational purposes (Pressey, 1926); later, Skinner (1954) developed the machine that would become the precursor to programmed learning (linear programming), and Crowder (1962) introduced Branching Programming or Intrinsic Programming. In fact, the first computers applied to education in the 1960s sought to implement strategies based on this type of programming, allowing for greater sophistication in tutoring possibilities and, consequently, greater adaptation to individual learning.

Personalized tutoring was the focus of psychological, pedagogical, and didactic theory and practice during this period, especially regarding technology-enhanced learning. Bloom (1984), for example, argued that the most effective way to teach was through individualised tutoring.

As educational technology matured in the second half of the last century, personalized learning took the form of intelligent tutoring systems. The development of microprocessors shifted the focus toward providing teachers with tools to produce computer-assisted instructional materials. The first authoring languages appeared, such as the pioneering Coursewriter, as well as Autotutor, Pilot, and Natal, followed in the 1980s and 1990s by Hypertalk, Toolbook, and Authorware.

At the same time, pedagogical foundations began shifting toward constructivism and the student-centred educational paradigm, which provided a theoretical justification for why teaching methods and content should be personalized.

In this century, big data, learning analytics, and other advances have led to personalized learning becoming a major focus of research (Shemshack and Spector, 2020). The transformative potential of technology appears to hold significant promise for a more equitable and personalized education. However, all these advances carry risks that accompany the promise of personalized learning. One such risk is individualisation, which can isolate students in algorithmic learning pathways, undermining the social aspect of education. But there are others, such as the paradox of empty dialogue (Mas, 2023) or the challenges raised by Barrera et al. (2025).

The researchers believe that a personalized learning experience facilitated by digital technologies can contribute to better learning for all. Thus, this study analyses current trends, research, and practices related to this topic. To achieve the objective of this study, the following research question was posed: What elements comprise a pedagogical approach to personalized learning from a holistic perspective?

This question can be broken down into several sub-questions that allow for a more specific focus on the study:

1) Is it possible to arrive at a definition of personalized learning from the perspective of educational technology?
2) What are the dimensions of personalized learning enabled by technology that should be considered?
3) What trends in research and practice are observed in the educational landscape?
4) What are the main challenges perceived in relation to personalized learning facilitated by digital technologies?

To explore possible answers, this paper takes the form of a theoretical essay that, based on a narrative review of relevant literature, analyses the state of the art regarding personalized learning facilitated by digital technologies. Articles from databases and journals specializing in educational technology were reviewed and selected based on their relevance, recency, and quality, with a preference for review articles and conceptual frameworks. The purpose is not to provide an exhaustive review, but rather to offer an integrative overview from the perspective of Educational Technology as a discipline.

1.1. What do we mean by personalized learning?

The idea of personalized learning stems from the principle that human beings learn through experience and by constructing knowledge. The term seems deceptively simple and common, but its use in an educational context is complex and involves many nuances. In other words, it can mean different things.

According to Conole (2010), personalization and personalized learning can be approached from three perspectives, and their definition will differ accordingly: in political discourse, in relation to technological advances, and in pedagogical discourse.

Numerous definitions of personalized learning have been published by government agencies, organisations dedicated to education policy, foundations and educational initiatives, influential figures, and researchers. Both Walkington and Bernacki (2020) and Bernacki et al. (2021) compile and classify several of these definitions, highlighting the variation in the characteristics included in them. These variations encompass both student characteristics to be accommodated, design elements, and the intended outcomes.

According to Coll (2015), personalization involves designing and developing learning experiences that cater to the diversity of learners, considering their characteristics, needs, and interests.

In the field of digital technologies, according to Spector (2018), for a digital learning environment to be classified as a personalized learning environment, it must adapt to everyone's knowledge, experience, and interests, and it must be effective and efficient in supporting and fostering desired learning outcomes.

Cuban (2018) proposes a spectrum or continuum to organise this diversity of meanings, identifying three key zones: At one end of the continuum are teacher-centred lessons and programs within the traditional school setting; in the middle of the spectrum are hybrid programs and schools that offer combinations of whole-class, small-group, and independent work activities; and at the other end of the spectrum are student-centred classrooms, programs, and schools with multi-age groups that pose big questions integrating reading, math, science, and social studies, while regularly incorporating new technologies into lessons.

When understood as addressing students' individual needs, the personalization of learning finds in the application of digital technologies the development of approaches and tools that aim to adapt the teaching-learning process to individual characteristics, itineraries, and motivations.

However, as Varona-Klioukina and Engel (2024) point out, recent reviews of the relationship between personalized learning and digital technologies tend to lean more toward teacher-centred approaches, according to Cuban's (2018) terminology—which use digital technologies to adapt learning activities and content to students' individual performance (technology as a content delivery mechanism)—rather than learner-centred proposals, in which students are recognised and empowered to make decisions about their own learning process, based on their interests and preferences (technology as a creative tool).

