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ARTIFICIAL INTELLIGENCE IN LEARNING DESIGN: A REVIEW OF INNOVATIONS IN DIGITAL EDUCATION

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ABSTRACT

Artificial Intelligence (AI) by shifting to a structural element of how learning is designed, delivered, and assessed, is becoming a central force in education more than a supportive tool. This article reviews studies published between 2020 and 2025 examining the innovations AI has introduced into digital learning design. The analysis is organized into four themes: human-centered AI, adaptive and personalized learning, AI-enhanced assessment and feedback, and inclusive and accessible learning design. Findings highlight that stressing the accountability of human-centered AI, transparency, and human agency, its application remains uneven in education. There are concerns about equity, algorithmic bias, and data privacy, although adaptive and personalized learning present strong potential to improve engagement, flexibility, and learner autonomy. AI-assisted assessment and feedback expand opportunities for timely and personalized support. Nevertheless, challenges around academic integrity and institutional policy remain. Within this scope, inclusivity and fairness emerge as key priorities, with evidence that AI can reduce barriers for marginalized learners, although risks of reinforcing exclusion remain without strong safeguards. Overall, the literature suggests that AI in education faces fragmentation more than a lack of innovation. This review contributes by synthesizing current research as a structured overview by offering insights for educators, researchers, and policymakers striving to integrate AI in learning design responsibly and equitably.

Keywords: Artificial Intelligence (AI); Learning Design; Human-Centered AI; Adaptive and Personalized Learning; Assessment and Feedback; Inclusive Education; Digital Education

INTRODUCTION

Artificial Intelligence (AI) is becoming the center of change in the education field. It is currently an integral part of how learning is designed and delivered. It is no longer viewed as an additional tool that helps, but it has become the main component itself. In many areas of teaching and learning, AI's role has expanded significantly over the years, thanks to advancements in machine learning, natural language processing, and generative systems. Recently, AI has been able to support personalization, enhance accessibility for diverse learners, and provide adaptive feedback. The recent influence of AI promotes the potential to create more engaging, inclusive, and flexible learning environments. (Prem Lata, 2024; Sato et al., 2024).

However, research on AI in education is still fragmented despite the progress. Various scholars have investigated human-centered AI (Auernhammer, 2020; Shneiderman, 2021; Capel & Brereton, 2023; Wanakuta et al., 2025), adaptive and personalized AI learning (Marienko et al., 2020; Soler Costa et al., 2022; Ullah et al., 2025), and AI-supported assessment and feedback (Khlaif et al., 2025; Shuaibu et al., 2024). Others have investigated further how AI can improve inclusivity and fairness in education (Prem Lata, 2024; Sato et al., 2024). Yet, instead of focusing on how these innovations collectively reshape learning design, most studies focus on isolated applications. There is no clear framework that integrates across these different areas in terms of the opportunities and risks of AI as a result. Adopting AI in consistent and pedagogically sound ways becomes more difficult for educators, policymakers, and curriculum designers as a result (Sato et al., 2024). Mentioning that AI has already introduced significant innovations that are redefining how learning is structured is also a guiding fact. Researchers emphasize

the need to place human values and agency at the core of AI systems. Auernhammer (2020) underscores the role of research design in developing responsible AI, while Shneiderman (2021) suggests transparency, accountability, and human control as principles. Capel and Brereton (2023) show that the perspectives in human-centered AI are various, and it is a broad field rather than a single model. Wanakuta, Walker, and Khan (2025) add that AI is beginning to play a role in design education itself, supporting the practices and collaboration in the field.

AI enables learning processes that adapt to each student's needs in adaptive and personalized learning. Marienko et al. (2020) described the way adaptive technologies support teacher education in sustainable ways. Soler Costa et al. (2022) highlight the role of the creation of flexible and student-centered learning by examining the practical and technological impact of personalization in education. Ullah et al. (2025) extend this work by creating a roadmap for the integration of the curriculum design in higher education. Together, these studies show that personalization is one of the main elements of AI in learning design.

