

REVIEW PAPER

Education 4.0 using AI & Allied Technologies for Next Generation Educational Transformation—A Review

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ABSTRACT

Education 4.0 has made learning more engaging for students through the modernization of the education system. The key feature of Education 4.0 is personalized learning. Since every learner is different, their learning patterns also vary. One of the significant features of Education 4.0 is presenting education to each learner according to their individual needs and learning difficulties. Generating customized learning materials for every learner is another important aspect of Education 4.0. Education 4.0 is a completely student-centered learning system, where learners must play an active role in the learning process. It is an interactive learning platform, enabling learners, teachers, and the system to technologically interact with one another. Education Technology is the application of Information Technology in Education Sector supported by various technologies, systems and tools. The role of AI and allied technologies are impactful and growing rapidly. This Paper is about the application of AI and allied Technologies in support of Education 4.0 which is about bringing of new age educational practices and development.

Keywords: AI, Artificial Intelligence, Educational Technology, Education 4.0, Smart Education

At its core, Education 4.0 is founded on three pivotal principles: flexibility, personalization, and collaboration. Departing from traditional educational models, it incorporates modular, self-paced learning through AI-centered platforms, empowering learners to take charge of their educational pathways. With a focus on competency-based education and outcome-driven designs, Education 4.0 aligns closely with the

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demands of real-world skills. The teacher's role transforms from merely delivering content to becoming a facilitator and mentor, thus cultivating an inclusive, self-directed learning environment^{[1],[15]}. AI's impact on education transcends simple content delivery; it revolutionizes the ways learners engage with knowledge and institutions. Underpinned by machine learning, natural language processing, and computer vision, contemporary AI applications range from intelligent tutoring systems to real-time sentiment analysis in classrooms. Virtual teaching assistants stimulate student engagement while alleviating administrative responsibilities and AI-driven learning analytics empower educators to tailor instruction and identify academic risks, establishing inclusive and impactful learning settings.

Objective of the Work

This paper entitled "Education 4.0 using AI & Allied Technologies for Next Generation Educational Transformation—A Review" primarily dedicated with following aim and objective—

- ❑ To learn about the basics of Artificial Intelligence and allied technological impact in promotion of educational systems.
- ❑ To learn about the development and progress of Education 4.0 for new age educational systems and transformation.
- ❑ To gather information regarding existing works related to the Education 4.0 and allied technologies in modernizing educational systems.
- ❑ To find out the challenges and issues of Education 4.0 and educational technology in brief.

Methods Adopted

There are many methods available for conducting research and as far as "Education 4.0 using AI & Allied Technologies for Next Generation Educational Transformation—A Review" is a kind of theoretical research and this include review of exiting literature related to the Education, ICT in Education, Artificial Intelligence. And to conduct the research work several materials are analyzed which include journal, books, articles, etc. All the collected materials are analyzed and reported in this paper scientifically.

Conceptual Framework: Understanding AI in Education

In the realm of education, AI involves using advanced technologies like machine learning, natural language processing, neural networks, and cognitive computing to enhance and replicate human cognitive skills associated with teaching and learning^{[4],[37]}. The role of AI extends across four key areas:

- ❑ **Content Delivery:** Adaptive learning platforms that customize content based on each student's unique needs.
- ❑ **Instructional Support:** Intelligent tutoring systems and chatbots that facilitate learning.
- ❑ **Assessment and Evaluation:** Automated grading and feedback systems that streamline evaluation.
- ❑ **Administrative Efficiency:** AI-driven solutions for scheduling, student tracking, and institutional analytics.

These functions are deeply rooted in constructivist and cognitivist theories, emphasizing that learning flourishes through real-time interaction, feedback, and data-informed decisions.