Algorithms capable of responding to individual differences, the implementation of learning analytics, the use of educational recommendation systems, the integration of chatbots, and, more recently, the application of technologies based on generative artificial intelligence (GenAI) are some of the ways digital technologies are applied to the personalization of learning from various perspectives (Varona-Klioukina and Engel, 2024)

All of this could represent a significant step forward in the pursuit of a more equitable and personalized education, supported by the transformative potential that technology appears to possess. However, it carries the risk of individualisation, which

could isolate students within algorithmic learning paths, thereby undermining the social aspect of education.

2. Dimensions of Personalization

Just as with the definition of personalization, the dimensions or components that determine such personalization are approached from different perspectives (Hargreaves, 2004; Järvelä, 2006; FitzGerald et al., 2018; Shemshack et al., 2021). Shemshack et al. (2021), for example, in their review of the components of personalized learning used in different approaches and models, consider learning styles, cognitive styles, self-reflection and self-regulation of learning, flexible itineraries, tools and systems, intelligent learning environments, intelligent tutoring systems, data mining and learning analytics, and wearable devices.

In analysing the similarities and differences among the components used in personalized learning approaches, these authors observed that, although cognitive components were initially the centre of attention, the focus has gradually expanded to include non-cognitive components (Esteban-Guitart and Moll, 2014).

For their part, when addressing how to apply personalization in technology-enhanced learning and how this can be effective for students and other stakeholders, FitzGerald et al. (2018) adapt the framework proposed by Hargreaves (2004), which classifies different dimensions of personalization, but in this case focuses on aspects of technology-enhanced learning. These six dimensions are:

- What is personalized: Personalization focuses on technology-enriched learning. This involves tailoring the educational experience: including resources, assessments, curriculum content, and specific learning plans; to the individual student (Walkington & Bernacki, 2020)

- The type of learning to which personalization is applied: This model applies to learning processes where technology acts as a mediator or enabler, ranging from literacy in elementary school to higher education and lifelong learning (Barrera-Castro et al., 2025)

- Which personal characteristics of the student can be considered: The design must consider variables such as the student's profile, learning styles, cognitive levels, prior knowledge, interests, personal goals, and specific inclusion needs (Barrera-Castro et al., 2025; Bernacki et al., 2021)

- Who or what carries out personalization: It can be carried out by technological systems (AI algorithms, intelligent tutoring systems), by the teacher (who acts as a guide or facilitator), or by the student themselves through the exercise of their agency, voice, and choice (Walkington & Bernacki, 2020)

- How personalization is carried out: FitzGerald et al. (2018) propose a framework that serves both to analyse existing practices and to create new, effective implementations of TE: Use of disruptive technologies and AI (Barrera-Castro et al., 2025; Reyes-Parra et al., 2024); system adaptability vs. learner adaptability (Kucirkova et al., 2021; Sachete et al., 2024); instructional design adjustments; biometric and

contextual monitoring (Reyes-Parra et al., 2024); creation of flexible learning pathways (Salinas et al., 2022).

– The impact and beneficiaries of personalization: Personalization seeks to improve the quality of education, promote equity and inclusion, and facilitate effective time management in educational activities (Barrera-Castro et al., 2025; Reyes-Parra et al., 2024). The direct beneficiaries are students, although it also has a positive impact on teaching practices and, in many cases, on institutions by reducing learning gaps.

For their part, Lee et al. (2018) propose five essential components that personalized learning should include: 1) a personalized learning plan that takes individual differences into account, 2) tracking student progress based on competencies rather than time, 3) criteria-based assessment rather than norm-based assessment for ongoing formative and summative evaluation, 4) project- or problem-based learning, and 5) multi-year mentoring of students by a teacher or tutor.

3. Trends

The potential of technology to adapt the learning process to individual differences represents a megatrend in research, theoretical development, and practice. This megatrend, when situated within Cuban's (2018) continuum, in turn presents different aspects. On the one hand, learning analytics (algorithms aimed at adapting the curriculum, the use of robots, virtual tutors, and adaptive platforms) that do not challenge teacher-centred approaches. On the other hand, greater curricular flexibility, the cultivation of competencies related to autonomy and agency, and the construction of one's own personal learning environment which, from learner-centred approaches, lead to greater personalization of experiences in pedagogical practice. Figure 1 summarises the main trends identified in these areas.

