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Article

Artificial Intelligence Driven E-Learning in Hybrid Higher Education: Applications, Emerging Trends, Challenges, and Future Perspectives

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Abstract: Introduction: Artificial intelligence (AI), when applied in e-learning, transforms in the concept of blended learning. Artificial intelligence integrated into the learning environment has helped the learners to be more engaging and interactive with their mode of learning. The research work aims to analyze the trend of the usage of Artificial Intelligence in the context of an e-learning environment and also intends to incorporate the trends of its usage and apply the same to create a successful learning environment. The utility of conducting the research work is to analyze the use and application of Artificial Intelligence incorporated through the use of data analytics and natural language processing.
Method: The study was undertaken as a thorough review with emphasis placed on successful implementation of artificial intelligence in hybrid higher education, and its success can be demonstrated through its effects or implications in curriculum development and performance in general.
Results: Based on the research study, the study shows that the pursuit of personalized instruction through heightening the level of processing various administrative issues and assisting teachers in delivering quality training, the use of AI technology shall be vital within the realm of hybrid education.
Discussion: This particular research covers challenges and ethics surrounding biases within algorithms, data privacy, and the need for transparency in AI-driven learning. This particular article also manifests the efficacy of AI technology in offering a personalized learning environment, administrative efficacy, and teaching efficacy.
Conclusion: The future will involve applying AI technologies in the domain of hybrid education. Hence, it is essential for all stakeholders to ensure that development with regard to AI is in line with the learning process and establishes a fair learning environment for all individuals.
Keywords: E-Learning, Hybrid Higher Education, Artificial Intelligence, Personalized Learning, Adaptive Learning Technologies, Student Engagement, Curriculum Design

1. Introduction

Artificial Intelligence has brought about modifications in the educational sector. As a whole, Artificial Intelligence is a new phenomenon that has substituted traditional learning and teaching methodologies. It is a range of technologies, including data analytics, machine learning, and a computer science discipline called natural language

processing, all of which draw inspiration from the intellect of a human being. This is an invention that has the potential to impart administrative efficiencies and learning/teaching methodologies to learning centers [1]. With regards to the perspective of Artificial Intelligence, it is a promising aspect of Artificial Intelligence in terms of learning centers, which has the potential to offer insights into the learning of students and decision-making [2, 3]. The introduction of hybrid models of Higher Education institutions via newer models of hybrid education that include an amalgamation of 'e-classes' and physical 'in-person classes.' Introduction of this particular education system is another trend of the current environment of education. Through this hybrid education platform, any student may interact with this platform of education in the most convenient way to himself or in accordance with his/her/their situation and requirement [4]. Introduction of the hybrid models of education has occurred in response to the crisis environment of COVID-19 and it specifically pertains to 'in-person classes'[5]. There is special potential and difficulties associated with the combination of AI with hybrid education. On one hand, evaluating student data and offering customized content and feedback can enhance personalized learning in hybrid settings through AI. In instances where students receive support that caters to their unique learning paths, engagement and academic results can increase. On the other hand, integrating AI raises ethical concerns such as algorithmic prejudice, data privacy, and a reduction of human contact in education [6]. Thus, the benefits of AI in hybrid higher education should be further explored, along with issues to be resolved for its successful application [7, 8]. The primary objective of this research is to examine how AI influences e-learning and hybrid education, focusing on current trends and future implications. The major purpose of conducting a specific research on the subject is learning how differently related AI technology is employed, how effectively it can enhance a learning experience, and what ethics it presents, along with existing and/or future ramifications of how and in what way it is done correctly for both education and legislation fields [9, 10]. Such a study is essential because of its potential to add to the present discourse on artificial intelligence in education, particularly in terms of a full exploration of the possibilities of new technologies in improving the quality and accessibility of higher education institutions. Appreciating the interplay of artificial intelligence and hybrid learning can prove to be essential in crafting venues where different kinds of learners can thrive in bringing equitable learning opportunities in a dynamic educational environment. This study aims to guide stakeholders in making informed decisions to improve hybrid learning systems [11].

2. Literature review

2.1 E-Learning and Its Evolution

The learning experiences one can find online offer abundant variety, and they all come under the umbrella of 'E-Learning.' The definition of e-learning is 'Electronic Learning.' It can be further explained by mentioning formats like 'webinars,' 'digital classrooms,' and 'learning through a mobile medium.' It is recorded that as computing training systems were introduced in the late 20th century, the image of 'E-Learning' actually started coming into view [12]. There has been considerable change in how 'E-Learning' is viewed since the 1990s and 2000s when there was an explosion of growth related to the use of the internet [13]. When e-learning first came into being, it primarily consisted of the distribution of static content in nature, such as reading materials or pre-recorded lectures. With the onset of LMS, which created standardized environments for course delivery, tracking, and assessment, e-learning continued to evolve with technology [14]. More recently, there is greater emphasis on multimedia elements such as interactive tests, video lectures, and discussion boards that have further enhanced student engagement with improved learning outcomes. Yet today, the integration of AI and AR/VR technologies has advanced e-learning further, creating an immersive, personalized learning experience for each type of learner preference and style [15-17].

2.2 Hybrid Higher Education: Benefits and Challenges

Blended learning has another name in the form of hybrid learning in a higher learning form. Blended learning has elements of both online learning as well as face-to-face learning methods. This flexibility offered by blended learning, while maintaining face-to-face interaction in its scope, provides a ground from which the traditional learning system can benefit from the strengths that both teaching methods have to offer [18]. Based on the opportunities provided to support a wide spectrum of learning methods, in-person learning is an opportunity to be in contact with

people while learning at one's own convenience [19,20]. More than this, there is a possibility to improve accessibility, particularly for non-traditional students who, due to different commitments such as jobs and family, are not able to participate in traditional programs [21]. A hybrid approach should provide a better learning environment. Besides that, there is an opportunity for the maximization of available resources, therefore minimizing the need for further infrastructure development [22]. Despite these advantages, several cons have also been identified to have a negative influence on a hybrid mode in higher education. Concerns surrounding the existence of a digital divide represent a critical issue for students to have access to the necessary technological gadgets and Internet access to participate effectively in a hybrid mode, thus acting to heighten inequalities among them [23]. Additionally, an instructor's ability to adapt their own teaching strategies to meet both online and offline settings is also a factor for the viability and success of a hybrid mode; consequently, a need for faculty support and exploration of their teaching methods to measure their success and achievement in terms of learning is pointed out [24].

2.3 Role of Technology in Transforming Educational Practices

Especially in the e-learning and hybrid education context, technology is the key factor in changing educational processes. Indeed, the way students gain access to learning materials and interact with them has been completely changed by integrating advanced technologies [25]. AI-empowered solutions can assess student performance data to provide students with comments and suggestions for further improvement. Hence, they help in ensuring that the student takes the entire responsibility for the learning process. Additionally, digital technologies, despite being used virtually, help in the creation of a feeling of community through collaboration, given that some facilitate group projects, discussions, and reviews [26,27]. Further, innovative methods used in inevitably fostering the vividness and enhancement of experiential learning lie in VR and AR technologies [28]. This is due to the fact that these technologies have the ability to apply simulations which replicate reality, enabling learners to gain experience not normally available through usual environment to ensure student understanding and remembrance [29,30]. The educational system is changing and adapting with the advent and development of e-learning and the "hybrid higher education concept." This model promotes a holistic approach combining online and face-to-face learning with comparative advantages of the two approaches online and physical training and education modalities [31,32]. For these educational and training modalities to prepare and deliver to meet the needs of the diverse students and prepare him or her to meet a world that is highly changing and adapting to a faster pace, there is a need to infuse technology to these approaches. For all to harness and benefit from the advantages offered in the academic and learning environments through the advent and use of artificial intelligence (AI) and various technologies, it is crucial to stay cognizant and mindful of the challenges and ethical dilemmas these technologies and trends are posing [33-35].

3. Materials and Methods

3.1 Study Design

This review presented current scientific research and policy analyses of emerging innovations in the effectiveness studies of AI-driven interventions, adaptive learning systems, or intelligent tutoring systems. Both empirical and conceptual studies were included to give a balanced and interdisciplinary perspective for investigating applications of AI in e-learning and hybrid learning environments [36]. The methodological approach followed in this study is presented below.

3.2. Literature Search and Data Sources

A systematic search was conducted using PubMed, PubMed Central, Scopus, IEEE Xplore, Web of Science, EMBASE, ScienceDirect databases to retrieve peer reviewed articles. Search queries combined medical subject headings (MeSH) and free-text keywords using Boolean operators (AND, OR) to enhance the retrieval of relevant literature. Key terms included e-learning, online learning, digital learning, distance education, blended learning or hybrid education, higher education, hybrid higher education, artificial intelligence, AI, machine learning, deep learning, natural language processing, chatbot, recommender system, personalized learning, adaptive learning technologies, student engagement, curriculum design [37,38].

3.3. Inclusion and Exclusion Criteria

Inclusion criteria were articles published between 2016 and 2025 on recent technological developments; peer-reviewed journal articles, systematic reviews, technical reports, and conference papers; studies involving focused on AI, machine learning, deep learning, or intelligent systems applied to e-learning, online education, blended learning, or hybrid higher education or tertiary-level learning. articles explicitly addressing AI integration in e-learning/hybrid learning systems; reviews, original research articles, and significant preprints; and publications in english.