Existing Works

To study Education 4.0 and its significance in future education system, it is necessary to make a study in the similar context. So of the previous study related with Education 4.0 are discussed below-

Caratozzolo *et al.* (2021)^[7] made a study on Virtual globalization. It analysis the utilization of education 4.0 framework for engineering students. The research examined the connection between skill development and learning outcomes. A tabular presentation was used to highlight how virtual environments help strengthen interpersonal soft skills and improve metacognitive awareness. The study further addressed the collaborative setup and activity timeline. Experiments were carried out in areas such as computerized control systems and energy distribution systems. Additionally, the findings were illustrated through diagrams showing students' preferences for different types of interventions, along with comparisons of pre-test skill levels before and during the interventions. Graphical representations were also used to demonstrate the correlation between final scores and post-test assessments, as well as the relationship between final scores and skill evaluations within each group.

Guerrero-Quíñonez, *et al.* (2023)^[16] carried out a descriptive study on Education 4.0 in higher education. The aim was to explore the effect of personalized learning in this field. The study used different research methods such as qualitative research, intervention or experimental design, and action research. It also examined the role of digitization and the issue of idiocracy in modern society. The work focused on new technologies in education and their impact, including access to information, online learning, virtual reality, augmented reality, evaluation, and monitoring. The study further discussed several ideas connected to Higher Education 4.0, such as The University of the Future, The University of the 21st Century, The Digital Transformation of Higher Education, The Intelligent University, and Higher Education of the Future. The conclusion highlighted the importance of technological integration, along with the need for flexibility and accessibility in higher education.

Hussin, A.A. (2018)^[17] conducted a descriptive study on different teaching approaches in Education 4.0 that make learning simpler and easier. The study explored ideas for applying Education 4.0 trends in language classrooms. It presented the learning experiences of students by collecting their feedback. The research also examined the role of Education 4.0 in Malaysia and learners' preferences in this context. In addition, it discussed strategies for creating a conducive learning environment. The study highlighted the skills needed by instructors and the strategies to support social and emotional learning. A table was used to show the basic digital skills required for instructors, while pictorial representations displayed different types of learning activities along with students' feedback on the topic.

Kizilkaya, *et al.* (2021)^[19] carried out a study on the use of new technologies in Education 4.0. The study explained various enabling technologies, identified the challenges in implementation, and suggested possible solutions. It emphasized the role of 5G technology in supporting Education 4.0. Key technologies discussed included high-quality 360° video streaming, Augmented Reality (AR), Virtual Reality (VR), Extended Reality (XR), Tactile Sensing, Teleoperation, Artificial Intelligence (AI), and Machine Learning (ML). The research also examined several technical challenges and how 5G solutions can address them, with focus on data rate and capacity, reliability and latency, edge and cloud computing, as well as security

and privacy. A case study on a remote circuit design laboratory was presented. In addition, a table compared throughput, latency, and jitter measurements between 5G systems and existing remote lab prototypes.

Mansor, *et al.* (2020)^[24] conducted a literature study on Education 4.0. The study examined the features of electronic learning within the Education 4.0 environment. It followed the PRISMA approach to carry out the review. Relevant keywords were collected from the Scopus database, and research objectives were identified. The search strategy was presented in a table. The teaching and learning process in Education 4.0 was also summarized in tabular form, based on criteria, definitions, and authors. A section discussed in detail the electronic learning features of Education 4.0. These features were classified and presented in tables, and the results were analyzed on the basis of the identified e-learning features.

Verma *et al.* (2021)^[40] made study on utilization of IoT for the intelligent monitoring and reporting. It find the IoT utilization of education 4.0 framework. It proposed an architecture based on IoT, Fog Computing and Cloud Computing and shown diagrammatically proposed a Conceptual Model of novel framework for Education 4.0. It also proposed IoT, Fog Computing and Cloud Computing based framework for real-time monitoring and reporting. It tabular format it shown IoT sensors for data extraction and communication and different IoT communication technologies and protocols. It proposed algorithms on Education Invulnerable State Prediction Determination and Real-Time Alert Generation Procedure. It tried to evaluate the performance and discussed on Simulation Environment, Efficiency Evaluation, Delay, Classification, Prediction, Reporting and Stability Analysis.