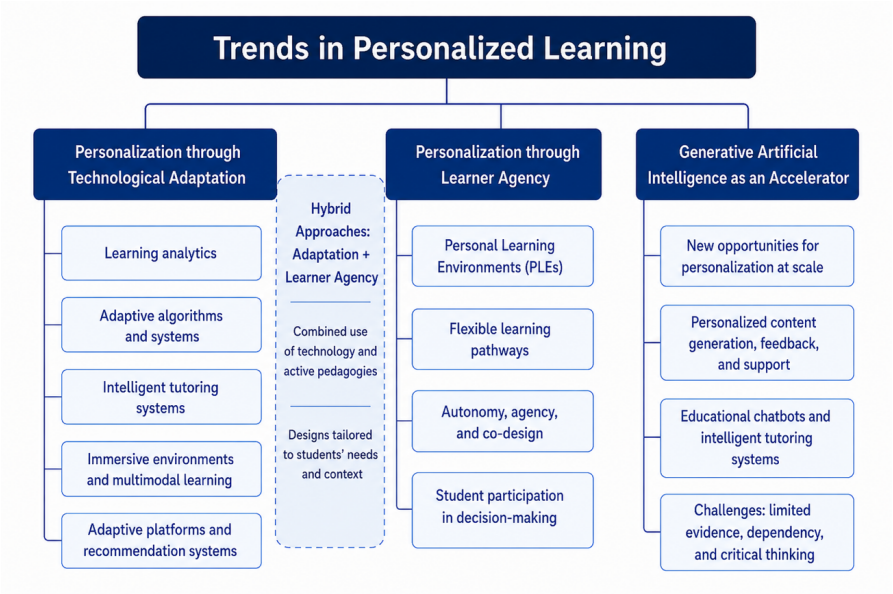

Figure 1.Trends in the Personalization of Learning. Note: Image generated by ChatGPT 5.5 based on a descriptive prompt

3.1. Personalization Through Technological Adaptation

In the first aspect, Varona-Klioukina and Engel (2024) highlight the design of various algorithms that can address individual differences, as well as the use of learning analytics, educational recommendation systems, the integration of chatbots, and, currently, the application of generative artificial intelligence. Intelligent and adaptive educational systems have sought to support students and teachers by providing meaningful, relevant, and appropriate educational content. However, in practice, adaptability has focused primarily on the personalized presentation of content and adaptive navigation through it (Walkington and Bernacki, 2020), leaving other dimensions of learning in the background.

The potential of learning analytics has been a widely explored trend in recent years (Chatti and Muslim, 2019; Zhang et al., 2018). This trend is currently gaining momentum due to models that enable predictive interventions (such as identifying the risk of dropout or detecting changes in learning dynamics or misconceptions before they become entrenched). In any case, this trend still lacks evidence beyond experimental projects and pilot studies.

Another area within this trend is immersive environments. Extended reality (which includes virtual reality, augmented reality, personalized labs, simulators, etc.) offers the possibility of customising not only the content but also the physical context of learning.

In the field of multimodal learning, technological advances have already led to interfaces that read voice, facial expressions, writing speed, and other biometric data from which affective and cognitive states can be inferred.

Traditional, rule-based intelligent tutoring systems are beginning to be replaced by systems capable of sustaining a genuine Socratic dialogue. Research in this area will need to examine these types of dialogic interventions, how and to what extent they impact learning, and how to calibrate the level of support without creating dependency (Bernacki et al., 2021).

3.2. Personalization Based on Learner Agency

In the second aspect, these authors focus on the application of digital technologies through student-centred approaches, in which students are recognised and empowered to make decisions about their own learning process, based on their interests and preferences. Here, students participate in identifying their needs and preferences. But they are not only involved in identification; they are also engaged in determining how to respond based on their personal interests and choices through a process of co-designing learning experiences. The potential of digital technologies to facilitate such flexibility and contribute to the adaptation of teaching-learning processes has led to extensive research and the emergence of various models.

Within the framework of a broader personalization strategy, the term "personal learning environments" (PLE) has gained popularity over the past decade and highlights the social dimensions of learning (Conole, 2010). The application of digital technologies from the perspective of building personal learning environments (Adell and Castañeda, 2010) is geared toward individuals who are aware of their needs and

limitations, who exercise a certain degree of autonomy in their learning, and who, in this sense, help reverse the trend of students adapting to a system that is increasingly tailored to the student.

According to Cuban (2018), flexible learning pathways provide students with sufficient flexibility to exercise autonomy in their own learning process through participation in decision-making (Bartolomé, 2020; Salinas and De Benito, 2020). In this sense, personalization would consist of developing personal competencies related to autonomy, agency, and the construction and cultivation of one's own personal learning environment.

Between these two aspects lies a whole range of experiences that make use of digital technology for adaptation (learning analytics, algorithms designed to adapt the curriculum and practices to these individual differences, the use of robots, artificial intelligence, etc.), as well as student engagement through innovative teaching methodologies or by adapting designs to users' needs and characteristics (Salinas and Lizana, 2025).

Undoubtedly, technology plays a key role in creating personalized learning environments, and technological advances make it possible to implement such environments on a large scale and at an affordable cost. However, very few studies have analysed how technology is used in the implementation of personalized learning and what the needs of teachers are in student-centred contexts when applying personalized learning (Lee et al., 2018).

In this context, a crucial aspect of personalization emerges that current educational technology barely addresses: the personalization of the entire learning environment, its components, tools, and functionalities. Students exhibit widely varying levels of digital competence, different preferences regarding the degree of guidance or autonomy they need and needs that change over time. This heterogeneity, coupled with the evolving nature of their demands as the learning process progresses, requires approaches with a higher level of adaptability (Chatti and Muslim, 2019).

3.3. Generative Artificial Intelligence as an Accelerator

Among the technologies highlighted in the first section, generative artificial intelligence (GenAI) deserves specific attention, both for the speed of its adoption and for the expectations it has generated in the field of education. As Serrano and Moreno-García (2024) point out, the emergence of large language models has reignited a recurring promise in the history of educational technology: that personalized tutoring at scale is, at last, possible. But they also warn of the risk of falling into what they call the "Law of the Polka": believing that something revolutionary has been discovered when, in reality, old ideas lacking sufficient empirical basis are simply being recycled.