This article reviews research published between 2020 and 2025 to integrate these different areas. This is being accomplished by focusing on four main themes: human-centered AI, adaptive and personalized learning, AI-enhanced assessment and feedback, and inclusive learning design. The article highlights both opportunities and challenges by bringing together insights from these areas of research. Its main contribution is to provide a structured overview of how AI is reshaping learning design and to offer guidance for educators, researchers, and policymakers looking forward to using AI responsibly in digital education.

LITERATURE REVIEW

HUMAN-CENTERED AI IN LEARNING DESIGN

According to Auernhammer (2020), the development of Artificial Intelligence (AI) frequently starts from a machine-centered perspective. By using human-centered design, it can be rebalanced by focusing more on people, their values, and real contexts. It is argued in the article that there are two perspectives in AI: The rationalistic perspective, in which humans are seen as cognitive machines and focus more on efficiency, and the design perspective, in which humans are seen in their full capabilities and their complexity and focus on real-world contexts. Human-Centered Design (HCD) approaches applied to AI include participatory design involving stakeholders directly in creating the tools, inclusive design making AI accessible to diverse populations, design considering the wider social effects of AI, interaction design by studying how people interact with AI systems to improve their usability, and need-design response, which indicates that AI should respond to real, identified human needs. On the track, the limitations that come within are that many projects label themselves as "human-centered" without applying true HCD principles. When it comes to that, there is a risk of ignoring ethical and social issues when design is not participatory. It encourages AI in education to be participatory, inclusive, and user-driven, yielding the ultimate results. This is a requirement to ensure that AI tools align with pedagogy and support real classroom needs.

Ben Shneiderman (2021) argues that most of AI development has been too focused on the autonomy-first principle, and it is more needed to adapt the configuration of human-centered AI that empowers people. It is indicated in the article that the core principle is "Humans in the group, computers in the loop," which supports that artificial intelligence should be a supportive tool and not a replacement for humans. To achieve a better outcome, design requirements should be explainable to users, allowing them to understand the decision-making process; transparent to clearly explain the processes behind outputs; accountable for audit trails and responsible for errors; and reliable in terms of safety, ensuring systems are trustworthy. It is indicated that AI has been too rationalistic, aiming for autonomous systems that are planning to replace humans. However, in reality, aiming for a better outcome, human-centered AI should lean toward empiricism, learning from real-world use, respecting human diversity and complexity, and also focusing on empowering them, not replacing them.

Capel and Brereton (2023) analyze that the broad and general term "human-centered artificial intelligence" is overused and unclear in sense, and it needs clearer definitions and frameworks. They explore four main areas of the research in HCAI: Explainable AI (XAI) makes decisions understandable for humans; it is a human-centered design method ensuring people are participatory and inclusive with design approaches. Human-AI teaming designs systems where humans and AI can participate and

collaborate effectively, and it is ethical AI for fairness, bias reduction, transparency, and an accountable future. In the study, it is mentioned that these four areas are considered and examined separately, and researchers rarely connect them into a unified framework. It argues that these four aspects need to be studied together to make a meaningful impact in real applications.

Wanakuta, Walker, and Khan (2025) explore how AI can support human-centered design in education in three main learning theories. Learning is viewed as an active process where students are able to build knowledge through experience. AI would be able to support this by real-time feedback and personalized pathways that adjust each learner's individual progress. Connectivism emphasizes learning as an ability to connect resources and people within networks. From this point of view, AI acts as a facilitator of knowledge flow by supporting collaboration across digital platforms or linking students to communities of practice. Socio-cultural theory highlights that learning happens in social and cultural contexts, and they are shaped by interaction with others. It is suggested that AI can expand this dimension by supporting group work, fostering inclusivity, and even providing multilingual opportunities so that diverse learners can participate equally.