Basic and Impact of Education 4.0 with AI & other technologies

Education 4.0 is a modern-generation education system. It is a completely technology-dependent system where different types of technologies are used to deliver education to learners in digital format. Keeping in mind the needs of future learners, the technology-driven education system that can fulfill those requirements is called Education 4.0. It addresses the various issues of the traditional classroom-based, face-to-face, on-campus education system by applying different technologies and makes education accessible to people at all levels^{[10],[38]}. Education 4.0 plays an important role in making education open to everyone instead of keeping it confined to a fixed syllabus. If someone has the curiosity to learn about a particular subject, they can use the internet and various technologies to gain knowledge on that topic.

To implement Education 4.0, various basic and emerging technologies are used. Information Technology and its different components help in the smooth functioning of Education 4.0. By using database technology, all user data of Education 4.0 can be systematically stored in databases and retrieved whenever needed. With the help of web technology, Education 4.0 can reach people across the globe. The education system also provides the advantage of being accessible 24 hours a day, enabling learners to study at their own convenience^{[3],[34]}. Through internet services, learners can access study materials from anywhere in the world, instead of being restricted to a specific location. Education 4.0 is truly time-independent and place-independent.

The use of multimedia technology makes content much more engaging for learners. Multimedia makes learning more attractive by incorporating animations and interactive presentations, which simplify the understanding of complex concepts. Learners can easily grasp topics through joyful learning experiences. Moreover, multimedia technology helps visualize concepts better, allowing learners to form a clear understanding of the subject matter^{[2],[21]}. Additionally, various software and tools are used to implement

Education 4.0 in a more systematic manner. These tools organize and present educational content effectively, enabling learners to maintain a more structured approach to their studies. Learning Management Systems (LMS) play a significant role by managing a learner's overall progress. The functions of an LMS include managing and organizing learning materials, assisting in study, tracking progress, developing appropriate study content, delivering relevant learning materials, storing assessment results, and more.

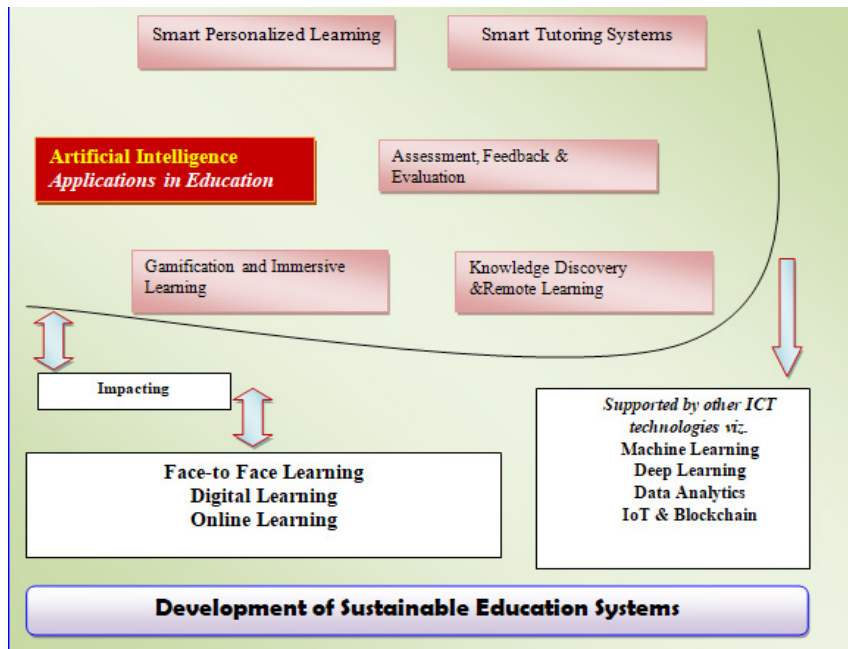


Fig. 1: Showing the effective means for sustainable educational systems using AI

Educational institutions are developing different LMS platforms to support learners effectively. To implement Education 4.0 properly, *Information and Communication Technology (ICT)* is of paramount importance. ICT connects the entire system through networks and ensures its proper functioning, thus playing a vital role in making Education 4.0 a reality. ICT also plays an important role in global collaboration by enabling communication between learners and teachers across different parts of the world^{[6],[25]}. By promoting digital education, ICT helps learners develop essential skills. It establishes a global network, shares a wide range of learning resources among learners, and promotes interactive digital education, thereby enhancing student learning outcomes.

