



Original Research Paper

EDUCATION 4.0: INTEGRATING ARTIFICIAL INTELLIGENCE (AI) FOR PERSONALIZED AND ADAPTIVE LEARNING

J.P.Pramod¹, Dr. Preeti G. Dharmik², Dr. N.Suresh³, Dr. M.Vasanth Rao⁴
Dr. Kandati Sai Chandu⁵

¹Researcher, Dept. of R&D, The Foundrys Pvt. Ltd. Madhapur, Hyderabad, Telangana, India.

²Assistant Professor, UGC Malaviya Mission Teacher Training Center,
Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur, Maharashtra, India.

³Faculty, Department of Economics, Andhra Kesari University,
Ongole, Prakasam District, A.P., India.

⁴Faculty, Department of Education, Nagarjuna University, Nagarjunanagar, Guntur, A.P., India.

⁵Associate Professor, Dept. of MBA, Siddhartha Institute of Engineering and Technology,
Puttur, Tirupati, A.P., India.

Orcid: <https://orcid.org/0009-0007-2892-4917>

Abstract

Education 4.0 represents a transition from standardized, technology-supported education toward learner-centered, flexible, data-informed and digitally connected learning ecosystems. Artificial Intelligence (AI) has emerged as one of the most significant technologies supporting this transition because it can analyse learner behaviour, identify learning gaps, recommend appropriate learning resources, generate feedback and facilitate adaptive learning pathways. The present study examines the role of AI in advancing personalized and adaptive learning within the broader framework of Education 4.0. The study adopts a descriptive research design and is based exclusively on secondary data obtained from peer-reviewed journal articles, systematic reviews, international organization reports, government publications, policy documents and authentic educational databases. The analysis indicates that AI-enabled educational systems can move beyond the conventional “one-size-fits-all” model by dynamically adjusting content, pace, assessment and feedback according to learner needs. However, the literature also demonstrates that technological capability alone does not guarantee educational improvement. Data privacy, algorithmic bias, unequal digital infrastructure, teacher readiness, academic integrity, transparency and excessive dependence on automated systems remain important concerns. In the Indian context, the National Education Policy (NEP) 2020 provides a favourable policy environment for AI-enabled education, while initiatives such as DIKSHA, AI curricula and the India AI Mission create opportunities for wider adoption. The paper argues that Education 4.0 should be developed as a human-AI partnership rather than a replacement model. Sustainable implementation requires teacher capacity building, responsible data governance, inclusive infrastructure, pedagogically sound AI systems and continuous evaluation.

Keywords: Education 4.0, Artificial Intelligence, Personalized Learning, Adaptive Learning, Learning Analytics

*Corresponding Author:

Received: 25th July, 2026 | Revised: 26th August, 2026 | Accepted: 30th August, 2026 | Available Online: 2nd September, 2026

(DOI): 10.70102/AEJ.2026.18.7s.9

1. Introduction

The Fourth Industrial Revolution has transformed the relationship between technology, employment, knowledge and education. Traditional education systems were largely designed around standardized curricula, fixed classroom schedules and relatively uniform instructional approaches. Although such systems have enabled mass education, they have often struggled to respond to differences in students' prior knowledge, learning pace, interests, motivation and support requirements. Education 4.0 has emerged in response to this challenge. It emphasizes learner-centred education, interdisciplinary competencies, digital technologies, problem solving, creativity, collaboration, adaptability and lifelong learning. The World Economic Forum conceptualizes Education 4.0 as an approach that places learners at the centre while combining pedagogical and technological innovation to prepare learners for rapidly changing economic and social environments (World Economic Forum [WEF], 2022, 2023).

The National Education Policy (NEP) 2020

India provides an important context for examining this transformation. The National Education Policy (NEP) 2020 explicitly recognizes the importance of emerging technologies, including Artificial Intelligence, machine learning and data science. The policy calls for contemporary subjects such as AI to be introduced at appropriate educational stages and emphasizes computational thinking and multidisciplinary learning.