The convergence of adaptive learning and IAGen, however, opens possibilities worth exploring. Current adaptive systems can combine the analysis of student performance with the generative capabilities of language models to produce content, feedback, and assessments tailored in real time (Guettala et al., 2024). Educational platforms already incorporate these capabilities, not only to adapt content and lessons but also, in some cases, to provide emotional support and foster interaction (Serrano and Moreno-García, 2024).

Educational chatbots are one of the most visible applications of this trend. Research indicates that they can improve learning outcomes, offer immediate assistance, and facilitate a certain degree of personalization. However, the effects on motivation, engagement, and, especially, critical thinking yield conflicting results (Labadze et al., 2023). Guan et al. (2024), in analysing chatbots' support for self-regulated learning, conclude that none of the systems studied offers comprehensive support across all phases of self-regulation, limiting themselves to specific tasks.

For their part, intelligent tutoring systems (ITS) perhaps hold the greatest promise for technological personalization. Based on machine learning algorithms to analyse large volumes of student data, these systems aim to simulate human tutoring and become proactive guides for learning. However, decision-making methods for designing personalized learning paths still have shortcomings, particularly in predicting content difficulty and in integrating motivational and emotional variables (Serrano and Moreno-García, 2024). The lack of empathy and emotional support remains one of the most frequently cited limitations, even in the most advanced systems.

All this calls for a fundamental reflection that connects both ends of the continuum. If the first end is advancing rapidly in the sophistication of algorithms and the second calls for the learner to play a greater role in decision-making, the tension between the two is not resolved with more technology, but with better pedagogy. Educational research, as has been repeatedly documented, lags technological development (Zawacki-Richter et al., 2019), and this gap has widened with the acceleration brought about by IAGen. There is a real risk that, as Mas (2023) warns with the paradox of empty dialogue, the appearance of personalization will replace genuine personalization: that a system will generate responses that appear tailored to the student without the student having been actively involved in the process.

These advances and tensions present us with a set of challenges that must be addressed.

4. Barriers to Personalization

The obstacles preventing the implementation of personalization are complex and of both a technical and pedagogical nature. In this context, the challenge facing the personalization agenda is how to identify and address these obstacles (Conole, 2010). Despite the widely documented benefits of personalized learning, significant challenges remain, especially in today's educational context, where emerging technologies—including artificial intelligence—are prevalent.

Barrera et al. (2025, p. 2) classify these challenges into five dimensions (Figure 2).

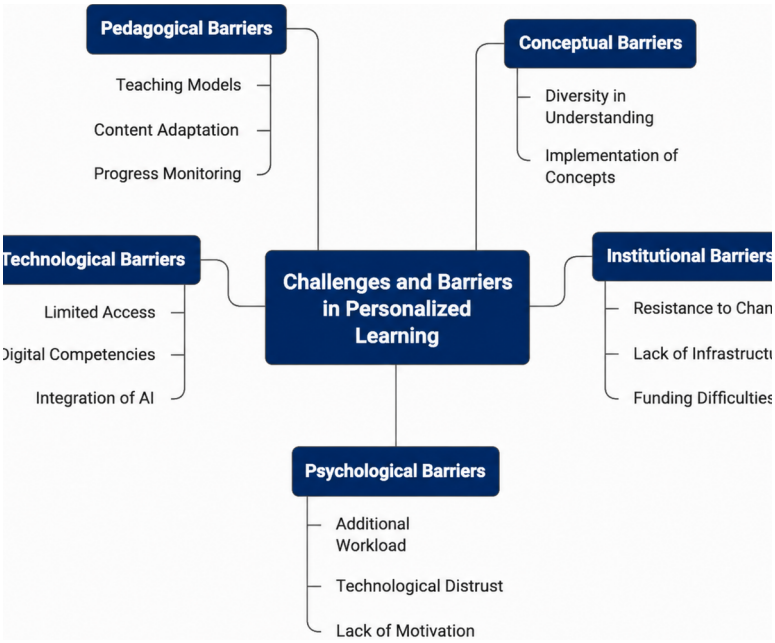

Figure 2. Challenges and barriers to personalized learning. Note: Image generated using the Napkin.ai app based on the content.

4.1. Conceptual barriers

There is a problem of diversity in the understanding and implementation of concepts related to the field of research (Spector, 2018; Varona-Klioukina and Engel, 2024; Walkington and Bernacki, 2020). Personalized learning and the personalization of learning are not terms on which there is consensus within the scientific community. There are different approaches to personalized learning that consider various components of learning. Personalized learning is defined differently in almost every context in which it is applied, and this diversity hinders research and evaluation of how it influences students' educational experience and academic outcomes (Walkington and Bernacki, 2020; Cuban, 2018).