INNOVATIONS IN ADAPTIVE AND PERSONALIZED LEARNING DESIGN

Soler Costa, Tan, Pivot, Zhang, and Wang (2022) provide the foundations of personalized and adaptive learning (PAL) in both classical educational philosophy and modern technological developments. In the article, the historical roots of PAL are explained as a concept of tailoring education that has been developed and is not a new concept. It is mentioned that in Confucian philosophy, the idea of "teaching to the talent" emphasized setting instruction according to each student's abilities. From another point of view, it is stated that Dewey's reflective learning added the importance of student-centered experiences, while Piaget's constructivism underlined learning as an active process of constructing knowledge. Clarification of the definition and distinction: the term "personalized learning" is defined as adapting what is taught (content) to how it is taught (the method) and how fast it is taught (pace), based on individual needs. Adaptive learning is defined as using AI, machine learning, or analytics to make these regulations automatically in real time, based on continuous data from the learner. Following the concepts, Learning Management Systems (LMSs) are mentioned as the providers of the digital backbone for adaptive courses. Benefits are listed as they remove learning barriers by offering individual support, reducing stress since learners work at their own pace, and improving efficiency, where time is used more effectively due to instructions that match students' needs. However, risks and challenges are listed as an important part, such as over-reliance on technology, which may reduce resilience and stress tolerance. Additionally, it is concerning that large amounts of learner data collected might raise ethical and legal concerns for the future.

Marienko et al. (2020) review how adaptive and individually tailored learning technologies can be applied in teachers' education to support sustainable development professionally. The article mentions the evolution process of the adaptive learning systems from programmed learning in the 1960s to today's AI and cloud-enabled platforms. Experiencing current applications such as adaptive LMS, testing systems, MOOCs, and subject-specific programs like DreamBox and ST Math. Empirical results of the pedagogical experiments prove that such systems improve ICT competence and collaboration among teachers. However, challenges remain regarding equity issues, as individuals might not have an equal chance to access AI technologies. Another challenging fact is that, considering the importance of responsible integration of AI technologies, they must be applied carefully to avoid ethical risks, misuse, or privacy issues.

Ullah, Hashim, Bandeali, and Akbar (2025) provide an empirical analysis of how AI integration into curriculum design can help adaptive and personalized learning in higher education. Collecting survey data from 250 faculty members and curriculum planners for the study illustrates a strong positive correlation between AI use and improvement of students' performance, engagement, and equity. AI-driven curriculum design is viewed as a strong predictor of academic performance, especially when accompanied by faculty preparation and suitable institutional infrastructure. Applications of AI in curriculum design help with real-time personalization of courses and adapting assessments tailored to each individual's progress, and are predicting and identifying at-risk students. However, there are significant points that must not be overlooked, such as data privacy risks, algorithmic biases, and unequal institutional capacity or resistance to adoption. The proposed roadmap for these challenges is listed as a probability of co-design between educators and AI developers, creating ethical safeguards

for fairness and privacy, and a possible institutional collaboration across universities for shared standards.

AI-ENHANCED ASSESSMENT AND FEEDBACK IN LEARNING DESIGN

Khlaif, Alkouk, Salama, and Abu Eideh (2025) investigate how generative AI is driving the redesign of assessments in higher education. Generative AI makes plagiarism and automated responses easier; for that reason, it is indicated that assessments must be redesigned to protect the originality and fairness of works. It is also mentioned that students need to learn how to work with AI responsibly, not avoiding it entirely, but in preparation for AI-driven workplaces. Also, institutional policies need to be created by universities to design evolving frameworks. Traditional essay exams are no longer reflecting real-world conditions where AI is commonly used and integrated. Educators need to encourage transparency, accountability, and responsible use of AI in various tasks. The AAAE Framework (Against, Avoid, Adopt, Explore) is designed to explain the concept better. "Against" is the description of the approach prohibiting AI completely and leaning more into traditional assessments such as closed-book exams and oral tests. Avoid design tasks that AI cannot do well, such as reflective writing and personalized portfolios or performance-based projects. It reduces the risk of AI misuse but might be limiting for innovation. Adopt is integrating AI into certain stages of learning, like brainstorming ideas and refining drafts, while keeping human originality. Explore is the most innovative approach among them; educators treat AI as a co-designer, encouraging students to collaborate with AI on problem-solving tasks, creativity, and critical thinking tasks. The benefits of AI-enhanced assessments are listed as encouraging creativity and innovation by using it for good use; it prepares students with practical AI literacy skills they will need in professional environments. However, the risk of integrity is also present, in which students may over-rely on AI or submit AI-generated works as their own. Another point of view is that of policy gaps. Many institutions lack clear and consistent guidelines on how AI should or should not be used in an assessment. Future directions are stated as assessments should reflect how students can responsibly use AI in real-world workplaces.