India has subsequently expanded AI-related educational initiatives. CBSE introduced AI as a skill subject at school level, while DIKSHA has incorporated technology-enabled features for content discovery, accessibility and teacher development. More recently, the IndiaAI Mission has sought to broaden the national AI ecosystem and improve access to AI capabilities. Government information released in 2026 also highlights the integration of AI into school curricula and the use of AI-supported functions within DIKSHA.

The research gap therefore lies not simply in identifying whether AI can personalize learning, but in understanding how AI should be integrated within Education 4.0 so that personalization remains pedagogically meaningful, ethically responsible and socially inclusive. The present paper addresses this gap through a descriptive synthesis of recent secondary evidence. The paper reviews the development of AI-enabled personalization, examines the Indian and global policy environment, identifies benefits and challenges, and proposes practical recommendations for responsible implementation.

2. Objectives of the Study

The study has the following objectives:

1. To examine the conceptual relationship between Education 4.0, Artificial Intelligence, personalized learning and adaptive learning.
2. To review recent secondary literature concerning AI-enabled personalized and adaptive learning.
3. To propose practical recommendations for human-centred, inclusive and responsible AI integration in education.

3. Review of Literature

- **Holmes et al. (2022)** examined the state of AI in education and classified different types of AI systems according to their educational functions and pedagogical assumptions. Their analysis cautioned against exaggerated expectations about AI and argued that educational purposes should determine technological design rather than the reverse. This is particularly relevant to Education 4.0 because the objective should be improved learning rather than technological adoption for its own sake.
- **Luckin and Cukurova (2019)** argued that AI-based educational technologies should be informed by learning sciences. Drawing upon educational technology examples, the authors demonstrated how learner data could potentially be used to scaffold learning and support teachers. Their contribution is significant because personalization should not be understood simply as algorithmic recommendation; it must reflect how learners actually develop knowledge and skills.
- **Miao et al. (2021)** examined the opportunities and risks associated with AI in education. The report emphasizes inclusion, equity, teacher preparation, governance and human agency. It recognizes AI's potential to support personalized learning while warning against technological determinism. Its major contribution is the integration of educational and policy perspectives. A limitation is that it is a policy guidance document rather than an empirical evaluation of particular AI systems.
- **OECD (2021)** Digital Education Outlook examined AI, learning analytics, robotics and other smart technologies in education. Its discussion of personalization describes systems that diagnose learner knowledge and adjust tasks, feedback or curriculum. Importantly, the OECD proposes hybrid human-AI approaches rather than complete automation. The limitation is that the report provides a broad international overview rather than institution-specific evidence. Nevertheless, it offers a strong conceptual basis for understanding adaptive learning as a partnership between teachers, learners and intelligent technologies.

- **Zawacki-Richter et al. (2019)** conducted a systematic review of research on AI applications in higher education. The review examined published research systematically and identified applications including profiling and prediction, assessment and evaluation, adaptive systems and intelligent tutoring. An important limitation identified by the authors was the comparatively weak participation of educators and educational theory in much AI research. The study is particularly relevant because it establishes an important principle for Education 4.0: technological sophistication must be accompanied by pedagogical understanding.

Personalized Education and AI in the United States, China and India (2022)

- **Crompton and Burke (2023)** systematically examined AI research in higher education covering the period 2016–2022. Their review identified rapid growth in AI research during 2021 and 2022 and demonstrated the expanding range of AI applications in higher education. The authors highlighted the increasing maturity of the field but also the need for further empirical and theoretically informed investigation. The study is valuable for establishing the scale and direction of the research field, although its focus is primarily higher education rather than school-level personalized learning.
- **Farhood et al. (2025)** conducted a systematic literature review of AI-based personalized learning covering research from 2015 to 2025 and synthesizing 125 studies. The review examined applications across K–12, higher education and institutionally supported online learning. It identified AI's growing role in recommending learning resources, designing individualized pathways and supporting assessment, while also identifying limitations associated with insufficient data, implementation complexity and ethical concerns. The study provides particularly current evidence for the present research.
- **Hariyanto et al. (2025)** systematically reviewed 142 empirical studies concerning AI in adaptive education. The review considered supervised and unsupervised machine learning, reinforcement learning and multimodal analytics. It concluded that AI can support real-time personalization by adapting instructional content to learner profiles. However, the authors also emphasized the need for further attention to equity and implementation conditions.
- **Kasneci et al. (2023)** investigated the opportunities and challenges of large language models in education. They argued that such systems could support personalized educational technologies and provide new forms of assistance, but emphasized limitations involving hallucinations, reliability, bias, human interaction, academic integrity and equitable access.