Exclusion criteria involved articles not focused on artificial intelligence approach for e-learning, studies focusing solely on K-12 education (unless generalizable to higher education). Studies were excluded which are irrelevant to AI in e-learning or hybrid higher education. Studies were excluded which are focused on primary/secondary education, medical simulations, corporate training, or unrelated technological domains unless directly relevant. Articles without a clear AI component (e.g., general ICT tools without AI-driven features), studies unrelated to higher education, conference abstracts, and editorials; and non-English publications.

3.4. Selection Process

At the initial screening stage, the titles and abstracts were screened by two independent reviewers to identify potentially relevant studies. Afterward, the selected articles underwent a full-text review to confirm eligibility based on the inclusion/exclusion criteria, and discrepancies between reviewers were resolved through discussion or consultation with a third reviewer. Inter-reviewer reliability was assessed using Cohen's kappa coefficient. Only studies with robust methodological design and clear diagnostic evaluation were included in the final analysis.

The selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, and a PRISMA flow diagram was used to document and report the selection process (Fig 1). The review process is summarized using a PRISMA flow diagram, detailing the number of studies identified, screened, excluded, and finally included.

Reference analysis –

Identification: Records identified through database searching (IEEE Xplore, PubMed, Scopus, Web of Science, Google Scholar, ScienceDirect): n = 1307

Screening: Records after duplicates removed: n = 866

Eligibility: Full-text articles assessed for eligibility: n = 486

Records excluded: n = 280

Included: Studies included: n = 206

Fig 1. PRISMA flowchart

3.5. Data Extraction and Analysis

A standardized data extraction form was developed to capture the following information as the study characteristics, for e.g., author, year, country, publication type; type of automation tool/technology. A data extraction form was designed to capture key details of AI technology/framework used (e.g., ML, NLP, recommender systems, chatbots). Application domain (adaptive learning, assessment, student engagement). Outcomes and key findings. Reported challenges, limitations, and future directions, type of study (e.g., case study, review, empirical research), key findings and outcomes, challenges/limitations reported. Extracted data were thematically categorized and analyzed. Quantitative data (e.g., effect sizes, accuracy rates of AI models, learning outcome improvements) were tabulated and compared. Studies were grouped by AI techniques (ML, NLP, recommender systems) and educational focus areas (personalization, engagement, assessment, administration). The findings were organized in a narrative format, accompanied by descriptions that are tabulated to address key contributions, technology, and results. The scientific rigor, based on certain criteria such as clarity in study design, on the other hand, was also performed on the

literature. While conducting these investigations, no specific tool was employed to detect a risk of bias, due to the technology being descriptive/quasi-explorative in nature. The direct relationship of this methodological framework to the research objectives can clearly be observed in terms of how a systematic analysis of AI tech and their application in hybrid higher education equates to a clear correlation of meeting the study's objective of assessing a wider picture of the effect of AI on learning results and considerations.

4. Research Statement

This study, therefore, revolves along the dimension of exploring how this concept modifies and changes aspects of online and hybrid higher education, especially in relation to trends in conducting research up until now and in relation to projections in the future in this regard. What is specifically focused upon in the present research, therefore, is trends in conducting research, as well as ramifications in relation to this in the future, as well as the more revolutionary form of innovation in relation to artificial intelligence, specifically in relation to e-learning in a more general sense of a hybrid concept in relation to more traditional academic institutions of higher learning. One of the more prominent emerging needs in this regard involves exploring new techniques for incentivizing students, as well as methods of speeding up educational processes as a function of more widespread adoption of a hybrid manner of learning. This study, in particular, assesses various tools of Artificial Intelligence integrated into e-learning in order to set up their potential to improve learning dynamics. The article is addressing the challenges and the ethical implications surrounding AI's assimilation and usage in terms of algorithm and data biases, data privacy, and the importance of AI decision-making regarding transparency. The aim and objectives include educating all AI stakeholders, including educators and administrators, concerning AI technology assimilation with the help of case study instances of the effective assimilation and use of AI in various hybrid educational settings [39]. By identifying emerging trends in AI-related research and emphasizing the potential to modify the learning environment with AI, as well as possible tactics for utilizing AI to enrich higher learning in the future, this article aims to contribute to the emerging discourse surrounding AI in higher learning. An examination of the various technologies employed in the incorporation of AI in e-learnings, with particular reference to the extent to which they promote student engagement in a hybrid higher education setup [40]. An examination of the various innovations in the incorporation of AI in hybrid learning, with particular reference to the strategies that have been successful in raising student performance, as revealed by various successful firms in the education sector [41]. Discussed as well is the challenges that could impede the integration of AI in the classroom and the importance of transparency in the use of the technology [42]. By conducting a study on these samples on how AI is being efficiently used, educators, higher learning administrators, and policymakers would be able to get an idea on how AI technology would be efficiently used through these suggestions based on samples on how to efficiently use AI technology [43]. In addition, in an effort to improve higher learning quality and/or inclusiveness, the study would focus on exploring the possibilities that are brought about through AI technology usage by students in a hybrid learning environment with suggestions on how to carry on an effort towards that goal, objectives, as mentioned in reference [44].

4.1 Finding on AI in Hybrid Higher Education

A good understanding of the various ways through which e-learning environments are using artificial intelligence and its significance to the revolutionization of the concept of hybrid higher education [45]. Information regarding the latest innovations that are seen through the various applications of artificial intelligence, such as data analytics, adaptive learning, and intelligent tutoring. Indication and expounding on the various important artificial intelligence technologies that are used to improve the concept of a hybrid learning platform, such as an automation system, a virtual assistant, and an analytics system, as well as the potential opportunities that artificial intelligence presents to improve learning materials that cater to the needs of each student to improve grades. Examination of the various challenges that are presented by the application of artificial intelligence to the education sector. Examples of successful AI applications in hybrid higher education settings that illustrate how educational institutions are harnessing the power of technology to improve learning outcomes and curriculum design [46]. Predictions for the future of hybrid education, focusing on the ever-increasing reliance upon AI technologies and their potential impact upon teaching and

learning paradigms. This means that, finally, valuable advice for educators, administrators, and legislators was given on the most appropriate way of embracing and integrating AI within e-learning with a view to improving the quality and diversification of education. The results thus obtained are oriented towards the objectives of the study as stipulated in the research questions. The observed trends in the adoption of AI and aspects of ethics accord with the stipulated objectives within the methods.

4.2 Significance of AI in Hybrid E-Learning

The integration of AI in e-learning has created chances for customized tailoring to match the demands of learners in a versatile learning process where everything a learner might demand in the process can be catered to within the revised process of learning. Learning efficacy has improved within a situation whereby learners are more inclined to take part in their own process of learning [47]. Problems of demands by the learner, especially in the development of education as a process, are addressed in a creative manner through the application of AI in the process of education, as it is important for a teacher who wishes to improve in the field to be aware of the techniques introduced by AI in an improved process of education or learning. The study also reveals how change is going to shape in the future of learning due to the arrival of AI as hybrid learning takes off into a new direction. This is important because stakeholders in learning processes ought to understand change and innovation in learning venues. The paper provides crucial information about change for educators, managers, and decision-makers based on an evaluation of current trends in educational research studies that worked. In this way, knowing helps make the process of making informed decisions towards adopting and utilizing AI technology in schools much facilitates. Ethical issues related to algorithmic bias and data privacy have been an essential issue that needs debate with regards to the broad utilization of AI technology. Shining a light on these issues provides the means for ensuring that AI is used fairly and morally, building trust between teachers and students [48]. The promotion of further study on the given topic is through the mentioning of gaps in the existing literature, as well as the formulation of a set of recommendations that must be observed in pursuing further research on the topic, as can be noted in the aforementioned piece of writing. This is noteworthy, especially as far as research interests on the topic are being pursued by a group of scholars who are keen on adding to the ever-expanding knowledge on the topic, especially on AI in Education [49]. Because of the experimentation with the hybrid approach in various learning institutions around the globe, the findings are no longer specific to the locations where the investigation was pursued, especially as far as improving the knowledge on the topic on the application of AI in various learning environments is concerned [50].

5. The Landscape of AI in E-Learning

5.1 AI Technologies Relevant to Education

Artificial intelligence refers to a collection of technologies that simulate human intelligence and learning capabilities. Machine learning (ML), NLP, and predictive analytics all have special relevance for the domain of education. Algorithms in this type of artificial intelligence allow systems to learn from data and improve over time without explicit programming. ML can be used in education to analyze student performance data, identify trends, and provide recommendations for personalized learning. For example, ML is applied in adaptive learning platforms which adapt course materials to an individual student's needs, resulting in greater retention and engagement of students' learning [51]. Computer systems are able to process, interpret, and generate human language due to their ability known as NLP. NLP enables several learning technologies to aid certain aspects of learning and teaching, such as offering learning assistance to students as needed or increasing language learning opportunities through interactive conversations. NLP would significantly enhance student learning as it enables more natural interactions to occur between students and learning systems [52]. This form of computer science allows individuals to forecast future occurrences based solely on learning from past happenings. Predicting analytics enables educators to implement preventive measures to help those students who are at risk of underperforming or dropping out of an educational institution. In an effort to ensure an increase in success rates of students in an institution, several targeted interventions are available in several identified factors such as attendance and student performance (Figure 1) (Table 1) [53].