To implement Education 4.0, various emerging technologies are used. These emerging technologies provide multiple advantages that transform the traditional education system into a futuristic education system. One such emerging technology used in Education 4.0 is *Cloud Computing*. Cloud computing technology offers the benefit of data virtualization and can store a huge amount of data in a highly efficient and cost-effective manner. Its different service models, such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS), and Storage as a Service (STaaS), make Education 4.0 more affordable and efficient. Cloud computing also plays an important role in data sharing among multiple users and in enabling collaborative learning. Moreover, it is used to create virtual classrooms, and cloud-based video conferencing platforms are widely employed to provide online education^{[5],[13]}.

Big Data Analytics is an emerging technology that significantly enhances the efficiency of digital education. In a digital education system, various types of data are generated, such as images, audio, video, text, documents, protected documents, animations, and many more. Big Data Analytics plays a crucial role in processing these diverse types of data. It can process both homogeneous and heterogeneous data and generate different kinds of predictive results. By analyzing various datasets related to students, Big Data Analytics can identify different types of learning gaps among learners and predict students' future performance^{[8],[41]}. It could able to identify the learners difficulty in learning.

To implement Education 4.0, various types of *Internet of Things (IoT)* devices are used. Different kinds of sensors and actuators used in IoT technology perform various tasks. In the field of education, IoT devices are employed to automatically manage different types of electronic equipment in classrooms. IoT technology is also used for tasks such as automatic lighting and temperature control in classrooms. Additionally, it is applied in automatic attendance monitoring and smart campus management^{[11],[27]}. For personalized learning, IoT technology is also utilized in virtual laboratories and remote laboratories.

Blockchain Technology is another important emerging technology used in Education 4.0. Blockchain plays a crucial role in ensuring the *security* of Education 4.0, as any form of data cannot be easily altered. Thus, the data stored on the blockchain remains tamper-resistant. Blockchain is applied in several areas, such as- Student records management, Certificate verification, Information storage, Transparent record management, Decentralized learning platform management, Digital identity storage, Digital payment information storage, Learning credential storage, Student marks storage and many more^{[12],[22]}.

Applications and Benefits of AI in Education

5.1 Personalized Learning: With AI, learning can be tailored in real-time to fit each student's pace, interests, and understanding. Tools like Carnegie Learning and Squirrel AI adjust their challenges based on how students respond, fostering mastery-based learning.

5.2 Intelligent Tutoring Systems (ITS): ITS offer immediate feedback and guidance that resemble the support of a personal tutor. Platforms like AutoTutor and Knewton utilize AI to facilitate one-on-one learning experiences^{[14],[20]}.

5.3 Automated Grading and Feedback: Natural language processing (NLP) facilitates the automated grading of essays and open-ended answers, relieving educators of some of their workload while ensuring timely feedback.

5.4 Predictive Analytics: Imagine the power of AI models in predicting student success! By meticulously analyzing attendance, participation, and historical scores, these models can shine a light on student performance and pinpoint dropout risks^{[18],[23]}. Institutions like Georgia State University are at the forefront of this revolution, using AI to uplift retention rates and bolster student support systems, leading the way for others to follow.

5.5 Special Education Support: AI is a game changer in creating inclusive educational environments for students with disabilities. With innovative tools like speech recognition and assistive technologies such as Seeing AI, access to learning materials is not just improved—it's transformed^{[9],[26]}. This ensures all students, regardless of their challenges, can thrive in their educational journeys.

5.5. Ethical and Social Implications: However, with great power comes great responsibility. The integration of AI in education brings forth critical conversations regarding data privacy, algorithmic bias, transparency, and the potential for widening digital divides. If over-reliance on AI tools occurs, there's a risk of education becoming depersonalized and disparities deepening. As emphasized by Williamson & Piattoeva (2020), it's essential for educators to find a harmonious balance between embracing technology and nurturing humanistic principles. The goal is to ensure that AI enhances, rather than substitutes, the invaluable role of educators.

