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Adaptive Learning Systems: Bridging Instructional Technology and Personalized Pedagogy through Design Thinking

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Abstract

This review explores how adaptive learning systems, when guided by the principles of design thinking, can bridge the gap between instructional technology and personalized pedagogy. While technology continues to transform education, its impact remains limited when introduced without focus on learner-centered teaching practices. This study argues that technology alone cannot drive meaningful change in the classroom unless it is thoughtfully integrated into the learning process through pedagogical strategies informed by the needs of learners and teachers. The review examines major instructional challenges in contemporary classrooms, including large class sizes, learner diversity, insufficient digital literacy, and inadequate feedback mechanisms. It discusses how design thinking through its stages of empathizing with learners, defining their needs, generating ideas, prototyping solutions, and testing them in the classroom offers a structured yet flexible approach to addressing these challenges. Within this framework, adaptive learning systems emerge as powerful tools for personalizing instruction, delivering differentiated learning pathways, providing real-time feedback, and supporting data-driven decision-making. The review proposes a step-by-step pathway to harmonize technology with pedagogy, emphasizing the importance of empowering educators with analytics and tools, tailoring instruction to individual learners, and creating inclusive environments where learners progress at their own pace. The findings reveal significant implications for practice and policy. It concludes that the fusion of design thinking and adaptive learning has the potential to transform technology from a detached tool into an integral part of teaching and learning, creating more equitable, learner-centered environments that reflect the realities of diverse classrooms and the demands of digital education

Keywords: Design thinking, educational innovation, learner-centered design, pedagogical equity, systems integration.

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Introduction

The rapid evolution of technology in the twenty-first century is redefining the nature of education in profound and far-reaching ways. Digital tools now shape how learning is designed, delivered, and experienced, influencing everything from curriculum planning to classroom interaction and learner assessment (Müller, 2025) Despite these remarkable advances, many classrooms continue to grapple with persistent structural and pedagogical challenges that technology alone has not resolved. Traditional teaching methods, often rooted in uniform instruction and static curricula, struggle to accommodate the increasingly diverse needs of today's learners. Large class sizes, diverse learner abilities, varying levels of digital literacy, and inadequate feedback mechanisms remain pressing obstacles to effective teaching and learning. These realities reveal a fundamental mismatch between the capabilities of modern educational technology and the pedagogical strategies currently in place. As classrooms become more complex and learner diversity deepens, (Darwin & Prasodjo, 2025) the need for innovative approaches that integrate technology with pedagogical intent to create flexible, inclusive, and learner-centered educational environments has become not just desirable but essential.

In response to these evolving demands, adaptive learning systems have gained significant attention as a promising solution capable of transforming instructional practices. Unlike conventional technologies that deliver uniform content to all students, Strielkowski et al. (2025) observe that adaptive systems use data-driven algorithms, learning analytics, and feedback loops to tailor instruction in real time to the specific needs, abilities, and progress of individual learners. By continuously analyzing learner interactions and adjusting content accordingly, these systems offer the potential to make education more responsive, personalized, and effective (Liu & Yu, 2023); (Zubair, 2025). However, their transformative potential often remains underutilized because many implementations are driven by technological capacity rather than pedagogical vision. Without a guiding framework that anchors their design and use in sound educational principles, adaptive technologies risk becoming mechanistic solutions that address surface-level problems while failing to engage with deeper questions about how students learn, what motivates them, and how teaching practices should evolve. It is within this frame that design thinking emerges as a compelling approach, offering the conceptual and methodological tools needed to bridge the gap between technology and pedagogy and to align adaptive systems with the complex realities of teaching and learning.

Design thinking, at its core, is a human-centered, iterative approach to problem-solving that prioritizes empathy, contextual understanding, and experimentation. It is rooted in the belief that solutions must begin with a deep understanding of the people they are meant to serve. Applied to education, Bathla et al. (2025) note that design thinking provides a structured yet flexible process for reimagining learning environments and instructional practices Vomund and Miller (2025) assert that the process begins with empathizing with learners seeking to understand their experiences, challenges, motivations, and aspirations. From there, it moves to defining specific learning needs, ideating creative responses, prototyping instructional interventions, and testing their effectiveness in the classroom. This process ensures that technology does not dictate educational practice but instead becomes a responsive instrument shaped by pedagogical goals and human needs. By framing adaptive learning systems within this approach, educators and instructional designers can shift from viewing technology as a tool that delivers content to seeing it as a dynamic partner in constructing meaningful learning experiences. Such a shift requires careful attention not only to technical design but also to the social, emotional, and cognitive dimensions of learning (Oise et al., 2025).