4.2. Institutional barriers

Institutional structures, designed primarily for standardised teaching models, exhibit curricular, scheduling, and assessment rigidities that hinder the flexibility needed to accommodate individualised learning paths. Added to this are insufficient technological infrastructure, institutional support that rarely places personalization among its strategic priorities, and difficulties in securing sustained funding (Crespo, 2023). Time is a cross-cutting barrier: designing, implementing, and evaluating personalized learning experiences requires a level of dedication that is difficult to reconcile with typical teaching workloads (Chan and Gastelum, 2016).

4.3. Psychological barriers

The implementation of personalization faces resistance that is not technical but attitudinal. On the part of faculty, the fear of adopting new teaching methods and the

difficulty in recognising the potential of available tools hinder pedagogical experimentation. On the part of students, research documents difficulties in maintaining sustained engagement with processes that require greater autonomy, as well as emotional factors (stress, anxiety) that must be considered in the design of personalized activities (Barrera-Castro et al., 2025).

4.4. Technological barriers

These include limited access to technology, gaps in digital skills, insufficient technical support, integration challenges, and ethical considerations (Hernández Cardenas et al., 2022; Walkington and Bernacki, 2020). Added to these barriers is a challenge specific to the present moment: the rapid pace of advances in generative AI makes it difficult for both educators and researchers to gain an in-depth understanding of a technology's possibilities before it has evolved and given way to new functionalities. Despite the exponential growth in studies on AI in education, recent reviews continue to identify the same gaps as a decade ago: insufficient attention to pedagogical and ethical aspects, limited participation by education professionals, and uneven methodological quality (Zawacki-Richter et al., 2019; Bond et al., 2024). Prendes and Serrano (2016) refer to this phenomenon as the "law of obsolescence": the results of research in educational technology are inevitably affected by the ephemeral nature of the technologies they study, so that findings that seem relevant may quickly become outdated. This disconnect is particularly pronounced in the case of IAGen, whose evolution seems to be measured in months, not years.

4.5. Pedagogical barriers

These refer to the models used for personalized instruction, a lack of the pedagogical knowledge needed to adapt content and learning activities, insufficient pedagogical support for teachers, fear of losing control over the curriculum, and the complexity of measuring and tracking students' individual progress (FitzGerald et al., 2018; Reyes-Parra et al., 2024; Salinas et al., 2022). In the current context, these barriers are exacerbated by the coexistence of learning environments designed with pedagogical intent and freely accessible generative AI tools that provide direct answers. This situation presents a specific challenge for personalized learning designs: even though teachers may provide guides, learning paths, or resources intended to foster reflection, support learning, and encourage student decision-making, students may turn to external tools that offer immediate solutions without requiring the same level of independent thought.

Recent evidence suggests that the use of generative AI without adequate pedagogical guidance may improve immediate performance on a task but hinder subsequent independent learning when students must work without technological support (Bastani et al., 2025). Furthermore, it has been noted that the support provided by these tools can foster forms of "metacognitive laziness", in which the final product improves without necessarily resulting in an equivalent gain in comprehension, transfer, or self-regulation of learning (Fan et al., 2024). This aspect introduces an additional pedagogical barrier: designing uses of generative AI that maintain students' cognitive engagement and avoid replacing the processes of comprehension, elaboration, and self-regulation that are integral to personalized learning.

5. Emerging Perspectives and Challenges

The discussion so far allows us to identify a set of perspectives and challenges that characterise the current state of personalized learning facilitated by digital technologies and that are likely to shape its evolution in the coming years.

The current landscape revolves around a tension that runs the entire length of the continuum described by Cuban (2018). On the one hand, there is the tension between technology-driven personalization; in which algorithms, analytics, and intelligent tutoring systems make decisions about what to present, in what order, and at what difficulty level. On the other hand, there is the student-driven personalization, in which students participate in identifying their needs and co-designing their learning path, with the support of the teacher (Salinas and De Benito, 2020; Varona-Klioukina and Engel, 2024).

This tension is not new, but each pole faces barriers of a different nature. Adaptive approaches tend to reduce personalization to the presentation of content (Walkington and Bernacki, 2020), and research in this area has been conducted with little involvement from education professionals, prioritizing technological aspects over pedagogical and ethical ones (Zawacki-Richter et al., 2019; Bond et al., 2024). Student-centred approaches face institutional barriers, resistance to giving students a central role, and a lack of co-design models that are scalable and transferable (Lee et al., 2018; FitzGerald et al., 2018).

In the immediate future, several challenges that warrant attention are on the horizon.

- The dual nature of generative artificial intelligence. Generative AI amplifies the possibilities at both ends of the spectrum: it enables the generation of content, feedback, and personalized assessments in real time (Guettala et al., 2024), but at the same time intensifies a central risk—that the appearance of personalization masks the absence of real learning (Mas, 2023). If students receive tailored responses without having actively engaged in the process, personalization becomes a mere simulation. This also raises questions inextricably linked to personalization that go beyond the scope of this paper: how to assess learning when it has been mediated by GAI tools, and how to distinguish what the student has learned from what the tool has produced on their behalf.