Applications of AI in Education 4.0

Artificial Intelligence is truly revolutionizing the educational landscape, bringing forth an era of dynamic, personalized learning experiences, streamlined assessments, and innovative content creation^[41].

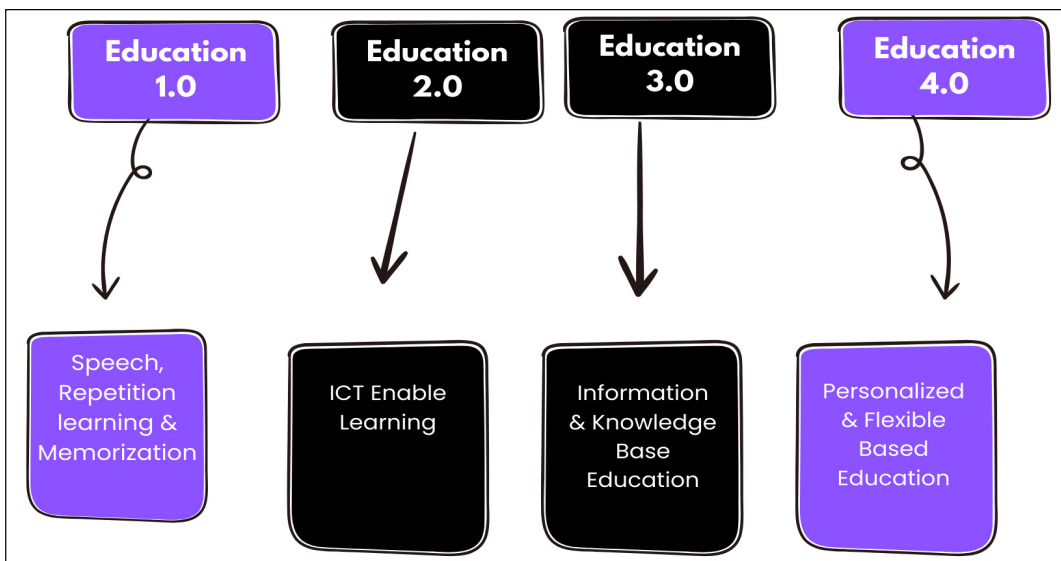


Fig. 2: Core of Education 4.0 along with other previous educational generations

Here's a closer look at how it's making waves in Education 4.0:

- ❑ **Personalized Learning:** Imagine students engaging with adaptive systems like DreamBox and Knewton. These platforms are harnessing learner data to tailor content and pathways, ensuring each student receives a unique educational journey that caters to their individual needs^[28].
- ❑ **Automated Assessment:** AI is stepping in to transform the grading process. With tools that automate grading, detect plagiarism, and provide real-time feedback using natural language processing, educators can devote more time to fostering creativity and critical thinking among their students.
- ❑ **Smart Content Creation:** The creativity doesn't stop there! AI is creating customized textbooks, quizzes, and simulations that include augmented reality (AR) and virtual reality (VR), leading to truly immersive learning experiences that capture learners' imaginations.

- ❑ **Enhanced Student Engagement:** The introduction of chatbots and AI-driven gamification is providing continuous support, igniting intrinsic motivation among students. Imagine a study environment that's vibrant and engaging, available 24/7.
- ❑ **Institutional Efficiency:** Institutions are also benefiting, with AI optimizing everything from scheduling to resource allocation^{[29],[43]}. This paves the way for agile, data-informed decision-making that enhances the overall educational framework.