This review study explores how design thinking can guide the integration of adaptive learning systems to bridge the longstanding divide between instructional technology and personalized pedagogy. It critically examines existing research on the instructional challenges that continue to constrain educational practice and analyzes how design thinking principles can inform the creation of adaptive prototypes that address these challenges in more nuanced ways. The study identifies models and strategies that use technology to support individualized learning pathways, deliver real-time feedback, generate actionable learner analytics, and provide differentiated instructional resources tailored to diverse needs. Through this analysis, the review highlights how adaptive learning systems, when grounded in a design-thinking framework, can move beyond superficial personalization to create deeply responsive educational environments. Such environments are not static but evolve alongside learners, continuously adapting to their growth, preferences, and changing contexts. They also create opportunities for teachers to act not merely as transmitters of knowledge but as designers of learning experiences who orchestrate the interplay between pedagogy, technology, and human development. (Dochia, 2025)

The recognition that each learner's journey is unique and that the convergence of instructional technology and pedagogy demands more than incremental improvements or instrumental solutions, it calls for a fundamental shift in mindset, a reorientation of how education is conceptualized and delivered. Through design thinking, the learning system can be reimagined as an evolving, responsive, and profoundly learner-centered ecosystem, where technology is not an add-on but an integral element of the pedagogical fabric. This perspective reframes adaptive learning systems as more than algorithmic engines of personalization, they become catalysts for transforming how knowledge is constructed, how learners engage with content, and how educators design and facilitate learning experiences. By foregrounding human needs and pedagogical purposes, design thinking ensures that adaptive technologies contribute meaningfully to equity, inclusivity, and innovation in education. It aligns instructional practices with the realities of twenty-first-century learning while remaining attentive to the enduring human dimensions of teaching and learning. In doing so, it points toward a future where technology and pedagogy are not opposing forces but complementary elements of a coherent educational vision, Saliao & Cajandig, (2025) one that is deeply attuned to the complexity, diversity, and potential of every learner.

Methodology

1. Design Thinking Process Theory

Design thinking is widely recognized as a human-centered approach to solving complex problems, (Oberer & Erkollar, 2024) particularly those that involve technology and human interaction. It emphasizes understanding users' real needs, framing problems from their perspective, generating creative solutions, and refining those solutions through rapid testing and iteration. In contrast to traditional problem-solving models that often rely on linear analysis and predefined procedures, design thinking embraces empathy, experimentation, and flexibility, making it particularly suitable for addressing educational challenges where learners, teachers, and learning environments are diverse and constantly evolving (Mayer & Schwemmle, 2025). The conceptual foundation of design thinking can be traced to the late 1960s, when scholars began to articulate design as a form of structured problem solving rather than purely aesthetic or technical work. Over the following decades, design thinking evolved from a practice within engineering and industrial design into a widely adopted methodology across business, health care, education, and technology. (Daymond & Knight, 2023) Its broader adoption was significantly advanced by practitioners and educators in the early 2000s, who formalized the process into a set of repeatable steps and introduced it to non-design fields. By the late 2000s, design thinking had become an influential framework in education and instructional technology, offering a way to align technological solutions with real human needs.

The core of design thinking rests on principles. First, it insists that solutions must emerge from a deep understanding of the people affected by a problem. Second, it recognizes that framing the problem clearly is as important as solving it. Third, it values a wide exploration of ideas before converging on specific solutions. Finally, it champions the development of quick, low-cost prototypes and the use of continuous feedback to refine ideas. (Houston & Manrique, 2024). These principles are often organized into five iterative stages: empathize, define, ideate, prototype, and test. While the stages are typically presented sequentially, in practice they are non-linear and cyclical, allowing designers to revisit earlier stages as new insights emerge.

1. Empathize: Understanding the Learner's World

The first stage of design thinking, empathy, involves engaging deeply with the people who will use or be affected by the solution. In the context of adaptive learning systems, this means understanding learners' experiences, challenges, motivations, and constraints. It also involves listening to teachers, administrators, and parents, who shape and support the learning environment. Empathy work goes beyond collecting demographic data. According to (Jaffe et al., 2025) it involves direct observation, conversations, classroom immersion, and mapping learners' daily journeys. Through these activities, designers can uncover subtle but critical details about how learners interact with technology, where they face barriers, and what motivates them to persist. For example, empathy may reveal that many students share devices at home, struggle with unstable internet connections, or prefer oral explanations over text-heavy content. These insights are invaluable because they shape how adaptive systems are designed not as abstract technological solutions but as tools that respond to real human contexts.