Shuaibu et al. (2024) examine the effectiveness of AI-enhanced feedback systems in supporting learning outcomes in open, distance, and e-learning (ODeL). The study evaluates six different feedback dimensions based on survey data from 426 postgraduate students. These categories are listed as personalization, adaptability, timeliness, multimodality, context awareness, and engagement strategies. Results substantiate that personalization, timeliness, context awareness, and engagement categories had positive impacts on student performance, while adaptability and multimodality were less effective. Technology Acceptance Model (TAM), Cognitive Load Theory (CLT), and Self-Determination Theory (SDT) are the methods utilized to explain the outcomes, mentioning that AI feedback is most successful when it is uncomplicated in its application, diminishes cognitive overload, and fosters learner engagement. The findings suggest that AI can close gaps in distance education by providing timely, relevant, and engaging feedback. Nevertheless, challenges persist with respect to equity, data privacy, and over-reliance on automation.

AI FOR INCLUSIVE AND ACCESSIBLE LEARNING DESIGN

Prem Lata (2024) delves deeper into the topic of how AI technologies—including adaptive learning systems, intelligent tutoring platforms, AR/VR, and emotional learning—are inclusive education. It is mentioned that the foundations of inclusive education are rooted in human rights and social justice practices and are influenced by Montessori, Dewey, Salamanca Statement (1994). They aim to maximize each learner's potential, not just access to the information. AI technologies in inclusive education are mentioned in different categories, such as personalized learning connected with platforms such as Khan Academy, Duolingo. Intelligent Tutor Systems (ITS) are mentioned as matching human tutors and freeing up more of the teachers' time. AR/VR, on the other hand, provides an immersive empathy-building learning experience for students with disabilities. Social-Emotional Learning (SEL) connects with AI chatbots and analytics that support empathy, regulation, and general well-being. One of the case studies includes Microsoft's Seeing AI, an application created specifically for people with visual impairments. It uses the smartphone camera combined with advanced computer vision and Natural Language Processing (NLP) to interpret and narrate the surrounding environment. The benefits of these components are listed as removing barriers for students with disabilities and providing

customized and equitable learning pathways. Enhancing engagement and participation is another aspect that is covered. However, it comes with great challenges: at a privacy and security might be compromised in student data use. Also, algorithmic bias may reinforce specific stereotypes. The article looks for several case studies to get a deeper understanding of the subject.

Sato, Shyyan, Chauhan & Christensen (2024) propose the Fair AI framework, a model that ensures fairness, equity, and inclusivity in AI-driven learner models for K-12 assessments. It explores the assessment triangle (cognition, observation, and interpretation) and illustrates that assessments must be valid across all three dimensions. If learner models are biased, assessments cannot be valid. It also highlights diversity and equity concerns as students from different cultural and linguistic backgrounds show knowledge differently (e.g., writing styles, oral explanations, gestures). If AI ignores these aspects, it risks reinforcing inequities rather than reducing them.

Most current policies are guidelines, not enforceable laws. This creates a gap between ethical aspirations and actual practice. It also introduces the fair AI framework proposed by Sato et al. (2024) to guide ethical and inclusive AI in education. The main components of the framework are accessible and inclusive design and ethical implementation. As a conclusion to the article, it is recommended that investing in teacher training is a must to prepare educators for inclusive AI practices. Also, regular controls must be conducted to identify bias and unfairness.

DISCUSSION AND CONCLUSION

The synthesis of the reviewed literature presents that AI is a structural force shaping how learning is designed, delivered, and evaluated, and is no longer a marginal addition to education. Emerging conclusions from the studies are not just the diversity of AI applications but also the challenge of bringing them together under a unified vision for education. Literature also exposes ethical, pedagogical, and structural tensions that must be considered for AI to evolve responsibly in the learning design area while showcasing significant achievements.