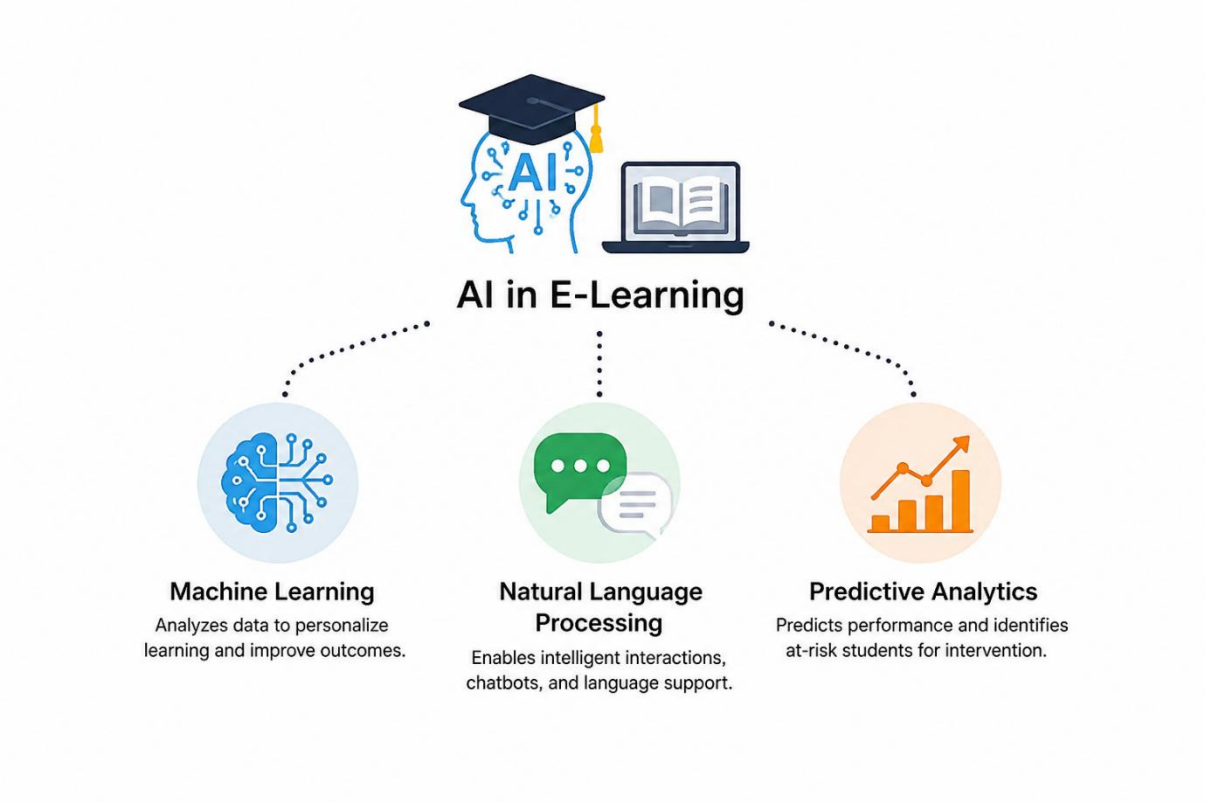

Figure 1. AI technologies such as machine learning, NLP, and predictive analytics transforming personalized and intelligent e-learning.

Table 1. The Landscape of AI in E-Learning

AI Technology	Description	Applications in E-Learning	Benefits	Challenges
Machine Learning	Algorithms that gradually enhance performance by learning from data.	Personalized learning pathways, adaptive assessments	Customization of content to meet individual student needs.	Requires large datasets for training; potential biases.
Natural Language Processing (NLP)	Makes it possible for machines to comprehend and analyze human language.	AI chatbots for automated essay grading and student assistance	Enhances student engagement through instant feedback.	Difficulty in understanding nuances of human language.
Predictive Analytics	Makes predictions about the future based on historical facts.	Identifying at-risk students, recommending interventions	Improves retention rates through timely support.	Data privacy concerns; reliance on accurate data.
Intelligent Tutoring Systems	AI-powered programs that offer	One-on-one tutoring simulations,	Provides individualized	May not fully replicate human

	individualized training.	interactive learning modules	attention to students.	tutoring effectiveness.
Learning Management Systems (LMS)	Platforms that make managing courses and online learning easier.	Integration of AI tools for analytics and personalized content	Streamlines administrative tasks and data analysis.	Implementation costs; resistance to change by educators.
Gamification	The use of game design components in educational settings.	AI-enhanced educational games that adapt to learner progress	Increases motivation and engagement among students.	Risk of distraction if not aligned with educational goals.
Robotics and Virtual Assistants	Use of virtual agents or robots driven by AI to aid with learning.	Virtual teaching assistants, interactive simulations	Provides additional support and resources for students.	High costs and technological complexity.
Augmented Reality (AR) and Virtual Reality (VR)	Blends the digital and real worlds to produce immersive experiences.	Interactive learning experiences, virtual labs	Enhances experiential learning opportunities.	Resource-intensive; requires technology access.

5.2 Current Applications of AI in E-Learning Environments

Various e-learning platforms have successfully integrated AI, which has enhanced the efficiency of teaching-learning processes. The platforms change according to the needs and preferences of each learner to ensure customized learning materials are presented to each learner individually. By presenting a learner with customized materials needed to fill in information gaps, the ITS assesses the learner's existing knowledge level.In mathematics, a learner may be given tutorials like those in Carnegie Learning that use AI in order to enhance learning-gathering processes [54]. In e-learning environments, AI-driven chatbots are increasingly used to support students. Such resources can provide individual feedback, guide the students through a course, and answer frequently asked questions. For example, Georgia State University has used an AI chatbot named "Pounce" to support students in administrative queries to improve engagement and consequently increased retention [55]. In the sense that it may automate the evaluating of student assignments, quizzes, and even essays, it may help accelerate the learning and evaluation of student achievements. In one sense, it may save the instructor time to allow the student to have the immediate results of the evaluation, and this is vital if learning is to be successful [56, 57]. The use of AI for learning analytics gathers enormous amounts of information created by the student when interacting with the available courseware on the internet. It may aid teachers to become better teachers by improving their strategy and helping them to maximize courseware, as well as gaining further knowledge of the learning behaviors of the student. For example, platforms such as Coursera and edX may use learning analytics to track student interest and course completion rates for the betterment of the courses delivered to the student by the institution of learning [58].

5.3 Research Trends in AI-Driven Educational Tools

Extensive research is currently being conducted due to the integration of AI technology in e-learning, and several significant areas have been considered for investigation. An ever-expanding range of research is focused on how AI could make e-learning more personalized to meet the requirements and demands of each individual learner. Adaptive learning technology is known to have a positive influence on individual learner achievements, particularly in a mixed group of learners [59]. Research is also conducted to understand the influence of AI-based learning resource packages on learner engagement and motivation levels in e-learning environments. Research results have proven that

an AI-based resource package could enhance learner engagement and motivation levels towards their respective courses [60, 61]. Academics have started exploring the ethical issue from the perspective of application: data privacy, bias, accessibility, etc. Thus, when the issue of unequal access to technology can magnify the preexisting educational inequalities, the concern of equal access to the AI-based educational tool is one of the research trends [62]. Another trend examines the importance of training in AI technologies, which should be conducted in the most effective way possible. Teachers should be in a position to clarify to themselves the best way in which they could incorporate the use of AI tools in their teaching process in order to witness its full benefits [63,64]. AI in e-learning is a continuous process that keeps changing with the development of related tools in the near future; hence, as our discussion takes another turn in considering the future of AI in teaching, it will remain crucial that at the same time, we are addressing some of the issues at hand that are concerned with moral dilemmas (Table 2).

Table 2. Research Trends in AI-Driven Educational Tools

Research Trend	Description	Key Applications	Benefits	Challenges
Adaptive Learning Systems	Systems that adjust learning paths based on student data.	Personalized course recommendations, adaptive assessments	Increases engagement and improves learning outcomes.	Requires extensive data and effective algorithms.
Natural Language Processing (NLP)	Technology that makes it possible for machines to comprehend human speech.	AI chatbots, automated essay grading	Enhances communication and reduces grading time.	Challenges in accurately interpreting context and tone.
Predictive Analytics	Using data to forecast student performance and engagement.	Early warning systems for students who are at risk	Enables proactive measures to increase retention.	Worries about data privacy and the need for high-quality data.
Gamification and Game-Based Learning	Integrating game mechanics into educational settings.	Educational games, simulation-based learning	Increases motivation and engagement among learners.	Risk of distraction if not aligned with educational goals.
Virtual Reality and Augmented Reality	technology that are immersive and improve hands-on learning.	Immersion simulations and virtual laboratories	Provides hands-on experiences that enhance understanding.	High costs and technology accessibility issues.
AI-Enhanced Learning Management Systems	Integrating AI features into LMS for improved functionality.	Analytics dashboards, personalized content delivery	Streamlines administrative tasks and data analysis.	Implementation challenges and user training needs.
Social Learning Platforms	AI tools that facilitate peer collaboration and interaction.	Discussion forums, collaborative projects	Promotes community building and shared learning.	Requires active participation and monitoring.

Content Creation and Curation	AI-driven tools for generating and organizing educational content.	Automated content generation, resource recommendations	Saves time and resources for educators.	Ensuring quality and accuracy of generated content.