Their analysis demonstrates that generative AI can supplement educational processes but should not be regarded as an infallible instructional authority.

- **Lo (2023)** conducted a rapid review of the educational literature surrounding ChatGPT. The review examined applications and limitations of generative AI in education and identified opportunities involving learning support, content creation and instructional assistance. At the same time, the review raised concerns about misinformation, assessment and academic integrity. Its principal limitation is the rapidly changing nature of generative AI, meaning that conclusions can become outdated quickly. Nevertheless, the study is important because generative AI has become a significant component of contemporary personalized learning.
- **Yusuf et al. (2024)** conducted a systematic mapping review of 407 publications on generative AI in education and research, drawing on Web of Science, ScienceDirect and Scopus. The review identified major themes involving applications, impacts, ethical concerns, adoption, experiences and educational performance. It also identified gaps in K–12 research and cultural perspectives. The breadth of the review demonstrates the rapid expansion of generative AI research, while its identified gaps reinforce the need for contextual studies.

Comparative Discussion and Research Gap

The reviewed literature demonstrates a clear transition from rule-based intelligent tutoring toward sophisticated AI-supported ecosystems incorporating machine learning, learning analytics, natural language processing and generative AI. Early research emphasized prediction, diagnosis and intelligent tutoring, while recent studies increasingly focus on dynamic personalization, learner pathways and human-AI collaboration.

Despite substantial research, three gaps remain. First, much of the empirical literature is concentrated in higher education and technologically developed contexts. Second, evidence concerning long-term educational outcomes remains less developed than evidence concerning technological feasibility. Third, research often examines individual AI applications rather than considering AI as one component of a broader Education 4.0 ecosystem involving curriculum, teachers, infrastructure, assessment, governance and learners.

4. Research Methodology

Research Design

The study adopts a descriptive research design based exclusively on secondary data. It does not involve primary data collection, respondents, questionnaires, interviews or experimental intervention.

Nature of the Study

The nature of the study is secondary-data based and conceptual-descriptive. Published evidence concerning AI, personalized learning, adaptive learning and Education 4.0 was examined and synthesized.

Type of Research

The research is descriptive, analytical and literature-based. It seeks to interpret existing evidence rather than establish causal relationships through primary statistical testing.

Sources of Secondary Data

Secondary information was obtained from:

- Scopus-indexed and Web of Science-indexed journal literature;
 - peer-reviewed educational technology journals;
 - Google Scholar-indexed scholarly literature;
 - UNESCO reports and policy documents;
 - OECD publications;
 - World Economic Forum reports;
 - Government of India and Ministry of Education publications;
 - NITI Aayog publications;
 - UDISE+ and Government Open Data resources;
 - international educational and technology reports;
 - policy frameworks and institutional publications.
- India's UDISE+ system provides official education-sector information concerning schools, students, teachers and infrastructure and therefore represents an important contextual source for understanding the technological conditions within which digital and AI-enabled education must operate.

Data Analysis Techniques

The collected information was interpreted through:

1. **Thematic analysis** – identifying recurring themes concerning personalization, adaptation, teacher roles, ethics and infrastructure.
2. **Comparative analysis** – comparing global and Indian developments.
3. **Trend analysis** – examining the movement from conventional digital learning toward AI-enabled adaptive systems.
4. **Content analysis** – analysing policy documents and scholarly publications.
5. **Narrative synthesis** – integrating findings from diverse secondary sources.
6. **Descriptive interpretation** – interpreting evidence without generating fabricated numerical estimates.

Limitations

Secondary research is constrained by the availability, quality and comparability of existing sources. AI technology is developing rapidly, which can make older evidence less applicable to current systems. Publication bias may also favour successful implementations, while educational contexts differ considerably across countries and institutions. Consequently, the findings should be interpreted as an evidence-based synthesis rather than as proof of universal causal effects.