- The complexity of the educational phenomenon. Research on personalization supported by digital technologies tends to oversimplify a process that is, by nature, complex and multidimensional. Studies focusing on academic performance as an outcome variable predominate; these are conducted under controlled conditions that hardly reflect the variability of real educational contexts. This methodological reductionism limits the generalizability of the findings and overlooks relevant dimensions of learning such as self-regulation, motivation, and the social dimension. Longer-term studies, replications in diverse contexts, and metrics that go beyond standardised tests are needed.

- Equity, access, and the digital divide. AI-mediated personalized learning risks becoming a privilege if access conditions are not addressed. Its use can perpetuate or amplify existing inequalities if it is not integrated responsibly (Salinas Ibáñez and Moreno-García, 2025). Research on personalization cannot be separated from the policy decisions that determine who has access to these technologies and under what conditions.

- Ethics, algorithmic biases, and the privacy of educational data. Personalized learning requires highly sensitive data, ranging from emotional states and cognitive difficulties to attention patterns and error histories. This raises questions about privacy, informed consent, and data sovereignty that demand interdisciplinary approaches from the fields of education, law, and public policy (Salinas Ibáñez and Moreno-García, 2025). Furthermore, algorithms incorporate biases stemming from their training data that can amplify existing inequalities (Holstein and Doroudi, 2022), with a differential impact based on gender, ethnicity, socioeconomic status, or special educational needs.

- Scalability. Research on AI-driven personalized learning has been conducted primarily with small samples and in specific contexts, highlighting a marked need for longitudinal studies, more diverse designs, and larger samples (Bond et al., 2024). Scaling the results obtained under these conditions to educational systems with millions of students, teachers with widely varying levels of digital competence, and heterogeneous institutional contexts poses a major methodological and political challenge.

6. Conclusions

Personalizing learning is, first and foremost, a pedagogical issue and, ultimately, a political one. Technology expands its possibilities, but also its risks; and it does not replace the pedagogical decisions that must guide it. The tools have changed: from teaching machines to intelligent tutoring systems and language models; but the fundamental question remains how to design learning experiences that respond to the diversity of students without losing sight of the social, emotional, and reflective dimensions that are part of the learning process.

The questions that have guided this work yield answers that, rather than being definitive, help define the field. Viewed from the perspective of Educational Technology, the personalization of learning does not admit a single definition but rather a continuum ranging from system-driven adaptation to the learner's full agency. Its dimensions transcend content adaptation and include aspects such as who personalizes, what is personalized, for what purpose, and for whom. Trends are advancing simultaneously from the perspectives of technological adaptation and student agency, and both approaches face barriers that cannot be resolved with more technology. What emerges from the analysis is the need to strike a balance between the structure provided by instructional design and the autonomy required by a student capable of making decisions about their own learning.

From our perspective, this balance depends on two interdependent pedagogical conditions. The first is the ability of teachers to assume their role as designers of learning experiences that intentionally integrate technology, adapting the

balance between structure and autonomy to each context. The second is the strengthening of student agency, understood as the ability to make informed decisions about their own learning process, to self-regulate, and to actively participate in the co-design of their learning. Without these two conditions, personalized learning designs are unlikely to result in learning that responds to the real needs and interests of students and the context.

7. Acknowledgements

This publication is part of the R&D&I project PID2024-157113OB-100, funded by MICIU/AEI/10.13039/501100011033/ and "FEDER/EU".

8. References

Adell Segura, J., & Castañeda Quintero, L. J. (2010). Los entornos personales de aprendizaje (PLEs): Una nueva manera de entender el aprendizaje. En R. Roig Vila & M. Fiorucci (Eds.), *Claves para la investigación en innovación y calidad educativas: La integración de las tecnologías de la información y la comunicación y la interculturalidad en las aulas* (pp. 19–30). Marfil; Roma TRE Universita degli Studi. http://hdl.handle.net/10201/17247

Barrera, G. P., Chiappe, A., Ramírez-Montoya, M. S., & Alcántar Nieblas, C. (2025). Key barriers to personalized learning in times of artificial intelligence: A literature review. *Applied Sciences, 15*(6), Article 3103. https://doi.org/10.3390/app15063103

Bartolomé Pina, A. (2020). Cambiando el futuro: "blockchain" y educación. *Pixel-Bit. Revista de Medios y Educación*, (59), 241–258. https://doi.org/10.12795/pixelbit.82546

Bastani, H., Bastani, O., Sungu, A., Ge, H., Kabakcı, Ö., & Mariman, R. (2025). Generative AI without guardrails can harm learning: Evidence from high school mathematics. *Proceedings of the National Academy of Sciences, 122*(26), Article e2422633122. https://doi.org/10.1073/pnas.2422633122

Bernacki, M. L., Greene, M. J., & Lobczowski, N. G. (2021). A systematic review of research on personalized learning: Personalized by whom, to what, how, and for what purpose(s)? *Educational Psychology Review, 33*, 1675–1715. https://doi.org/10.1007/s10648-021-09615-8

Bloom, B. S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher, 13*(6), 4–16. https://doi.org/10.3102/0013189X013006004

Bond, M., Khosravi, H., De Laat, M., Bergdahl, N., Negrea, V., Oxley, E., Pham, P., Chong, S. W., & Siemens, G. (2024). A meta systematic review of artificial intelligence in higher education: A call for increased ethics, collaboration, and rigour. *International Journal of Educational Technology in Higher Education, 21*, Article 4. https://doi.org/10.1186/s41239-023-00436-z

Chan Núñez, M. E., & Gastelum Parra, M. (2016). Tendencias en la personalización de los entornos de aprendizaje: Experiencias y modelos de personalización en instituciones de educación superior mexicanas.