6. AI for Personalization and Engagement

6.1. Enhancing Personalized Learning Experiences

A learning technique called "personalized learning" is customized to the individual needs, interests, and preferences of a student. With large amounts of data to recognize and respond to individual learning styles, artificial intelligence is at the core of delivering personalized learning. Adaptive learning systems, which analyze student interactions and performance data to tailor curriculum to individual students—thus making them essential to artificial intelligence and personalized learning—ensure to engage students at a perfect level through systems like DreamBox Learning and Smart Sparrow, which adjust the current level of "difficulty" in a number of lessons based on a learner's rate of progress; thus, enabling them to learn at their own pace and keeping them motivated for learning [65, 66]. Also, AI can offer students more materials like articles, videos, or exercises relevant to their requirements through the analysis of their past performance and their mode of learning. For example, to make the course more interesting and relevant to the students, Coursera and Khan Academy make use of artificial intelligence to offer relevant material on the course the students will like depending on their activity and comments [67]. By making use of AI evaluation tools, students can track their performance immediately, thus being able to know their areas of strength as well as areas of weakness. To achieve this, platforms like Gradescope and Turnitin can offer AI-assisted grading to students not only to save teachers' effort but also to offer the students the information to aid their own self-study. Through the information offered by these tools, students can take the necessary measures to improve their performance [68, 69]. AI can yield information concerning learning behavior through metrics like time on activities, conversation participation, and assignment completion rates. Such information can enhance personalized learning experiences via assisted teacher identification of students who may need help, along with developing targeted interventions (Figure 2) [70, 71].

6.2 AI's Role in Fostering Student Engagement in Hybrid Settings

The role of AI is extremely significant in fostering student engagement in a new form of learning that incorporates a combination of online and offline learning. It is true that, through technological assistance, a learning environment that is interesting, immersive, and interactive can easily be created. For example, AR and VR technology allow for exposure to real-life scenarios that improve learning experiences. For example, virtual trips using Google Expeditions allow for the exposure of the student to new experiences even if they cannot access the place, such as creating active learning of complex issues for the student, something the teachers may not have the ability to create for their classrooms [72, 73]. AI-driven chatbots can provide students with instant support, which enhances continued engagement. Universities have implemented chatbots, for example, to answer frequently asked questions, guide students through their course and programme, and notify them of assignments or upcoming deadlines. The students remain up-to-date and engaged because the chatbots' immediate support reduces feelings of isolation that are often associated with online learning [74,75]. Gamified elements in online learning platforms can be added to highly enhance the student experience. AI can assess individual student performance and adjust the nature of the game, including challenges and rewards, according to preferences. Online learning platforms like Kahoot! use AI to create a unique, fun, and competitive learning environment that encourages students to participate with their peers in learning [76,77]. Students can effectively collaborate in hybrid learning environments through several AI-powered collaboration tools, including Microsoft Teams and Google Docs. AI can review participation and group dynamics in order to give teachers ideas on encouraging better collaboration. This promotes peer-to-peer bonding and a sense of community-both of which are important for effective learning (Table 3) [78,79].

Table 3. AI's Role in Fostering Student Engagement in Hybrid Settings

AI Application	Description	Impact on Student Engagement	Benefits	Challenges
AI-Powered Chatbots	real-time virtual assistant interactions with students.	Provides instant support and answers to student queries.	Enhances accessibility and reduces wait times for help.	Limited understanding of complex questions.
Individualized Educational Routes	AI systems that adapt educational experiences according on each learner's performance	Keeps students motivated by offering relevant content.	Increases engagement by aligning materials with interests.	Requires robust data collection and analysis.
Gamification Elements	AI-integrated game mechanics to enhance learning experiences.	Makes learning fun and interactive, boosting participation.	Improves motivation through rewards and challenges.	Risk of distraction if not well-integrated.
Interactive Content	AI-generated quizzes, simulations, and multimedia presentations.	Encourages active participation and deeper learning.	Stimulates interest and facilitates hands-on learning.	Development can be time-consuming and costly.
Adaptive Learning Systems	AI programs that, in response to student performance, instantly modify the level of difficulty of the material	Keeps students engaged by providing appropriate challenges.	Supports diverse learning paces, catering to individual needs.	May lead to frustration if adjustments are too drastic.
Predictive Analytics	Analyzes student data to identify engagement patterns and predict outcomes.	Informs timely interventions to re-engage students.	Enables proactive measures to prevent dropouts or disengagement.	Data privacy concerns and reliance on accurate data.
Social Learning Platforms	AI tools that facilitate collaboration and communication among peers.	Promotes community building and peer-to-peer interaction.	Enhances engagement through shared learning experiences.	Requires active participation and monitoring.
Virtual Reality (VR) Experiences	Immersive simulations that allow for	Engages students in a hands-on manner, increasing interest.	Provides unique learning experiences that are memorable.	High costs and accessibility issues for some students.

	experiential learning.			

6.3 AI Applications That Have Improved Learning Outcomes

Many AI applications have proved successful in making learning more engaging and personalized, and consequently more effective. Carnegie Learning is an AI-powered adaptive learning platform that provides personalized math training. Its intelligent tutoring system analyzes in real-time the students' interactions and offers them personalized feedback and resources. Schools using Carnegie Learning report increased student engagement and achievement in mathematics [80]. Duolingo is a language learning tool which is itself based on users' performance and participation. Its AI algorithms design customized lesson plans. Duolingo has been able to engage millions of students around the world with its game-like features and to create exercises tailored to the abilities of each learner. Duolingo has increased the rate of language learning in the US [81,82]. ALEKS is being used to implement an AI technique to determine the level of knowledge of students in mathematics. Consequently, students have access to education services, depending on their own pace. Studies on the system have yielded more desirable results compared to other education methods targeting students, according to research [83]. Edmodo is being employed as an educational tool to ensure students collaborate through the use of AI to improve their own modes of communication. Consequently, the teacher has the opportunity to identify students who need education through the use of the AI analytics tool from the interactions of students who have failed [84]. It is a game-changer for enhancing individualized instructions and motivating learner engagement, particularly when applied in a hybrid mode. It is also a potential means for greatly enhancing the overall results for individual learning processes by making use of interactive media, individual learning processes, and mechanisms for providing feedback. It is reasonably expected to result in a greater potential for more personalized and engaging learning processes as institutions become more accustomed to its overall application for their processes, providing for more inclusive and effective learning processes in the future [85].

Figure 2. AI-driven personalization and engagement enhance adaptive, interactive, and student-centered learning experiences in hybrid education

7. Ethical Considerations and Challenges

7.1 Obstacles in the Integration of AI

Institutions face various obstacles while trying to combine the AI technologies in the relevant setting of e-learning to enjoy the maximum benefit provided by those technologies. Application of these tools involving AI sometimes requires extensive technical expertise together with sufficient funding. The facilities absence that are adequate to host the technologies of AI, including the platforms of software which are dependable, access to the internet at high speed, together with the facilities that are proper to store the technologies. There is also the issue of the lack of adequate knowledge on the part of teachers necessary to make proper use of these technologies effectively [86, 87]. A well-thought-out infrastructure for making data collection, storage, and analysis facilitates is also crucial for the effective application of AI in education. To develop an infrastructure for applying AI in education, costly investments will have to be made to procure necessary infrastructure facilities. It is also not easy to integrate AI systems and devices with existing systems and technologies due to their lack of compatibility, particularly those pertaining to education [88, 89]. Teachers and administrators accustomed to more traditional approaches to teaching would resent the intrusion of AI technologies. Humans avoid change, may question the effectiveness of AI, and could also be threatened due to loss of jobs. These systems require developing an innovative culture and providing necessary training to alleviate these fears and engender stakeholders' support for such solutions [90, 91].A major factor pertaining to the caliber and volume of data accessible for analysis is also a major factor influencing the performance of AI systems. Data silos, insufficient data, and ineffective data collection mechanisms have a major influence on the correctness of data insights derived through AI systems. It is thus crucial for institutions to develop data governance systems to ensure the security and correctness of data used for AI programs [92,93].

7.2 Ethical Concerns

It is also important to note there is a set of ethical issues concerning the inclusive use of AI in the classroom. Moreover, there is a major issue concerning the privacies around the collection and use of data for the purpose of artificial intelligence for the students. Institutions are required to manage sensitive data sensibly and in accordance with applicable laws, including the General Data Protection Regulation (GDPR) and the Family Educational Rights and Privacy Act (FERPA). Personal information may be abused or obtained by unauthorized parties, which could result in privacy and trust violations [94,95]. FERPA and GDPR are implementable regulations aligned with computer-science practice as follows. Data minimization strategies are enforcing the schema-restricted data collection, pseudonymization of student identifiers, retention limits, and task-specific feature stores to ensure only necessary data is processed. Consent flows for LMS integrations is implementing the just-in-time consent prompts, granular purpose declarations, auditable consent logs, revocation mechanisms, and least-privilege OAuth scopes for LMS–AI communication. Privacy-enhancing technologies is adopting the federated learning to keep data on institutional servers, secure aggregation to protect individual updates, and differential privacy to add mathematically bounded noise during training or analytics. Fairness auditing workflows conducts the pre-deployment dataset bias checks, publish standardized model cards, and monitor ongoing disparate-impact metrics (e.g., error-rate gaps across groups). Incident and rollback planning defines the AI-specific incident categories, create rapid disable/contain protocols, maintain a versioned model registry, and support immediate rollback to safe model versions.