2. Define: Framing the Right Problem

The second stage, defining, translates the insights from empathy into a focused design challenge. Rather than starting with a broad objective like "improve learning outcomes" the define stage seeks to articulate the specific problem to be addressed in a way that is actionable and grounded in user needs. A well-constructed problem statement might take the form of "How might we provide timely, personalized feedback to students in classrooms with limited digital infrastructure?" Such a statement narrows the scope of design, clarifies the priorities of the adaptive system, and ensures that solutions remain relevant. In adaptive learning, defining the problem is particularly important (Mayer & Schwemmle, 2025) because technology often tempts designers to pursue sophisticated features that may not address the most pressing issues. By focusing on the user's perspective, the define stage helps prevent solutions that are technologically impressive but educationally irrelevant. It also informs the selection of metrics for evaluating adaptive systems for example, prioritizing accessibility, engagement, or speed of feedback over purely technical measures of algorithmic accuracy.

3. Ideate: Generating Creative Possibilities

Once the problem is clearly defined, the next step is ideation a structured process of generating as many potential solutions as possible. Ideation thrives on diversity of thought, encouraging contributions from different stakeholders, including teachers, learners, technologists, and curriculum experts. The goal is to move beyond obvious or conventional solutions and explore a wide range of approaches.In the context of adaptive learning, ideation might produce ideas that range from algorithmic adaptations, such as dynamic content sequencing based on learner performance, to low-tech solutions, such as teacher-guided grouping supported by simple analytics dashboards. Some ideas might involve language adaptation for multilingual learners, while others might focus on scaffolding prompts tailored to different cognitive levels. By withholding judgment during this stage, even unconventional ideas can lead to innovative combinations or inspire more feasible solutions

later in the process. Ideation also bridges the gap between instructional technology and personalized pedagogy. It forces designers to think not just about what the technology can do, but how it can support differentiated instruction, collaborative learning, and formative assessment practices. This alignment is essential if adaptive systems are to enhance, rather than disrupt, the educational process.

4. Prototype: Bringing Ideas to Life Quickly

Prototyping is the stage where ideas become tangible. In design thinking, a prototype is not a finished product but a simple, low-cost representation of an idea that can be tested and improved. (Baran & AlZoubi, 2024) Prototypes can take many forms from paper sketches and storyboards to clickable interfaces or rule-based models implemented in spreadsheets. For adaptive learning systems, prototyping might involve creating a simple decision tree that adapts lesson difficulty based on learner responses, or a mock-up of a teacher dashboard that visualizes student progress. These early versions allow designers to explore how the system might function, reveal potential usability issues, and gather feedback before investing significant time and resources in development. Importantly, prototypes help expose the practical realities of implementation. For example, a prototype might reveal that teachers do not have time to input certain types of data, or that learners become confused by too many content pathways. Identifying such challenges early enables iterative refinement and ensures that the final system aligns with classroom workflows and learner capacities.

5. Test: Refining Through Real-World Feedback

Testing closes the loop in the design thinking cycle and often leads back to earlier stages as new insights arise. Testing involves putting prototypes in front of real users, learners, teachers, or administrators and observing how they interact with them. The goal is not to validate a solution once and for all, but to learn from its strengths and shortcomings in the classroom. In adaptive learning, testing can be as simple as a week-long classroom pilot that measures how students respond to adaptive prompts or how teachers use the data generated by the system. Feedback collected through interviews, observations, and usage data informs the next iteration of the design. Some ideas will prove effective and be refined further, others will be discarded or reimagined. Over successive cycles, the solution becomes more aligned with learner needs and more robust in addressing the original problem. Testing also provides the evidence base for evaluating the impact of adaptive learning systems. Instead of focusing solely on algorithmic performance, testing highlights outcomes such as student engagement, teacher satisfaction, instructional efficiency, and learning gains, outcomes that reflect the broader pedagogical value of the technology.