Universidades, (70), 69–88. https://www.redalyc.org/articulo.oa?id=37348529006

Chatti, M. A., & Muslim, A. (2019). The PERLA framework: Blending personalization and learning analytics. *International Review of Research in Open and Distributed Learning, 20*(1), 244–261. https://doi.org/10.19173/irrodl.v20i1.3936

Coll, C. (2016). La personalización del aprendizaje escolar: El qué, el por qué y el cómo de un reto insoslayable. En J. M. Vilalta (Dir.), *Reptes de l'educació a Catalunya. Anuari d'Educació 2015* (pp. 1–36). Fundació Jaume Bofill. http://psyed.edu.es/archivos/grintie/Coll_2016_LaPersonalizaci%C3%B3nDelAprendizajeEscolar.pdf

Conole, G. (2010). Personalisation through technology-enhanced learning. In J. O'Donoghue (Ed.), *Technology-supported environments for personalized learning: Methods and case studies* (pp. 1–15). IGI Global. https://doi.org/10.4018/978-1-60566-884-0.ch001

Crespo, D. (Ed.). (2023). *UNIVERSITIC 2022: Evolución de la madurez digital de las universidades españolas*. Crue Universidades Españolas. https://www.crue.org/wp-content/uploads/2023/11/Universitic-2022-Crue.pdf

Crowder, N. A. (1962). Intrinsic and extrinsic programming. In J. E. Coulson (Ed.), *Programmed learning and computer-based instruction* (pp. 58–66). John Wiley & Sons.

Cuban, L. (2018). *The flight of a butterfly or the path of a bullet? Using technology to transform teaching and learning*. Harvard Education Press.

Esteban-Guitart, M., & Moll, L. C. (2014). Funds of identity: A new concept based on the funds of knowledge approach. *Culture & Psychology, 20*(1), 31–48. https://doi.org/10.1177/1354067X13515934

Fan, Y., Tang, L., Le, H., Shen, K., Tan, S., Zhao, Y., Shen, Y., Li, X., & Gašević, D. (2025). Beware of metacognitive laziness: Effects of generative artificial intelligence on learning motivation, processes, and performance. *British Journal of Educational Technology, 56*(2), 489–530. https://doi.org/10.1111/bjet.13544

FitzGerald, E., Kucirkova, N., Jones, A., Cross, S., Ferguson, R., Herodotou, C., Hillaire, G., & Scanlon, E. (2018). Dimensions of personalisation in technology-enhanced learning: A framework and implications for design. *British Journal of Educational Technology, 49*(1), 165–181. https://doi.org/10.1111/bjet.12534

Guan, R., Raković, M., Chen, G., & Gašević, D. (2025). How educational chatbots support self-regulated learning? A systematic review of the literature. *Education and Information Technologies, 30*, 4493–4518. https://doi.org/10.1007/s10639-024-12881-y

Guettala, M., Bourekkache, S., Kazar, O., & Harous, S. (2024). Generative artificial intelligence in education: Advancing adaptive and personalized learning. *Acta Informatica Pragensia, 13*(3), 460–489. https://doi.org/10.18267/j.aip.235

Hargreaves, D. (2004). *Personalising learning – 2: Student voice and assessment for learning*. Specialist Schools Trust. https://webcontent.ssatuk.co.uk/wp-content/uploads/2014/08/14142830/PL2-Student-Voice-and-Assessment-for-Learning.pdf

Hernández Cárdenas, L. S., Castaño, L., Cruz Guzmán, C., & Nigenda Álvarez, J. P. (2022). Personalised learning model

for academic leveling and improvement in higher education. *Australasian Journal of Educational Technology, 38*(2), 70–82. https://doi.org/10.14742/ajet.7084

Holstein, K., & Doroudi, S. (2022). Equity and artificial intelligence in education: Will "AIEd" amplify or alleviate inequities in education? In W. Holmes & K. Porayska-Pomsta (Eds.), *The ethics of artificial intelligence in education: Practices, challenges, and debates* (pp. 151–173). Routledge. https://doi.org/10.4324/9780429329067-9

Järvelä, S. (2006). Personalised learning? New insights into fostering learning capacity. In *Personalising education* (pp. 31–46). OECD Publishing. https://doi.org/10.1787/9789264036604-3-en

Kucirkova, N., Gerard, L., & Linn, M. C. (2021). Designing personalised instruction: A research and design framework. *British Journal of Educational Technology, 52*(5), 1839–1861. https://doi.org/10.1111/bjet.13119