Case Studies and Global Best Practices of Education Technology & Education 4.0

The basic features of Education 4.0 changing global educational maps effectively and here figure 3 showing basic features in this regard. Internationally there are certain institutions have started the project of inclusion of Education 4.0 in their education system and some of them are as follows—

- ❑ **Finland:** Innovative AI tools like Claned are pioneering personalized tutoring and monitoring student emotional well-being, creating a supportive environment for learning.
- ❑ **United States:** At the forefront of academic advising and learning analytics, IBM Watson is bolstering universities to ensure students get the guidance they need to succeed.
- ❑ **China:** Companies like SenseTime are employing emotion recognition technologies, which analyze real-time engagement in classrooms enhanced by AI.
- ❑ **India:** Leading EdTech platforms such as Byju's and Vedantu are leveraging AI for adaptive testing, predictive analytics, and bespoke content personalization, making education more accessible and relevant.

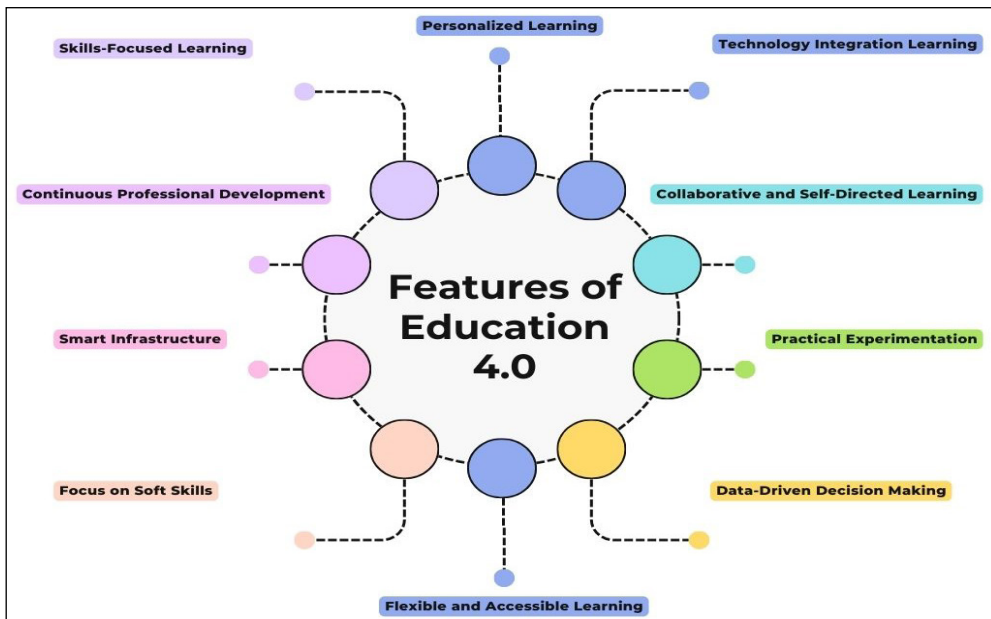


Fig. 3: Basic features of Education 4.0 at a glance

These diverse examples illustrate AI's incredible potential to democratize education, enhance learning outcomes, and establish ethical models that can be scaled to fit a variety of contexts.

Ethical Considerations and Challenges in AI for Education 4.0

While the possibilities are exciting, we must also navigate some important ethical considerations:

- ❑ **Data Privacy and Security:** Safeguarding sensitive student data is paramount. It's essential to create robust governance frameworks and ensure consent mechanisms are in place to protect against breaches and misuse.
- ❑ **Algorithmic Bias:** We must be vigilant about bias in datasets that can perpetuate educational inequities. Emphasizing transparency and diverse data curation is crucial in mitigating such biases^{[31],[33]}.
- ❑ **Digital Literacy Gaps:** To ensure an equitable adoption of AI, both teachers and students require targeted training in AI literacy. This bridges the gap and empowers everyone to harness the capabilities of AI effectively.
- ❑ **Human-AI Balance:** Finally, while AI offers wonderful enhancements, it is vital that it supports rather than replaces our human educators. Maintaining mentorship, empathy, and ethical reasoning in knowledge transfer is key to fostering an open and inspiring learning environment.

With AI leading the way, the future of education holds immense promise—let's embrace these changes with enthusiasm and commitment to ensuring a brighter, smarter future for all learners!