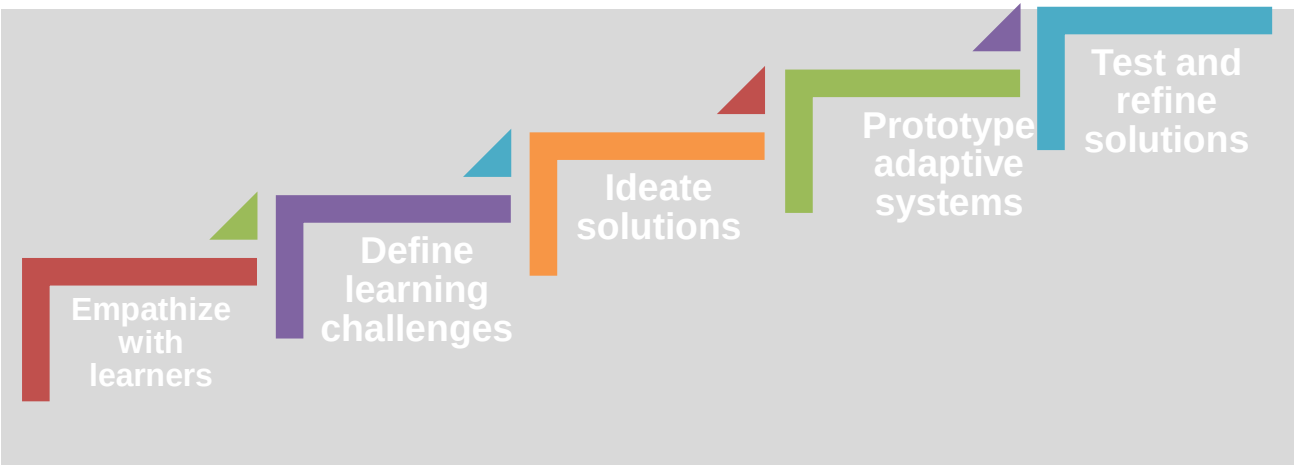

Figure 1. Design thinking process (Authors'generated illustration, 2025)

6. Why Design Thinking Strengthens Adaptive Learning Initiatives

Applying design thinking to adaptive learning system development ensures that technology does not outpace pedagogy. Many educational technologies fail because they are designed in isolation from the real conditions of classrooms or the lived experiences of learners. (Jones, 2024).kaya Design thinking addresses this by embedding human perspectives at every stage of development. It keeps attention focused on the problems that matter most, encourages experimentation with multiple solutions, and supports continuous improvement through feedback and iteration. Design thinking naturally aligns with the goals of personalized pedagogy, by emphasizing empathy and problem definition. It ensures that adaptation responds to genuine learner diversity. By encouraging ideation and prototyping, it supports creative, context-sensitive solutions that integrate smoothly with existing instructional practices. And by prioritizing real-world testing, it ensures that adaptive systems evolve in response to the complex realities of teaching and learning. In contemporary education where classrooms are often large, learner abilities and backgrounds are diverse, and technological infrastructure is uneven design thinking offers a practical pathway for bridging instructional technology and personalized pedagogy. It enables researchers and practitioners to move beyond abstract theories of adaptation toward solutions that genuinely transform the learning experience. In doing so, design thinking does not merely guide the creation of adaptive learning systems, it helps reimagine what effective, inclusive, and learner-centered education can look like in the digital age. (George, 2025)

2. Bridging Technology and Pedagogy: A Step-by-Step Approach

Technology, no matter how advanced, cannot by itself transform teaching and learning. Classrooms are not just spaces where information is delivered, they are human environments shaped by relationships, emotions, differences, and evolving needs. (Kayyali, 2024) Digital tools may automate tasks, analyze patterns, and expand access to content, but without thoughtful integration into teaching practice, they remain disconnected from the real work of education. This is why design thinking with its focus on the learners and practical solutions becomes essential. It helps educators and developers align technological possibilities with pedagogical goals, ensuring that innovation strengthens rather than overshadows the human purpose of education. A 4 steps pathway has been proposed to achieve this alignment. Each step builds on the previous one and together they create a coherent process that places learners at the heart of technological innovation.

a. Identify Instructional Challenges

The journey begins by examining the real problems that teachers and learners face in everyday classrooms. Some technologies are introduced as a solution without a deep understanding of the issues it is meant to address. This leads to tools that may be impressive in physical design but irrelevant or ineffective in application to the needs of learners. Identifying instructional challenges grounds innovation in reality. Common challenges include large class sizes, which make individualized attention difficult. It presents a significant barrier to effective teaching and learning, as they limit opportunities for individualized attention and tailored instructional support. In such settings, educators often struggle to address the diverse needs, abilities, and learning paces of learners, which can hinder engagement and academic performance (Taddese et al., 2025). In many schools, a single teacher may be responsible for fifty or more students, each with unique strengths, weaknesses, and ways of learning. Tracking progress under such conditions becomes overwhelming, and providing timely feedback to every learner is nearly impossible. Another challenge is learner diversity, not just differences in ability, but also in learning preferences, language backgrounds, and levels of motivation. These factors influence how students engage with content and how quickly they grasp new concepts, these variations present unique abilities and challenges, necessitating inclusive instructional designs that support different learners' success (Azuka et al., 2024). Insufficient digital literacy is also a challenge, many teachers and learners lack the necessary skills and confidence to