The objectivity of AI systems depends on the quality of the training data. Certain student groups may be treated unfairly if the AI algorithms that are produced reinforce any biases present in the training data. Biased algorithms may affect suggestions for personalized learning, grading, or admissions decisions. In order to guarantee justice and fairness in educational opportunities, algorithmic prejudice must be addressed [96]. A lot of AI systems function as "black boxes," which means that their decision-making procedures are opaque. This can present problems that make it difficult to understand how certain decisions are being reached or the basis on which certain determinations were reached, which can present problems in the academic arena since academic decision-making plays a large role in the path that students' academic careers will take. For the data utilization process, as well as the determinations that are reached, to be comprehended, measures that foster transparency with regard to AI technologies are necessary [97,98].

There can be passivity with regard to the development or exercise of one's ability to think critically, as relying too extensively on the technologies that are offered through AI can cause disservice to the development or exercise of the ability to think critically or attempt solutions on one's own or in the company of other students [99].

7.3 Strategies for Addressing Challenges and Ethical Considerations

There are several strategies that institutions could utilize to tackle some of the problems and ethical concerns linked to teaching and learning with AI. For example, it is important that educational institutions consider setting aside finances to upgrade their technical facilities. This would include updating their Internet facilities, as well as their software and hardware. We believe teachers would feel more relaxed and confident when teaching and learning with AI had adequate and comprehensive training in how to utilize it effectively [100-102]. Another factor for IT organizations to look into is how they develop a framework with regard to their data governance strategy, such as putting down procedures on how to utilize or process their institutions' collected data. It would also entail how they would look into proper security measures to promote strict compliance as well as risks to address concerns regarding their data management [103]. Organizations can prioritize the importance of transparency while dealing with AI technologies. Transparency might mean providing stakeholders with information on the ways in which the algorithm works, the sources of the data used in the algorithm, and the biases that can be present within the algorithm. This can help the organization build more joint efforts and cooperation by dealing with such issues regarding the integration of AI within the organization [104]. In terms of the biases present within the algorithm being used by an organization, the organization can attempt to evaluate their own AI technology in the hope that biases can be cleared within the algorithm itself. Multidisciplinary working by educators, data-scientists, and ethicists working together using different datasets within the algorithm can ensure that biases rarely make their way into the algorithm [105, 106]. Organizations should design policies that identify ethical issues in the implementation of AI with a focus on responsible behavior for teachers and students. These include the sensitivity of prejudice, data security, and the importance of using technology in a balanced manner within the learning process. While there are several opportunities to enhance learning with AI in e-learning, difficulties and ethical dilemmas also abound. The proactive approach to such issues will allow educational institutions to create a more open, equitable, and efficient learning space-one that safeguards student rights and interests while adopting AI technologies [107,108].

8. Case Studies of Successful AI Implementation

It is to be noted that the recent past has witnessed the use of artificial intelligence tools to improve the use of the hybrid learning environment, with many learning institutions incorporating artificial intelligence tools to improve learning for the scholars. In this regard, cases of successful use of artificial intelligence tools by various organizations have been highlighted, along with the results obtained and the lessons learned thereof, as illustrated in the table below (Table 4) [109,110].

8.1 Case Study 1: Georgia State University (GSU)

Georgia State University is recognized as leveraging the usage of data analytics, as well as artificial intelligence, to improve the results of students, particularly in the hybrid mode of learning. There were several problems related to the high dropout rates of students at the Georgia State University, and the university was looking to implement innovative measures to retain the students. An AI-based predictive analytics tool was implemented to monitor the results and engagement of students in real-time. In order to monitor the poor-performing students, the tool processes various parameters, including the demographics of students and enrollment status as well. The chatbot 'Pounce' was implemented in GSU as part of the technology integration process. Moreover, a significant improvement in terms of retention rates was a result of AI technology integration into the educational setup at GSU. As mentioned in a study by GSU, a 20 percent improvement in retention rates was recorded by students who are at risk. The other notable functions performed by the artificial intelligence chatbot include answering over 15,000 questions in order to reduce the workload associated with being an academic advisor. The need of integrating models of data-driven decision-making alongside the necessity of frequently evaluating the use of artificial intelligence technologies are noteworthy

lessons that can be learnt from the integration of artificial intelligence technologies in GSU. The need of instilling a culture of academic success among students by engaging them alongside responding to their questions in a prompt manner is a noteworthy aspect which is of great importance in realizing success in an entity/organization in general [111, 112].

8.2 Case Study 2: Arizona State University (ASU)

Arizona State University has been a pioneer when it comes to effectively utilizing technology with respect to learning. Arizona State has used this hybrid approach, which means that physical learning and online learning have both been incorporated. AI has helped with respect to the overall development and growth of students. A new technology has been introduced that uses AI with respect to this learning approach. This particular technology has been termed "ASU+," and with this, Arizona State has effectively used AI with respect to this learning approach [113]. Furthermore, ASU has adopted AI chatbots that provide instant support services to the students. Such chatbots help students resolve their doubts or questions regarding various courses or other activities related to them. There has been a significant improvement in student participation as well as an increase in the satisfaction level. Students had a positive sentiment regarding the learning experience from the AI-powered learning system. As compared to other courses, the university recorded a 10% improvement in course completion rates among those students who adopted the learning system. The experience of ASU well illustrates the importance of integrating AI with learning and educational approaches rather than isolating both. In integrating AI-based learning with existing approaches, it is of utmost importance to involve the cooperation of teachers, IT specialists, and learning specialists [114, 115].

8.3 Case Study 3: University of Southern California (USC)

Challenges were being experienced by the University of Southern California (USC) in providing students with a more personalized experience while dealing with their diverse student population in a hybrid mode. To mitigate the above problems experienced by the university, the University aimed at applying new technologies in the field of AI to improve student support. 'Trojan Vision,' an AI-based solution introduced by the University of Southern California, uses machine-learning technology to analyze student data while providing students with suggestions on courses with the help of machine algorithms. Student support can be offered on a priority basis with the help of AI-based chatbots. The implementation of the Trojan Vision led to increased student engagement as well as improvements in academic performance. The institution noticed an upgrade of 15% students' satisfaction due to the implementation of the system. The AI also facilitated the identification of students who needed more guidance to avoid performance dissatisfaction on the part of the students. To efficiently utilize AI among academic advisors, the USC experience emphasizes the need for constant support. To improve the applications of AI while ascertaining whether the applications fully satisfy the students' demands, teachers and students need to offer their contributions. The case studies of the University of Southern California, Georgia State University, and Arizona State University are crucial in illustrating how AI can transform the current hybrid environment of learning. This is because the two types of AI technologies were effectively used in the three schools' environments to enhance the level of student retention rates and create an environment in the classrooms where all the participating scholars became engaged in the required activities. Importantly, the key lessons from the activities conducted in the three institutions' environments center on the importance of collaboration and the need for teachers to be fully supported in their activities. Undeniably, ethical issues in the future should be the main focus of all the concerned organizations to ensure all the scholars benefit from the applications of AI in the classrooms equally [116-117].

Table 4. Case Studies of Successful AI Implementation in hybrid learning

Case Study	Institution/Program	AI Technologies Used	Implementation Strategies	Outcomes Achieved	Key Lessons Learned

Case Study 1: Intelligent Tutoring System	Georgia State University	Adaptive Learning Algorithms	Integrated an AI-driven tutoring system in STEM courses.	Increased pass rates in challenging courses by 20%.	Importance of data-driven personalization in education.
Case Study 2: Predictive Analytics	Purdue University	Predictive Analytics	Implemented analytics to identify at-risk students early.	Improved retention rates by 15% through timely interventions.	Need for ongoing data monitoring and adjustment of strategies.
Case Study 3: AI-Powered Chatbots	University of Southern California	Natural Language Processing (NLP)	Deployed chatbots for 24/7 student support and FAQs.	Enhanced student satisfaction and engagement by 30%.	Effective communication channels increase student trust.
Case Study 4: Personalized Learning Paths	University of Illinois at Urbana-Champaign	Machine Learning	Customized learning pathways based on individual performance.	Improved student engagement and academic performance metrics.	Tailored approaches yield better learning outcomes.
Case Study 5: Virtual Reality Labs	Stanford University	Virtual Reality (VR)	Integrated VR for hands-on experiences in science courses.	Increased student participation and retention in lab courses.	Immersive experiences can enhance understanding of complex concepts.
Case Study 6: Gamification in Learning	University of Colorado Boulder	Gamification Techniques	Used game mechanics in course design to increase engagement.	Higher student motivation and completion rates.	Game-based learning fosters a fun and interactive environment.
Case Study 7: AI-Driven Learning Management System	Arizona State University	Learning Management System (LMS) with AI	Enhanced LMS with AI features for analytics and content.	Streamlined administrative tasks and improved resource allocation.	The learning process can be improved by integrating AI into LMS
Case Study 8: Collaborative Learning Tools	Massachusetts Institute of Technology (MIT)	AI-Enhanced Social Learning Platforms	Utilized AI to foster peer collaboration and interaction.	Enhanced collaboration and community	Collaboration tools are essential for

				building among students.	hybrid learning success.