Future Directions and Innovations in AI for Education 4.0

Education 4.0 constantly encourages learners to explore new things, making it a lifelong education system. It provides a flexible learning platform, where learners can learn anything, from anywhere, at any time, for as long as they wish. Education 4.0 promotes a skill-oriented education system, helping students develop critical thinking skills and problem-solving abilities, thereby preparing them to solve real-world problems. Through various skill development programs and MOOCs, personalized learning can be delivered to a large number of learners simultaneously^{[27],[32]}. Education 4.0 is dedicated in collaboration between industry and academia by preparing learners to meet industrial demands. To address the requirements of Industry 4.0, Education 4.0 plays a significant role in creating a future-ready workforce capable of fulfilling the needs of Industry 4.0. The exciting wave of emerging technologies is set to revolutionize AI-powered education, paving the way for remarkable advancements that will reshape the learning landscape:

- ❑ **AI + XR:** Immerse yourself in transformative learning experiences where AI seamlessly tailors virtual environments, enhancing understanding like never before.
- ❑ **Lifelong Learning Companions:** Picture AI agents as your personal mentors, guiding you through every stage of your personal and professional journey.
- ❑ **Blockchain + AI for Credential Verification:** Secure and decentralized methods will ensure that your learning achievements are transparently verified.

- ❑ **Predictive AI for Curriculum Design:** Imagine curricula that are not just responsive, but also anticipatory, aligning with the ever-evolving demands of the labor market to ensure you acquire future-proof skills.

These groundbreaking innovations hold the promise of widening access to education, upholding integrity, and ensuring the relevance of learning in our interconnected global digital economy. Looking ahead, the evolution of AI promises to introduce even more advanced systems equipped with emotional intelligence, cultural awareness, and the ability to adapt in real-time. Picture classrooms enhanced by immersive technologies that blend AI with augmented reality (AR) and virtual reality (VR)^{[35],[36]}. To foster a sustainable future, several actions are vital:

- ❑ Equip educators with AI literacy and understanding.
- ❑ Establish strong ethical frameworks guiding AI usage.
- ❑ Invest in solutions that are inclusive and accessible to all.
- ❑ Promote interdisciplinary research that bridges pedagogy with machine learning.

Educational policies should prioritize collaborative efforts between humans and AI, cultivating an atmosphere where technology elevates—not dictates—the learning experience. AI in education is not just another trend; it represents a pivotal opportunity to reinvent the landscape of teaching and learning^{[39],[42]}. Although the potential is immense, we must venture through ethical, pedagogical, and technological challenges with care. By thoughtfully and equitably integrating AI, education systems can become more personalized, efficient, and inclusive, forging a path for learners in a world characterized by relentless innovation.

CONCLUSION

AI is at the forefront of a remarkable transformation in education, enabling pathways to personalized learning and data-driven teaching while fostering agility within institutions. For students, AI paves the way for adaptive and inclusive educational journeys. Educators gain the freedom to embrace creativity and mentorship, while policymakers are inspired to create frameworks that harmonize innovation with equity. As we witness the convergence of AI and human intelligence, a new hybrid model emerges, where collaborative intelligence is set to redefine the future of learning, growth, and our contributions to society. Let's embrace this thrilling evolution together! The journey of integrating AI into education is both exciting and complex, opening up a world of possibilities while also presenting significant ethical challenges. Key concerns like data privacy, algorithmic bias, and the widening digital divide must not be overlooked. There's a risk that an over-dependence on AI could lead to a reduction in vital human empathy and interaction within the learning experience. To navigate these challenges successfully, we need strong ethical guidelines and effective regulatory oversight. Artificial Intelligence stands as a transformative force in realizing the vision of Education 4.0, paving the way for personalized learning experiences, enhancing administrative efficiencies, and increasing accessibility to education for all. However, it is imperative that we approach the implementation of AI in a way that is human-centered, inclusive, and ethically guided. Looking ahead, our goal should be to ensure that AI complements, rather than replaces,

the fundamental human essence of teaching and learning. Embracing this approach can lead us toward a more enriched educational environment where technology and humanity thrive together.

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