use digital tools effectively. This gap limits how well technology can be integrated into teaching and learning. When users struggle with basic tasks such as navigating learning platforms, using educational software, or interpreting digital information even the most advanced tools become underused or misused. As a result, technology fails to deliver its potential benefits, and classroom innovation remains shallow or inconsistent. Also, **inadequate feedback mechanisms**, in many learning environments, systems for giving and receiving feedback are weak or slow. Students often complete assignments without timely, meaningful responses that show them what they did well or how to improve. Teachers, in turn, may lack clear data on learner progress, making it harder to adjust instruction or provide targeted support. According to Becerra, Mohseni, Sanz, and Cobos, (2024) students frequently report feeling "alone" in their learning journeys due to insufficient support and the absence of timely, meaningful feedback from instructors. This lack of responsive interaction not only hampers motivation but also limits opportunities for reflection, improvement, and deeper understanding of learning objectives. (Sylvia & Ponidi, 2025) Without effective feedback channels, learning becomes guesswork rather than guided growth, and opportunities for personalization and deeper understanding are lost. Recognizing these issues is not a one-off activity but an ongoing process. It involves listening to teachers, observing classroom dynamics, and engaging with learners themselves to understand where and why they struggle. This first step ensures that any technological intervention is not built around abstract assumptions but around the real, lived experiences of the learner it is meant to serve.

b. Apply Design Thinking

Once the challenges are clearly identified, the next step is to approach them using design thinking. (Romero Caballero et al., 2025) note that applying design thinking is crucial for crafting effective, learner-centered solutions. Through its iterative stages of empathizing with learners, defining their needs, ideating creative strategies, prototyping interventions, and testing their effectiveness. This method starts with empathy, understanding learners not as data points but as individuals with aspirations, fears, and distinct ways of making sense of the world. Teachers' perspectives are equally important, their professional judgment and classroom experiences shape how solutions can be used effectively. (Corbin et al., 2025). The problem must be defined in a precise and actionable way. For instance, rather than vaguely stating, students need better results, a sharper problem statement might be students in large classes struggle to receive timely feedback on assignments. Such clarity directs design efforts toward the learner and meaningful educational goals. Ideation follows, encouraging educators, developers, and learners to brainstorm possible solutions without prematurely dismissing unconventional ideas. This could include new feedback systems, adaptive content delivery, or tools that help teachers address learners' needs strategically. Prototyping takes care of developing simple, testable versions of these ideas and trying them out in the classrooms. Finally, testing to gathers insights from trials, revealing what works, what does not, and what needs refinement. This process is iterative and human-centered. It stops technology from sitting apart from real teaching and learning, and instead makes it a natural part of the classroom, shaped by what teachers and students truly need.

c. Empower Educators with Analytics, Tools, and Decision-Making Support

Technology is most effective when it strengthens teachers' ability to make informed decisions. (Sajja et al., 2023), in their work *Integrating AI and Learning Analytics for Data-Driven Pedagogical Decisions and Personalized Interventions in Education*, emphasize that technology attains its greatest educational impact when it enhances teachers' capacity to make informed instructional decisions. By leveraging artificial intelligence and learning analytics, educators can gain deeper insights into learners' needs, monitor progress in real time, and design targeted interventions that support personalized learning. This approach shifts technology from a mere tool of content delivery to a

strategic partner in pedagogy, enabling more responsive and effective teaching practices. Data generated by technological tools can reveal complexities and patterns that might otherwise remain hidden, (Wilder & Calderone, 2025) such as, which learner is at risk of falling behind, which topics consistently cause difficulty, and how engagement levels shift over time. When presented clearly and meaningfully, this information becomes a powerful decision-making tool. Teachers can use it to plan targeted interventions, adjust instructional strategies, and personalize support. For example, if analytics show that a learner is struggling with reading comprehension, the teacher can organize a focused session while the rest of the class continues independently. Decision-making support can also extend beyond the classroom. Administrators can use aggregated data to plan teacher training or allocate resources where they are most needed. ("Teaching Learners with Special Educational Needs," 2025). In this way, technology not only enhances teaching practice but also informs broader educational planning and policy.