5. Discussion and Analysis

5.1 AI as an Enabler of Education 4.0

Education 4.0 requires learning systems capable of responding to learner diversity. AI provides technical mechanisms through which this responsiveness can be achieved. Intelligent tutoring systems can identify knowledge gaps; recommender systems can select learning resources; predictive models can identify learners who may require additional support; and generative AI can provide explanations and examples in different formats.

The important distinction is that personalization is not synonymous with automation. OECD evidence suggests that effective personalization is increasingly conceptualized as a hybrid human-AI process in which AI performs computational functions while educators exercise professional judgement.

5.2 From Personalized to Adaptive Learning

Personalized learning traditionally refers to adjusting learning experiences according to individual needs. Adaptive learning adds a dynamic element: the system continually evaluates learner performance and modifies content, sequence, difficulty or feedback. Recent reviews indicate that adaptive technologies increasingly use machine learning and other computational techniques to construct learner profiles and modify learning pathways. Farhood et al. (2025) and Hariyanto et al. (2025) demonstrate that the literature is moving toward increasingly sophisticated forms of personalization. This development can be particularly useful where learners enter classrooms with substantial differences in prior knowledge. Instead of requiring all learners to progress through identical materials at identical speeds, adaptive systems can potentially provide additional practice to learners who require it while offering enrichment to advanced learners.

5.3 Role of Generative AI

Generative AI has added a new dimension to adaptive education. Traditional adaptive systems generally operate within predefined content structures, whereas large language models can generate explanations, examples, questions, summaries and conversational feedback. However, generative AI introduces a fundamental paradox. It can make learning more

individualized while simultaneously generating unreliable information. A learner may receive an apparently convincing explanation that is inaccurate or incomplete. Consequently, personalization must be accompanied by verification, source awareness and teacher oversight.

5.4 Transformation of the Teacher's Role

AI is likely to change rather than eliminate the role of teachers. When routine explanation, content generation and basic assessment become increasingly automated, teachers can devote more attention to mentoring, motivation, classroom interaction, project-based learning and higher-order thinking. UNESCO's 2024 AI Competency Framework for Teachers recognizes this changing teacher-AI-student relationship and identifies competencies required for responsible AI use. The implication is that teacher education must move beyond basic digital literacy. Teachers need the ability to evaluate AI outputs, understand data protection, recognize algorithmic bias, design AI-supported learning activities and determine when human intervention is necessary.

5.5 Indian Policy and Institutional Environment

India's policy environment is increasingly supportive of AI-enabled education. NEP 2020 identifies AI, machine learning and data science as important areas for future education and employment. It also emphasizes multidisciplinary education and technological capabilities. The Government of India has also reported the integration of AI into school education through CBSE and NCERT, along with AI-supported functions on DIKSHA. The IndiaAI Mission, launched in 2024, further strengthens the broader national ecosystem surrounding AI development and access. This policy direction creates an opportunity to connect AI education with personalized learning. However, implementation must account for differences in school infrastructure, connectivity, teacher capacity and regional language requirements.

5.6 Equity and the Digital Divide

One of the greatest risks is that AI may reproduce or deepen existing educational inequalities. Advanced adaptive systems require reliable connectivity, computing infrastructure, high-quality digital content and learner data. Institutions with limited resources may therefore be unable to provide the same AI-enabled learning experiences as well-funded institutions. The WEF's Education 4.0 India initiative identifies digital infrastructure, curriculum, content, capacity and community as interconnected building blocks for transformation. UNESCO similarly warns that technology should not widen technological divides within and between countries. Thus, the objective should not be simply to make AI available but to ensure that AI-supported personalization is

accessible to learners across socioeconomic, geographic, linguistic and ability differences.

5.7 Data Privacy and Ethical Governance

Personalization depends on data. AI systems may process assessment results, learning behaviour, interaction patterns and other learner information. This creates significant responsibilities regarding data minimization, consent, security, transparency and retention. UNESCO's generative AI guidance specifically identifies data privacy and regulatory preparedness as critical issues. For India, responsible AI integration therefore needs to be aligned with applicable data protection requirements and institutional governance. Educational institutions should know what data are being collected, why they are collected, how long they are retained and who can access them.