9. Future Trends and Research Directions

The changing hybrid education environment has come to be greatly determined by the continuous development and advancements in the incorporation of artificial intelligence into e-learning. In order to fully take advantage of the current benefits associated with the use of technology and AI, a critical examination of the probable emerging trends, knowledge gaps particularly with regards to the literature, and suggesting research areas as the institutions continue embracing AI technology is critical. Emerging trends that are expected with future AI technology integrating with e-learning are the personalization that future AI would offer with regards to the educational experience. AI can offer personalized educational pathways ascertained by the knowledge and performance records of every learner with the aid of sophisticated algorithms and modern technology. Through the addressing of personal needs by every learner, the outcome would not only serve as a motivational factor but would also enhance the outcome of the learning processes [118]. With the integration of adaptive technologies used in tasks like adaptive learning, the platforms will have the capabilities to adapt the mode of delivery of the information provided in real-time depending on the interactions of the students. With the platforms continuously being able to learn from the students who use the information, the students will be given the necessary resources and guidance depending on their own interactions, thus being given the necessary levels of guidance [119]. Such technologies being driven by Artificial Intelligence, such as a tool which can better evaluate how a student is performing can, in all probability, find their way in which teacher-students in this field can be assessed in the near future in the educational sector of human society. Teachers would be in a position to quickly evaluate assignments or projects which a student has undertaken in a written format through grading that is driven by Artificial Intelligence technology, which in turn would minimize the working loads of teachers in this field to enable them to intensely dwell on teaching [120, 121]. AI is expected to continue converging with the Integration of Virtual Reality and Augmented Reality technologies to create immersive educational opportunities. There are possibilities that a teacher could design interactive scenarios that foster engaging learning by combining AI with Virtual and Augmented Reality.For example, a group of medical students could engage in a virtual surgery that adjusts levels based on their skills [122-124]. It will also help in developing collaborative learning by emphasizing collaboration and group projects created by AI tools. There are also some options that would come up in the near future to infuse itself to improve group behavior by developing an ideal mix of different groups based on strength and weakness levels of an individual to implement collaborative learning in a mixed learning mode of operation (Figure 3) [125,126].

9.1. Gaps in Current Research

Even though the AI-based e-learning program has shown signs of more advancement, some gaps have to be filled through more research in the future. It has been decreed that the longitudinal research has to be conducted in the future to assess the long-term effects on the retention levels and learning of the people embracing the AI-based e-learning program. A knowledge gap has been identified from the above discussion to exhibit the long-term effects of the implementation of the AI-based e-learning program and systems, considering the fact that a short-term analysis has to be conducted on this topic in most of the literature [127-129]. Even though the applications of AI have tremendous potential to improve the learning of all kinds of people in the world, several aspects have to be studied in the future to know the justice and equality for the people embracing this kind of program, considering the aspects of designing the AI-based e-learning program for different kinds of people in the world, especially those from underprivileged groups in the world [130, 131]. A comprehensive ethical system that guides the growth of the use of such AI tools is critically needed as these tools become part of the fabric of education, as they increasingly have been, while dealing with the generalized concerns of effectively implementing such tools as a whole in education institutions around the world [132-134]. The relevance of enabling educators to proficiently integrate AI into their educational practices is something that is easily missed in literature currently in publication. Thus, the desirable practice should be to create curricula to facilitate the effective use of AI by the educators themselves and provide them with the

necessary information to use the tool sets proficiently without compromising the integrity of the learning [135-139]. There exists an intrinsic interdisciplinarity of association between technology, education, and artificial intelligence domains. As a way of developing complete guidelines for the adoption of artificial intelligence technology in learning settings, the desirable approach should be to incorporate a multiplicity of disciplines with the involvement of different professional groups within the spheres of education, computer science, and social science [140-142].

9.2. AI Influence Hybrid Higher Education in the Future

The value of AI technologies can also be detected regarding the course that hybrid higher education will be taking, especially in several respects, especially regarding the one that has already been seen, i.e., that AI has to offer students an interesting, personalized, and flexible kind of experience; a totally different kind of learning, that will enable students to take ownership of the process, through a realization of their own learning preferences [143-145]. Decisions regarding the curriculum, resources, as well as support services, are expected to be made through AI-based analytics, where administrators/lecturers are able to take well-informed decisions to create a conducive learning environment through AI-based analytics results [146,147]. The capability to reduce operating costs, better manage resources, and speed up administrative tasks in higher learning institutions exists in AI. The repetitive tasks carried out routine tasks such as scheduling and gradations in these fields may not only be automated but will also free up time to concentrate on more complex tasks to enhance the performance of students [148, 149]. The use of AI in the education sector will help in bringing a paradigm shift to lifelong learning through the opportunity for people to get involved in lifelong professional development. Learning will be tailored to the changing needs of people through AI systems [150, 151]. However, the elimination of geographical boundaries through the usage of AI will also facilitate the establishment of global learning communities through interdependence among the students of different backgrounds. Therefore, this interdependence will promote the educational processes in an intercultural manner. In the future, e-learning in hybrid education through the usage of AI will revolutionize the face of education in a tremendous manner. Through the applications of AI in the educational sector, the educational institutions can facilitate the establishment of highly engaging learning communities in an egalitarian manner required in the future by filling up the upcoming educational gaps in a highly ethical manner [152-154] (Table 5).

Table 5. *How AI may Influence Hybrid Higher Education in the Future*

AI Application	Description	Impact on Hybrid Higher Education	Benefits	Challenges
Tailored Educational Opportunities	AI systems tailor learning programs to each learner's need	Creates tailored educational experiences for students.	Enhances student engagement and academic performance.	Requires robust data collection and analysis.
Smart Learning Environments	AI tools that adapt to different learning styles and paces.	Provides flexible learning spaces that support diverse learners.	Increases accessibility and inclusion in education.	Complexity in integration with existing systems.
Intelligent Tutoring Systems	AI-powered systems that offer students individualized assistance	Offers personalized assistance to supplement teaching.	Improves learning outcomes by addressing individual challenges.	Cost of development and implementation.

Automated Administrative Processes	AI systems streamline administrative tasks like enrollment and grading.	lessens the administrative load on staff and professors	gives teachers more time to devote to mentoring and instruction	Dependence on technology for critical processes.
Enhanced Student Engagement Tools	AI-powered applications that foster collaboration and interaction.	Promotes community building among hybrid learners.	Increases student retention and satisfaction.	Ensuring participation in hybrid environments can be challenging.
Data-Driven Decision Making	AI analytics provide insights into student performance and engagement.	Informs institutional strategies and policies.	Allows for targeted interventions and resource allocation.	Data privacy and security concerns.
Real-Time Feedback Mechanisms	AI-powered tools that give students immediate performance feedback.	Supports continuous improvement in learning outcomes.	Helps students to identify and address weaknesses promptly.	Possible overload of feedback leading to confusion.
Augmented Reality and Virtual Reality	VR/AR technologies with AI enhancements for engaging educational experiences	Facilitates experiential learning in a hybrid context.	Offers unique and engaging learning opportunities.	High costs and accessibility issues may limit implementation.

9.3. AI Techniques in Hybrid Higher Education and Their Computing/Communications Considerations

The hybrid higher education increasingly depends on the AI systems developed for distributed, multi-modal learning environments which extend the physical campuses and online platforms. The following computer science focused assessment connects the key AI techniques to core communications and computing constraints that influence their deployment, governance, and performance.

9.3.1. LLMs / NLP for Chatbots, Automated Feedback & Grading

LLM-based chatbots and auto-grading tools require horizontal scalability to handle increase in student queries and batch-grading loads. Where the real-time response is essential, low-latency inference via on-device, or the edge deployment can reduce round-trip delays in remote classrooms. Integrating with the institutional LMSs demands interoperable APIs (LTI 1.3, xAPI) to ensure the secure grade exchange and auditability. The privacy concerns mandate privacy-preserving analytics, such as partial-redaction pipelines or differential privacy for log data. Continuous improvement is typically managed through A/B testing pipelines, enabling safe rollout of upgraded models [155].

9.3.2. Recommender Systems for Personalized Learning Pathways

Curriculum-level personalization requires distributed data processing frameworks to utilize clickstreams, assessments, and engagement logs at scale. To avoid computation bottlenecks in maximum sessions, hybrid campuses

often use microservices and cloud auto-scaling. Interoperability with LMS content repositories depend on xAPI learning records, enabling consistent cross-platform tracking. Privacy preserving analytics secure aggregation, federated training which support the personalization without exposing individual learning histories [156].

9.3.3. Sequence Models for Early-Warning & Risk Prediction

Time series based models (LSTMs, Transformers) for dropout prediction depend on streaming data pipelines with low-latency ingestion (e.g., Kafka-like systems) to identify disengagement early enough for intervention. These models are often process sensitive behavioral traces, they benefit from secure multiparty computation or DP-protected feature stores. When this model deployed across multiple campuses, predictions must be synchronized via interoperable LRS (Learning Record Stores) compatible with xAPI [157].

9.3.4. Knowledge Tracing Systems

Knowledge-state inference engines can run efficiently in the large hybrid classes, thus computational efficiency and model compression matter for scalability. The real-time question sequencing in active-learning classrooms requires near-edge inference to minimize classroom latency. Interoperability with assessment tools depend on LTI-based item banks, while continuous experimentation on question difficulty uses multi-armed bandit A/B testing frameworks. The privacy-preserving analytics prevent reconstruction of students' mastery profiles [158-160].