Labadze, L., Grigolia, M., & Machaidze, L. (2023). Role of AI chatbots in education: Systematic literature review. *International Journal of Educational Technology in Higher Education, 20*, Article 56. https://doi.org/10.1186/s41239-023-00426-1

Lee, D., Huh, Y., Lin, C.-Y., & Reigeluth, C. M. (2018). Technology functions for personalized learning in learner-centered schools. *Educational Technology Research and Development, 66*, 1269–1302. https://doi.org/10.1007/s11423-018-9615-9

Mas Garcia, X. (2023). *La paradoxa del diàleg buit: Una història sobre el rol de la IA en l'aprenentatge i l'avaluació*. Universitat Oberta de Catalunya. https://hdl.handle.net/10609/149548

Prendes Espinosa, M. P., & Serrano Sánchez, J. L. (2016). En busca de la tecnología educativa: La disrupción desde los márgenes. *RiiTE Revista Interuniversitaria de Investigación en Tecnología Educativa*, (0), 6–16. https://doi.org/10.6018/riite/2016/263771

Pressey, S. L. (1926). A simple apparatus which gives tests and scores—and teaches. *School and Society, 23*(586), 373–376.

Reyes Parra, D., Rozo García, H. A., & Buitrago Espitia, J. E. (2024). Aportes de la tecnología al aprendizaje personalizado: Una revisión a la literatura. *Diálogos, 16*(28), 9–29. https://doi.org/10.61604/dl.v16i28.352

Sachete, A. dos S., Gomes, R. S., Filho, A. B. C., & de Lima, J. V. (2024). Indicadores de aprendizaje adaptativo en entornos virtuales de aprendizaje: Revisión sistemática de la literatura. *Revista Latinoamericana de Tecnología Educativa - RELATEC, 23*(2), 69–87. https://doi.org/10.17398/1695-288X.23.2.69

Salinas, J., & De-Benito, B. (2020). Construction of personalized learning pathways through mixed methods. *Comunicar, 28*(65), 31-42. https://doi.org/10.3916/C65-2020-03

Salinas, J., De-Benito, B., Moreno-García, J., & Lizana-Carrió, A. (2022). Nuevos diseños y formas organizativas flexibles en educación superior: Construcción de itinerarios personales de aprendizaje. *Pixel-Bit, Revista de Medios y Educación*, (63), 65-91. https://doi.org/10.12795/pixelbit.91739

Salinas, J., & Lizana, A. (2025). Presentación de la sección especial: Itinerarios flexibles de aprendizaje.

Tecnologías digitales para la personalización y la inclusión educativa. *Edutec, Revista Electrónica de Tecnología Educativa*, (93), 1-8. https://doi.org/10.21556/edutec.2025.93.4477

Salinas, J., & Moreno-García, J. (2025). Visiones sobre la integración educativa de la inteligencia artificial. En P. Román-Graván, J. Barroso-Osuna, J. Cabero-Almenara, & C. Llorente-Cejudo (Eds.), *Visiones sobre la integración educativa de la inteligencia artificial* (1ª ed.). Dykinson. https://doi.org/10.14679/4177

Serrano, J. L., & Moreno-García, J. (2024). Inteligencia artificial y personalización del aprendizaje: ¿innovación educativa o promesas recicladas? *Edutec, Revista Electrónica de Tecnología Educativa*, (89), 1-17. https://doi.org/10.21556/edutec.2024.89.3577

Shemshack, A., & Spector, J. M. (2020). A systematic literature review of personalized learning terms. *Smart Learning Environments, 7*, Article 33. https://doi.org/10.1186/s40561-020-00140-9

Shemshack, A., Kinshuk, & Spector, J. M. (2021). A comprehensive analysis of personalized learning components. *Journal of Computers in Education, 8*, 485–503. https://doi.org/10.1007/s40692-021-00188-7

Skinner, B. F. (1954). The science of learning and the art of teaching. *Harvard Educational Review, 24*, 86–97.

Spector, J. M. (2016). The potential of smart technologies for learning and instruction. *International Journal of Smart Technology and Learning, 1*(1), 21–32. https://doi.org/10.1504/IJSMARTTL.2016.078163

Varona-Klioukina, S., & Engel, A. (2024). Prácticas de personalización del aprendizaje mediadas por las tecnologías digitales: Una revisión sistemática. *Edutec. Revista Electrónica de Tecnología Educativa*, (87), 236–250. https://doi.org/10.21556/edutec.2024.87.3019

Walkington, C., & Bernacki, M. L. (2020). Appraising research on personalized learning: Definitions, theoretical alignment, advancements, and future directions. *Journal of Research on Technology in Education, 52*(3), 235–252. https://doi.org/10.1080/15391523.2020.1747757

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education: Where are the educators? *International Journal of Educational Technology in Higher Education, 16*, Article 39. https://doi.org/10.1186/s41239-019-0171-0

Zhang, J. H., Zhang, Y. X., Zou, Q., & Huang, S. (2018). What learning analytics tells us: Group behavior analysis and individual learning diagnosis based on long-term and large-scale data. *Educational Technology & Society, 21*(2), 245–258. https://www.jstor.org/stable/26388404