5.8 Future Opportunities

Future AI-enabled Education 4.0 systems are likely to become more multimodal, conversational and context-aware. Rather than responding only to test scores, systems may integrate text, speech, interaction patterns and other learning signals. AI could also expand access to multilingual learning materials and assist learners with disabilities. The opportunity is particularly significant for India because multilingual AI systems could support access to educational resources across diverse linguistic communities. Government initiatives already demonstrate interest in AI-assisted translation and accessibility. The long-term direction should therefore be toward human-centred adaptive ecosystems, where AI handles large-scale personalization while teachers remain central to interpretation, relationships and educational judgement.

6. Major Findings

1. **AI is a major technological enabler of Education 4.0**, particularly because it can support data-informed and learner-centred educational processes.
2. **Personalized learning is evolving into adaptive learning**, where educational content, difficulty, sequence and feedback can change according to learner performance.
3. **Generative AI has broadened the scope of personalization** by enabling conversational explanations, content generation and individualized assistance.
4. **AI cannot replace the pedagogical role of teachers**. The strongest policy and research evidence supports hybrid human-AI models rather than full automation.
5. **Teacher AI competency is becoming a strategic requirement**. Teachers require capabilities extending beyond conventional digital literacy.

6. **Data privacy and ethical governance are central challenges** because personalization depends on learner data.
7. **AI adoption can intensify educational inequality** when infrastructure, connectivity, digital skills and quality content are unevenly distributed.
8. **India has a supportive policy foundation** through NEP 2020, AI curriculum initiatives, DIKSHA and the wider IndiaAI ecosystem.

7. Suggestions

1. Develop institutional AI strategies

Schools, colleges and universities should formulate institutional AI strategies covering pedagogy, infrastructure, data protection, assessment and responsible use rather than adopting AI tools on an isolated basis.

2. Strengthen teacher AI competency

Continuous professional development should train teachers in AI literacy, prompt design, AI-output verification, algorithmic bias, privacy, assessment redesign and pedagogical integration. UNESCO's teacher competency framework provides a useful reference point.

3. Adopt human-in-the-loop learning

Important educational decisions should not be delegated entirely to algorithms. Teachers should retain authority over interventions, learner support, assessment interpretation and sensitive decisions.

4. Build equitable digital infrastructure

Government and educational institutions should prioritize connectivity, devices, computing facilities and accessible digital content in underserved regions before large-scale AI personalization is introduced.

5. Establish strong data governance

Institutions should implement transparent policies governing data collection, consent, storage, access, retention and deletion. Students and parents should understand how educational data are used.

8. Conclusion

Education 4.0 represents a fundamental rethinking of how teaching and learning can respond to a rapidly changing knowledge society. Within this transformation, Artificial Intelligence offers considerable potential to make learning more personalized, adaptive, flexible and responsive. The evidence reviewed in this study indicates that AI can assist with learner diagnosis, content recommendation, adaptive sequencing, automated feedback, intelligent tutoring and conversational learning support. However, the evidence also demonstrates that AI should not be treated as an autonomous substitute for teachers. Effective personalization depends not only on algorithms but also on pedagogical knowledge,

learner motivation, social interaction and professional judgement. The emerging human-AI model is therefore more educationally appropriate than a technology-only model. For India, NEP 2020 provides an important policy foundation for integrating AI and emerging technologies into education. Initiatives involving CBSE, NCERT, DIKSHA and the IndiaAI ecosystem demonstrate growing institutional commitment. Nevertheless, infrastructure inequality, teacher readiness, data privacy, linguistic diversity and responsible assessment remain important implementation challenges. The principal contribution of this study is its synthesis of AI-enabled personalization within the broader Education 4.0 framework rather than treating AI as an isolated educational technology. Future research should examine longitudinal learning outcomes, AI effectiveness across socioeconomic and linguistic groups, teacher-AI collaboration, algorithmic fairness and the educational consequences of generative AI. Ultimately, the success of Education 4.0 will depend not on how much AI is introduced into education, but on how intelligently, ethically and inclusively it is integrated into human learning systems.