9.3.5. Computer Vision for Proctoring, Labs & Practical Assessment

Computer vision driven proctoring and remote-lab analysis must address latency constraints because delayed feedback undermines exam integrity. This encourages the use of edges or client-side inference (e.g., browser-based ONNX/WebGPU) to avoid high-bandwidth video transmission. The scalability challenges emerge in multi-room hybrid exam sessions and are mitigated through event-driven architectures. The privacy and legal compliance require on-device processing, ephemeral storage, and the minimal transmission of biometric features. LTI-based exam modules enable secure integration with institutional proctoring systems [161].

9.4. Technology Acceptance and Motivational Dynamics in Hybrid Higher Education

9.4.1. Technology Acceptance Model (TAM)

In AI-mediated forms of hybrid higher education, especially in fields such as business and management programs, Technology Acceptance Model (TAM) components retain their base structure for predicting the intention to use online technologies and programs for higher learning based on Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) in prediction as Behavioral Intention (BI). In the case of hybrid learning environments, the infrastructure and support mechanisms available to the students, such as technical and academic support, help in moderating and correlating these three elements in a positive manner with regards to the enhanced intentions in the minds of those who have been assisted in various aspects and enhanced self-confidence level among these students so that they are comfortable with AI-mediated programs and environments [162, 163].

9.4.2. Self-Determination Theory (SDT)

Complementing TAM, SDT explicates the motivational processes which translate acceptance into relevant learning outcomes. Indeed, AI-enhanced hybrid systems that provide autonomy-supportive features (e.g., adaptive pacing, flexible tasks), competence-building feedback, and opportunities for social connection help satisfy the needs for autonomy, competence, and relatedness of learners. These elements give rise to playfulness, intrinsic motivation, and emotional engagement that act as mediators between technology acceptance and educational outcomes like satisfaction, persistence, and performance. These motivational states, vitally important to be sustained beyond initial adoption, are particularly relevant in business and management education where simulations, analytics dashboards, AI tutors, and collaborative platforms are regular occurrences [164-166].

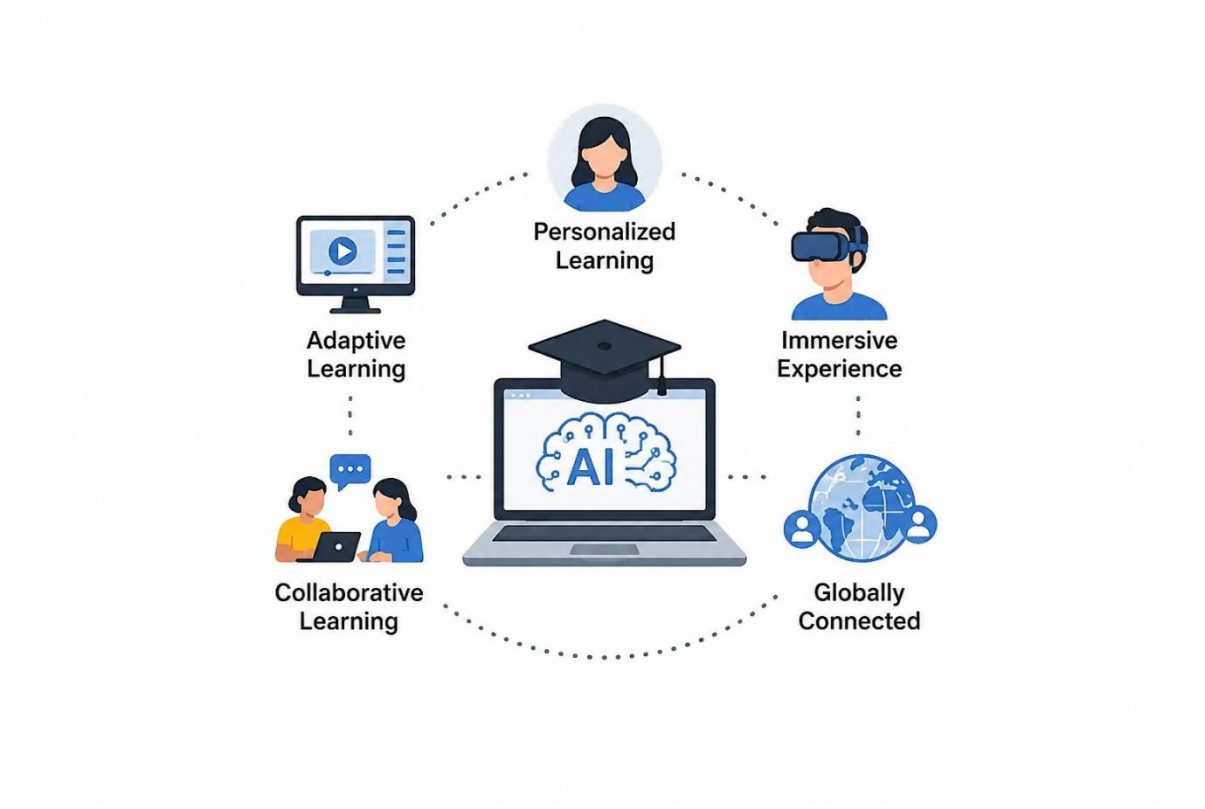

Figure 3. AI-powered future of hybrid education: personalized, adaptive, immersive, and collaborative learning.

10. Results

The aim of the study was to have a clear understanding of various AI technologies and how they are applied in e-learning, understanding the potential for the technologies to enhance general learning outcomes in a hybrid mode, and developing and adapting to the needs of various individual learners [167,168]. The study was able to establish the various best practices for the effective use and incorporation of AI in hybrid higher education environments based on case studies and trends in modern society. Teachers and bodies wishing to apply AI technologies in future to enhance or enrich procedures for improved teaching and learning are advised to use these best practices [169-172]. Such a study clearly outline the ethical dimensions of the incorporation of AI into the classroom setting. Such an achievement shall assist in the formulation of morality concerning the effective application of AI technology in the classroom setting [173,174]. The study provides the audience with a number of ideas concerning the effective application of the incorporation of AI technology in e-learning institutions and the successful integration of e-learning into the classroom setting based on improved standards of morality, effective learning outcomes, and increased student engagement [175-177]. The study will also identify the possible directions that the research concerning the interrelation of artificial intelligence and hybrid models of higher education may take. This achievement is crucial since it is going to back the continued initiative to improve research and development regarding the knowledge gaps, culminating in the generation of unique teaching and learning processes [178-180]. By achieving the aforementioned objectives, the study is sure to improve the model of hybrid higher education that sufficiently meets the needs of diverse learners while ushering in a new wave of studies concerning artificial intelligence in education.

11. Discussion

One of the most significant changes in the manner education is offered can be highlighted through the accompaniment of Artificial Intelligence (AI) and the related issue of the hybrid model of higher education through

the field of e-learning. The conclusions of the given research can be highlighted through the discussion of the present conclusions as related to the potential future changes in the field.

11.1. AI as a Catalyst for Personalization and Enhanced Learning - One of the most attractive opportunities that serve as the major advantage offered by AI in the support mechanism of individualized student learning experiences is the acquisition ability that still persists with the inclusion of AI in e-learning. Ultimately, the acquisition ability that has become an impactful contribution is the adaptive mechanism that can tailor the content being used in the course of learning according to the individual student's needs, preferences, and student style with the help of data analytics. This adaptive mechanism can become very vital, especially in the implementation of the hybrid approach that students find difficult to manage due to the independent nature that comes with e-learning. Other academic works are directed towards finding the usability of other mechanisms offered by AI that can create the best outcome on the development achievable by students in specific academic disciplines [181-183].

11.2. Challenges in Implementation and Infrastructure - It should also be noted that, while there may be some benefit, it seems that there might be great challenges associated with the use of the technology in an education setting. It appears that one of the greatest challenges could be those of infrastructural, security, and training issues; furthermore, ethical issues such as those of bias and privacy should not be taken lightly. It is anticipated that ongoing discussion on these issues will be necessary as they will play an important role in the development of robust frameworks and regulatory practices geared towards ensuring ethical use of the technology in the educational sector. There are significant barriers to the implementation of AI as mentioned above. There is still an underdeveloped technological base in some institutions, as well as many concerns around issues surrounding data security and preparation of the teaching force [184,185].

11.3. Ethical Implications, Guidelines and Responsible Use - However, it cannot be emphasized enough that with regard to ethics in artificial intelligence in education, a head-on approach to solving and addressing it is needed and mandatory. And it is not possible not to denote and emphasize on the issue of fairness, accountability, and transparency in terms of considering it as a very crucial issue, given that there will be biases that promote inequalities in terms of achievement and accessibility of resources. Thus, it is very possible and it is very imperative to emphasize well-defined ethics in artificial intelligence in e-learning as shown and exhibited through the present research. Besides, it is significant to see the ethics taking central stage in the evaluation guideline that highlights the suitability of employing AI in enhancing learning in higher learning institutes. The ethical concerns render themselves evident in line with the formation of decisions that result in allocation and resource systems after being impacted by the decisions made by the AI in a biased way. First and foremost, it is paramount to realize that it was of great need to advocate the formation of guidelines that were heavily liberal in nature. Stakeholders play an extremely instrumental role in the formulation of fairness in the development of the AI [186,187].