d. Create Inclusive Environments Where Learners Advance at Their Own Pace

The deeper purpose of harmonizing technology with pedagogy is building learning environments that respect learners' differences and allow every learner to thrive. In such environments, learners' progress becomes a personal journey rather than a race. (Nwachukwu et al., 2025) assert that the fundamental goal of education is the creation of equitable and inclusive learning environments where every learner, regardless of background, ability, or circumstance, is given the opportunity to succeed. Such environments go beyond merely providing access to education, they actively dismantle systemic barriers, value learner diversity, and promote participation and belonging for learners. By prioritizing inclusivity and equity, education becomes transformative forces that not only imparts knowledge and skills but also achieve social justice, nurtures individual potential, and prepares learners to contribute meaningfully to the society. Teachers, equipped with data and insights, can guide each learner more effectively, adjusting strategies, and connecting learning to real-life experiences. Inclusive environments are not only fairer but also become more effective. When learners feel that the system recognizes and supports their individuality, motivation increases, confidence grows, and deeper learning takes place. This is the ultimate goal of integrating technology with pedagogy, not simply to digitize education but to humanize it.

Results and Discussion

1. Tech-Powered Adaptive Learning Ecosystem

This is an ecosystem leverages artificial intelligence, learning analytics, and interactive digital tools to respond dynamically to learners' unique needs, abilities, and progress. It integrates diagnostic assessment, differentiated instruction, learner analytics, real-time feedback, and continuous refining and optimization that evolve with each learner.

a. Diagnostic Assessment

Any effective adaptive learning system begins with diagnostic assessment, an initial evaluation conducted at the beginning of instruction to determine each learner's current knowledge level, prior understanding, and readiness. This pre-assessment is essential for identifying existing knowledge gaps, misconceptions, and learning strengths, enabling educators to tailor instruction to individual learner profiles (Universidad Nacional de San Agustín de Arequipa, Peru & Maraza-Quispe, 2024). By providing a clear picture of where each learner stands before instruction begins, diagnostic assessment transforms technology from a generic delivery mechanism into a responsive,

learner-centered ecosystem. It ensures that subsequent teaching strategies, tools, and resources align precisely with each learner's readiness and potential which is the essence of personalized pedagogy.

b. Differentiated Instruction

According to (Dr., Dothan City Schools, ELA Teacher, USA, Y.Grecu2027@o365.ncu.edu & Grecu, 2022) differentiated resources are instructional materials and tools designed to address the diverse needs, abilities, and learning preferences of students, ensuring that all learners can access and engage with content meaningfully. Instead of applying a uniform teaching approach, differentiated instruction tailors learning experiences to individual readiness levels, interests, and learning styles, allowing learners to achieve the same learning objectives through varied pathways. This approach is essential in adaptive learning environments because it recognizes learner diversity as a strength and ensures that no learner is left behind due to rigid instructional methods. The use of differentiated resources enhances learner engagement, supports deeper understanding, and promotes equity in the classroom. (McKoy & Merry, 2023) It allows educators to provide materials and activities that are appropriate for every learner, all within the same learning environment. It empowers learners to take ownership of their learning, builds confidence, motivation, and self-efficacy. A range of digital tools supports differentiated instruction, such as: Curipod- it enables teaching in multiple formats and provides rubric-aligned AI feedback in real time, encouraging learners to reflect on and improve their work continuously. Canva for Education- it facilitates the creation of customized visual materials, catering especially to visual learners and enhancing content accessibility. Kahoot- uses gamified quizzes tailored to varying ability levels, promoting active engagement and formative assessment. Google Workspace- supports differentiated assignments that can be adjusted to learners' pace and competencies, allowing for flexible progression.

c. Learner Analytics- Data-Driven Understanding & Decision-making

Learner analytics refers to the systematic collection, analysis, and interpretation of data generated through learners' interactions with digital platforms and instructional activities. (Kew & Tasir, 2022) These analytics offer valuable insights into learners' engagement patterns, performance trends, learning progress, and areas of difficulty. By transforming raw data into actionable information, learner analytics empower educators to make informed, evidence-based decisions about instruction, curriculum design, and targeted interventions. It is important because of its ability to personalize education and enhance learning outcomes. It allows teachers to identify struggling learners early, understand why certain learners may be disengaged, and adjust instructional strategies accordingly. With real-time data, educators can track how learners progress over time, monitor the effectiveness of teaching methods, and refine instruction to better meet diverse needs. Also, learners benefit from analytics by gaining a clearer understanding of their strengths, areas for improvement, and learning paths, which ensures self-regulation and ownership of their learning process. Several tools facilitate the effective use of learner analytics in educational settings. Moodle Analytics- it provides detailed reports on learner engagement, activity completion, and performance, helping educators provide targeted support where it is most needed. Google Classroom Insights- it monitors assignment submissions, participation trends, and learner progress, allowing teachers to adapt instruction based on real-time data. Learning Locker (LRS)-aggregates data from multiple learning sources into a centralized system, enabling deeper analysis of learner behaviour and outcomes across various platforms. By integrating these tools into the learning ecosystem, educators can move from reactive to proactive teaching. Learner analytics not only enhance instructional precision and effectiveness but also contribute to a more equitable and personalized educational experience, ensuring that every learner receives the right support at the right time.