The field of human-centered AI demonstrates both unity and fragmentation. Auernhammer (2020) and Shneiderman (2021) highlight the need for AI systems that enhance human capacities, explainability, and accountability rather than replacing them. However, Capel and Brereton (2023) warn that the concept of "human-centered AI" has been stretched so broadly. Due to this reason, it has risks of losing meaning, unless it is grounded in clear frameworks. Wanakuta et al. (2025) situate AI within learning theories such as constructivism and sociocultural approaches, providing a more practice-oriented perspective while showing how it can support contextualized learning by supporting collaboration. Considered as a whole, these works suggest that while human-centeredness is strong rhetorically, its operationalization remains uneven, and often symbolic rather than structural in the field of education.

AI demonstrates pedagogical impact at its strongest in the area of adaptive and personalized learning. Studies by Marienko et al. (2020), Soler Costa et al. (2022), and Ullah et al. (2025) point to AI-driven curriculum and improved engagement, efficiency, and learner autonomy through adaptive pathways. However, the challenges they highlight—such as inequitable access, data privacy concerns, and algorithmic bias—raise critical questions as to whether personalization necessarily ensures educational equity. The literature reveals a paradox: if poorly managed, those systems precisely designed to reduce barriers can reproduce new ones. Therefore, the promise of personalization should be understood as a social responsibility, not only as a technical capacity.

AI also facilitates learning processes that are tailored to each student's needs with adaptive and personalized learning. Marienko et al. (2020) portrays the way teacher education is supported by adaptive technologies in a sustainable way. Soler Costa et al. (2022) mentions the importance of examining the practical and technological impact of personalization in education and the role of creating flexible and student-centered learning systems. Ullah et al. (2025) widen this work by providing a roadmap for curriculum design integration in higher education. Collectively, these studies prove that personalization is one of the key aspects of AI in learning design.

Generative technologies' disruptive potential becomes apparent during the process of investigating AI-enhanced feedback and assessment. Khlaif et al. (2025) outlines the ways of evaluation that are being unsettled by AI's capacity to generate text referring to frameworks such as AAAE to reconsider

assessment strategies. Shuaibu et al. (2024) analyzes through timelines and personalization aiming to provide evidence of AI-assisted feedback proving that it improves student outcomes in distance learning. However, there are several problems that cannot be considered separately other than questions of trust and policy such as issues of integrity, overreliance, and inconsistent institutional guidelines underscoring innovation in the space. The literature suggests that assessments in the future will need to measure also how responsibly students engage with AI tools themselves as much as what students know.

The themes of inclusivity and fairness highlights the ethical dimension of AI at the center of attention. Prem Lata (2024) and Sato et al. (2024) illustrate the capability of AI tools in generating opportunities for learners with marginalized backgrounds, disabilities and linguistic diversity. The evidence underscores AI's potential to reduce systematic barriers from intelligent tutoring systems to immersive AR/VR and also fairness-centered assessment models. Nevertheless, furtherly noted that these technologies may unintentionally reinforce exclusion without precautions against bias. The main issue is that there is a gap between aspirational guidelines and enforceable practices. Moreover, policies remain largely advisory leaving a significant discretion to developers and the institutions.

Across these four areas, one theme recurs which is AI in education is characterized by a lack of integration more than a lack of innovation. Research has generated valuable insight but rarely fields merged together into a shared framework that can roadmap educators and policymakers. In the sense of institutions seeking to adopt AI responsibly, the absence of synthesis results in uncertainty. Therefore, the challenge is systematic other than being only technical or pedagogical, requiring collaboration across disciplines and clarity in ethical standards mentioning deliberate investment in teacher preparation.

In conclusion, the reviewed literature illustrates the enabling and disrupting power of AI in the field of education. Its future impact will depend more on how well human values and pedagogical integrity are incorporated in its design and governance and depend less on technological sophistication. Prospectively, efforts must ensure that AI contributes not only to efficiency and personalization but also to inclusivity and educational justice. Future efforts should focus on integrated frameworks that overcome fragmentation in current research and practice.

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