References

1. Crompton, H., & Burke, D. (2023). Artificial intelligence in higher education: The state of the field. *International Journal of Educational Technology in Higher Education*, 20, Article 22. <https://doi.org/10.1186/s41239-023-00392-8>
2. Farhood, H., Nyden, M., Beheshti, A., & Muller, S. (2025). Artificial intelligence-based personalised learning in education: A systematic literature review. *Discover Artificial Intelligence*, 5, Article 331. <https://doi.org/10.1007/s44163-025-00598-x>
3. Hariyanto, H., Kristianingsih, F. X. D., & Maharani, R. (2025). Artificial intelligence in adaptive education: A systematic review of techniques for personalized learning. *Discover Education*, 4, Article 458. <https://doi.org/10.1007/s44217-025-00908-6>
4. Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning*. Center for Curriculum Redesign.
5. Holmes, W., Porayska-Pomsta, K., Holstein, K., Sutherland, E., Baker, T., Shum, S. B., Santos, O. C., Rodrigo, M. M. T., Cukurova, M., Bittencourt, I. I., & Koedinger, K. R. (2022). Ethics of AI in education: Towards a community-wide framework. *International Journal of Artificial Intelligence in Education*, 32, 504–526.
6. Kasneci, E., Seßler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeiffer, F.,

- Poquet, O., Sailer, M., Schmidt, A., Seidel, T., Stadler, M., & Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences*, 103, 102274. <https://doi.org/10.1016/j.lindif.2023.102274>
7. Lo, C. K. (2023). What is the impact of ChatGPT on education? A rapid review of the literature. *Education Sciences*, 13(4), 410. <https://doi.org/10.3390/educsci13040410>
8. Lo, C. K., Hew, K. F., & Jong, M. S. Y. (2024). The influence of ChatGPT on student engagement: A systematic review and future research agenda. *Computers & Education*, 219, 105100. <https://doi.org/10.1016/j.compedu.2024.105100>
9. Luckin, R., & Cukurova, M. (2019). Designing educational technologies in the age of AI: A learning sciences-driven approach. *British Journal of Educational Technology*, 50(6), 2825–2835. <https://doi.org/10.1111/bjet.12861>
10. Miao, F., & Cukurova, M. (2024). *AI competency framework for teachers*. UNESCO.
11. Miao, F., Holmes, W., Huang, R., & Zhang, H. (2021). *AI and education: Guidance for policy-makers*. UNESCO.
12. Miao, F., Shiohira, K., & Lao, N. (2024). *AI competency framework for students*. UNESCO.
13. Ministry of Education, Government of India. (2020). *National Education Policy 2020*. Government of India.
14. Ministry of Education, Government of India. (2025). *National Education Policy 2020 initiatives*. Government of India.
15. OECD. (2021). *OECD digital education outlook 2021: Pushing the frontiers with AI, blockchain and robots*. OECD Publishing. <https://doi.org/10.1787/589b283f-en>
16. Peng, J., & Li, Y. (2025). Frontiers of artificial intelligence for personalized learning in higher education: A systematic review of leading articles. *Applied Sciences*, 15(18), 10096.
17. UNESCO. (2023). *Global education monitoring report 2023: Technology in education: A tool on whose terms?* UNESCO.
18. UNESCO. (2023). *Guidance for generative AI in education and research*. UNESCO.
19. WEF. (2022). *Catalysing Education 4.0: Investing in the future of learning for a human-centric recovery*. World Economic Forum.
20. World Economic Forum. (2022). *Education 4.0 India: A report on education transformation*. World Economic Forum.
21. World Economic Forum. (2023). *Defining Education 4.0: A taxonomy for the future of learning*. World Economic Forum.
22. Yusuf, A., Noor, N. M., et al. (2024). Generative AI in education and research: A systematic mapping review. *Review of Education*, 12(2), e3489. <https://doi.org/10.1002/rev3.3489>
23. 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>