d. Real-Time Feedback and Recommendation

This is the provision of immediate, targeted responses to learners' actions and performance. Unlike traditional feedback, which is often delayed until after assessments, real-time feedback occurs during the learning process, allowing learners to recognize errors, clarify misconceptions, and make improvements instantly. This immediacy transforms learning into a continuous, interactive process where students are actively engaged in monitoring and refining their understanding. It enhances learning effectiveness, making learners to become more conscious of how they learn, why they make mistakes, and how they can improve. It also reinforces knowledge acquisition by providing timely support that prevents misconceptions from becoming entrenched. For educators, real-time insights into learners' progress enable them to adjust instruction on the spot, ensuring that teaching remains responsive and aligned with the learner needs. Several powerful tools facilitate this process such as Mentimeter- it allows instructors to pose questions and gather instant responses, enabling immediate adjustments to instruction based on learner input. Socrative- delivers real-time quiz feedback, highlighting learning gaps as they occur and guiding both learners and teachers in addressing them promptly. Edmodo- supports two-way feedback, adapting content and instructional pace in response to learner performance and engagement. While these tools mentioned above are powerful examples, they are by no means exhaustive. Numerous other technologies exist that can be integrated into adaptive learning environments. However, their effectiveness depends on the foundation laid by diagnostic assessment and application of design thinking process. Without first understanding each learner's starting point, even the most advanced tools risk delivering generalized instruction rather than truly adaptive, personalized learning experiences.

Figure 2. Authors'generated illustration-2025

2. Implications for Practice and Policy

The integration of adaptive learning systems with design thinking principles holds transformative potential for contemporary education, but its effectiveness depends on how it is translated into classroom practices, institutional frameworks, and broader policy environments.

a. Pedagogical ImplicationsTeacher Training:

(Zhang & Zhang, 2024) assert that teachers occupy a fundamental role in the effective implementation of adaptive learning systems. Their professional judgment, pedagogical expertise, and capacity to interpret and act upon learner data are essential for translating technological capabilities into meaningful educational outcomes. However, many educators lack the skills required to interpret learner data, leverage adaptive tools effectively, and embed design thinking principles in their pedagogy. Professional development initiatives must therefore extend beyond technical training to encompass mindset transformation. Teachers need to be equipped with the capacity for empathic observation, problem framing, ideation, and iterative testing skills that mirror the stages of design thinking. This approach shifts their role from information transmitters to learning experience designers who co-create adaptive pathways with their students. Embedding such competencies into teacher education programs and continuous professional development frameworks ensures that educators can navigate and harness adaptive systems to personalize instruction meaningfully.

b. Curriculum Design:

(Vreuls et al., 2025) argue that curriculum development must shift from rigid, content-focused models to flexible, learner-centered frameworks that reflect with the principles of adaptive learning. Such evolution enables curricula to respond to learners' diverse needs and integrate real-time data for personalized learning pathwaysTraditional curricula are often rigid, sequential, and content-heavy, leaving limited room for personalization. A design thinking-informed curriculum should instead emphasize flexibility, modularity, and responsiveness to diverse learner needs. Content can be structured into adaptive modules that allow students to progress at individual paces and follow differentiated learning pathways. Curricula should integrate problem-based and project-based learning approaches that align with design thinking principles, thereby ensuring creativity, critical thinking, and real-world application. Collaboration between curriculum designers, educators, and developers is essential to ensure that adaptive tools are not just add-ons but integral components of the learning design.

c. Assessment Practices:

Assessment paradigms must also shift to align with adaptive learning and design thinking. Conventional assessments, often summative and standardized, fail to capture the different shades and iterative nature of personalized learning. Instead, assessment should become a continuous, formative process that leverages real-time learner analytics generated by adaptive systems. (Nair et al., 2025) Such data-driven insights allow teachers to monitor progress, diagnose misconceptions promptly, and provide targeted interventions. Also, assessments should measure not only content mastery but also creativity, problem-solving, and collaboration competencies central to design thinking. Policy frameworks can support this shift by endorsing alternative assessment models such as performance-based tasks, and adaptive testing systems that reflect individual learning journeys.

d. Institutional Implications Infrastructure Development:

For adaptive learning systems to effectively transform teaching and learning processes, educational institutions must prioritize significant investment in technological infrastructure. This infrastructure forms the backbone of adaptive learning, enabling real-time data collection, personalized content delivery, and responsive feedback mechanisms that are essential for meeting diverse learner needs. As (Isaeva et al., 2025) argue, thriving in the era of adaptive education requires institutions not only to adopt emerging technologies but also to ensure their robust acquisition and continuous upgrading. This strategic investment lays the groundwork for scalable, sustainable, and inclusive adaptive learning environments capable of addressing the evolving demands of 21st-century education. Reliable internet connectivity, adequate digital devices, and learning management systems capable of supporting adaptive functionalities are essential. Beyond hardware, institutions need

platforms that integrate analytics dashboards, collaborative tools, and learner-friendly interfaces accessible to both teachers and learners. Infrastructure planning should also consider scalability and sustainability, ensuring that systems remain functional and relevant as technologies evolve.

e. Support Systems:

The successful adoption of adaptive learning is not solely a technical endeavor but an organizational one. (Wong & Li, 2025) Institutions must establish comprehensive support structures, including technical support teams, instructional designers, and developers/specialists who assist educators in optimizing adaptive tools. Such structure can further enhance implementation by enabling educators and other stakeholders to share best practices and constantly co-create adaptive strategies.

f. Inclusivity Policies:

Adaptive learning, when combined with design thinking, has the potential to promote equity and inclusion by tailoring instruction to diverse learner. (Aigbe et al., 2025). However, this potential can only be realized if inclusivity is deliberately embedded in institutional and policy frameworks. Policies should mandate accessibility standards in digital content and tools, ensuring that learners with disabilities or limited digital literacy are not marginalized. It then follows that adaptive systems must be designed to respect diversity, allowing content customization to reflect different contexts and learner identities. Policymakers can further advance inclusivity by incentivizing research and development in diversity-responsive adaptive technologies and by supporting initiatives that address the digital divide through equitable resource distribution.In summary, the convergence of adaptive learning and design thinking requires systemic transformation across pedagogical practices and institutional structures. Teacher training, curriculum flexibility, and formative assessment are important for classroom-level change, while robust infrastructure, sustained support systems, and inclusive policies create the enabling environment necessary for attainment, toward a more responsive, equitable, and innovative educational landscape that aligns technology with the evolving needs of diverse learners.

Conclusion

This review demonstrates that the gap between instructional technology and personalized pedagogy can be meaningfully addressed when adaptive learning systems are developed within a design thinking framework. Technology, while powerful, cannot transform teaching and learning in isolation, its effectiveness depends on how well it is aligned with learners' needs, instructional goals, and classroom experiences. By following the iterative stages of design thinking, empathizing with learners, defining their needs, generating creative solutions, prototyping interventions, and testing them in the classroom, designers and educators can ensure that teaching respond directly to critical challenges such as large class sizes, learner diversity, insufficient digital literacy, and inadequate feedback mechanisms. The integration of design thinking into the development and deployment of adaptive learning systems offers a practical and sustainable pathway toward innovation in education. It enables a more responsive, equitable, and effective learning experience, ensuring that technology enhances rather than displaces the fundamental human work of teaching and learning.

Recommendations for Future Research

While this review highlights the transformative potential of adaptive learning systems guided by design thinking, some areas require deeper exploration. Future studies should investigate how design thinking practices can be more systematically integrated into teacher training and professional development programs, particularly in low-resource countries where digital literacy remains limited.

Understanding how educators adopt and adapt design thinking in their everyday practice will help refine models that are both scalable and adapted to specific learning environments. Also, future research should explore how adaptive technologies can be co-designed with teachers and learners to ensure they reflect true classroom needs of learners. This collaborative and participatory approach should yield more effective and sustainable solutions. Finally, as technology evolves rapidly, researchers should continue to examine ethical and equity considerations, ensuring that adaptive learning systems do not reinforce existing inequalities but instead expand access to quality education. Addressing these questions will strengthen and guide the next generation of adaptive, learner-centered learning innovations.

Conflicts of Interest

No conflict of interest.

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