11.4. Impact of AI on Educational Outcomes - The issue of enhancing the outcomes of education with the help of AI becomes more relevant in consideration of the fact that more and more institutions begin to apply the so-called hybrid model. Other examples of how AI technology contributed to the improvement of the outcomes of education as well as the education experience are provided in the study. These examples can be viewed as a guidance for seeking the opportunities of developing AI application in various education institutions. To determine exactly the indicators of success in this case, more research is to be conducted. It is presumed that AI is to continue to provide a promising platform to better education outcomes, especially in a hybrid mode. Various instances concerning the bettering of education experiences and outcomes through the application of AI were presented within the case studies; such instances create a kind of guide to implementing AI on a broader scale, but again, there is a need for more research on defining precisely the parameters of its success [188-190].

11.5. Future Directions and Research Priorities - The dynamic environment of hybrid education institutions has presented several research opportunities awaiting future research. Other areas of research require the frontiers of the study of AI-powered collaborative learning environments, integration of AI features with other cutting-edge technologies like VR, and establishment of methods of constant evaluation and feedback. Future research also has to

be conducted on the long-term effects of hybrid education institutions using AI tools, such as the formation of ideas on the eventual effects of the technology on the education sector, which is bound to continue changing dynamically. The dynamic environment of hybrid education institutions has presented several research opportunities awaiting future research. Some of the future areas of research include the following: AI-powered collaborative environments, Integration of AI and other cutting-edge technologies like VR, Constant evaluation methods, Positive effects on the education sector [191,192].

11.6. Towards Responsible and Inclusive AI Integration - There are a number of challenges associated with the integration of AI technology into e-learning. Despite all the challenges and impediments, education institutions can serve the diverse needs of modern students by crafting a more inclusive, efficient, and engaging education environment by addressing the challenges and realizing the opportunities that AI technology has to offer. While AI technology has the capacity to change hybrid higher education, careful and exhaustive planning is very crucial. At the same time, the challenges can be effectively addressed. This calls for further concerted efforts among educators, institutional leaders, and policymakers to promote the pull of transparency, fairness, and inclusiveness across the development of any related artificial intelligence programs [193,194]. The above discussion concludes with the initial objectives of the related research and incorporates the relevance of the results with artificial intelligence personalized learning, the results of hybrid education, as well as the challenges observed with the related ethics.

12. Limitations of Evidence and Future Computer Science / Communication Studies

Currently, the methods to assess LLMs only involve BLEU, ROUGE, or correctness scores defined by the instructor. These methods of assessment do not suit the requirements of assessing the pedagogy of the AI-generated information. There is also the need to create online-learning specific LLM evaluation benchmarks to suit other factors uniquely experienced in online classrooms, including constructive alignment, information accessibility, fairness, and online-learning gains [195,196]. Currently, the application of AI-generated analyses is cloud-centralized, thus creating latency problems where real-time applications of these results in hybrid classrooms demand AI research in creating an information-inferencing network capable of addressing results within online classrooms in less than 100 milliseconds [197,198]. Most deployed systems are providing periodic, static analyses while hybrid learning environments are increasingly requiring continuous and streaming analytics. In this environment, applying differential privacy remains underdeveloped. The future work will have to develop new privacy-budget accounting schemes to support ongoing data utilization with student confidentiality and regulatory compliance [199,200]. Most of the studies hold small cohorts or isolated courses. There is a need for standardized A/B testing architectures integrated within LMS that allow institutions to run reproducible experiments across thousands of learners. This can enable the robust measurement of causal effects, behavioral changes, and long-term performance outcomes [201,202]. Beyond the technological challenges, research in the field of Communication Studies is also necessary to understand the perspective of the students regarding the AI-generated feedback, the building of trust, as well as the different formats of the messaging system employed. Effective models of AI-student communication have not yet been fully explored [203,204]. It also does not have access to large, open, anonymized data from hybrid learning settings. A series of replications will also play an instrumental role to strengthen the findings and to reveal context-sensitive effects on the efficiency and efficacy of AI systems. It would also demand some methodological innovations and collaborative works from different disciplines to establish a good foundation of knowledge [205, 206].

13. Conclusion

AI has great potential for changing the teaching and learning processes and decisions in either online or hybrid higher education. Artificial Intelligence will unquestionably alter educational processes when it is integrated into e-learning and hybrid higher education. Based on this understanding, the present study investigated the multifaceted dimensions through which artificial intelligence may influence the future of education, emphasizing significant findings and their implications for institutions, educators, legislators, and learners. This paper seeks to answer the research questions by critically discussing the implementation status of AI technologies and outlining the prevailing trends of research about the same, evaluating the effectiveness of applying such technologies for improving learning

experiences, keeping in view ethical issues, and thereby presenting case studies for suggestions on responsible adoption. The study revealed that these AI technologies have increasingly begun to act as a medium for personalizing learning, with such intelligent systems having the ability to tailor learning materials according to the learner's personal needs, preferences, and learning styles. In fact, this falls in line with the reason behind the study and the possibility of enhancing learning via these AI systems and their integration. The ability for AI technologies to enhance individual learning based on tailored information materials to a student's needs, preferences, and learning style is among the most substantial findings in the subject area. These technologies have likewise depicted promise in elevating the levels of academic achievement as well as engagement, thus elevating the rates of retention in hybrid modes of learning. There is also the potential in the processes of creating grades as well as providing feedback through an array of technologies powered by artificial intelligence, which can assist teachers in focusing on more teaching-related activities. The ethical implications of AI in education are an additional key aspect that was also discussed. In order to ensure that the benefits of AI are shared by all, concerns relating to issues such as data privacy, bias, and equity must also be adequately addressed. Additionally, in order to overstate the importance that must be attached to ensuring that the staff is adequately prepared to enable a successful integration of AI, is brilliantly impossible. This is because, for AI to be implemented, development programs that place adequate importance on ensuring that AI is adequately utilized must be a key aspect.

In conformity with the objective of the research on identifying the prevailing research trends, it is submitted that with the advancements witnessed in intelligent tutoring systems, learning analytics, automated gradations, and AI-based hybrid classroom management, the above developments indicate the significant influence of the AI on the prevailing educational techniques and its future projection.

Another objective of the study with regard to ethical as well as implementing challenges was also supported by the fact that this objective of the study emphasized various challenges such as having bias, data privacy as well as issues of lack of clear sentiments with regard to making decisions based on artificial intelligence. It is the presentation of various cases with regard to this objective of the study that there are other challenges with regard to teacher as well as institutional readiness. Here, teachers have to use AI in ways that support pedagogy better. The infrastructure, training programs, and ethical guidelines in this context are worthy investments that higher education institutions will undertake, and this will help AI systems deliver equity, transparency, and student wellness. There is, however, the issue that higher education policymakers have to work through in terms of data privacy concerns that will require proper regulations to be in place along with guidelines on ethical AI use in higher education. The findings have highlighted the adoption of AI as a medium that will help educators improve their methodologies in teaching and learning. Educational centers should promote investment in AI that facilitates personalized learning processes, with emphasis on laying down proper ethics in AI that guard and promote learner interests. Governmental figures need to contemplate laying down guidelines that encourage proper AI integration, while data security and privacy legislation need to be adhered to appropriately. Effective and proper utilization and harnessing of AI integration need the cooperation of all participants in processes of constant monitoring and laying down proper and transparent practices.

A responsible use of AI in education will be characterized by, on one end of the spectrum, exploiting all there is to positively exploit of AI and, on another end of the spectrum, minimizing all there is to negative exploit of AI. This will require collaboration between stakeholders to formulate some guidelines under which AI will be used in education. This is precluded through establishing standards under which AI will work in best serving children and teacher interests with regard to aspects as data collection and algorithmic decisions. Furthermore, another aspect is that, lastly, the intent and aim of the present research is to emphasize the importance of stakeholders engaging in collaboration across disciplines, as well as to focus on the fundamental necessity to conduct more study on the factor pertaining to how AI shapes education. It is upon these factors that the successful amalgamation of hybrids shall depend, based on the consequences derived from the gaps present within the study, particularly pertaining to the sustainability and the core challenges faced due to the considerations surrounding access and the formulation of substantialized education programs. Thus, in conclusion, even though there exists great prospects in improving e-learning and mixed learning through the use of AI, it is necessary that we have cooperation in terms of teachers,

schools, legislators, as well as examining the ethical impacts carried out by AI in order to build up a future that will allow AI to improve student experience like never before through innovation and inclusiveness.

ABBREVIATIONS

AI - Artificial intelligence

ML - Machine learning

NLP - Natural language processing

VR - Virtual Reality

AR - Augmented Reality

AI DISCLOSURE STATEMENT

During the preparation of this manuscript, the author(s) used an online tool solely for language checking, grammar and spelling checks, grammar improvement, enhanced image quality. No AI tools were used for concept development, hypothesis formulation, data collection, analysis, or interpretation. After its use, the author(s) thoroughly reviewed, verified, edited, and revised content to ensure accuracy and originality.

AVAILABILITY OF DATA AND MATERIALS

All data generated or analyzed during this study are included in this published article.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

Not applicable.

INFORMED CONSENT

The research does not contain any study with human participants

CONSENT FOR PUBLICATION

Not applicable.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

AUTHORS CONTRIBUTIONS

V.S.G., S.B.D. and P.R.N., contributed to the derived the model, research design and implementation, as well as the data analysis and manuscript writing.

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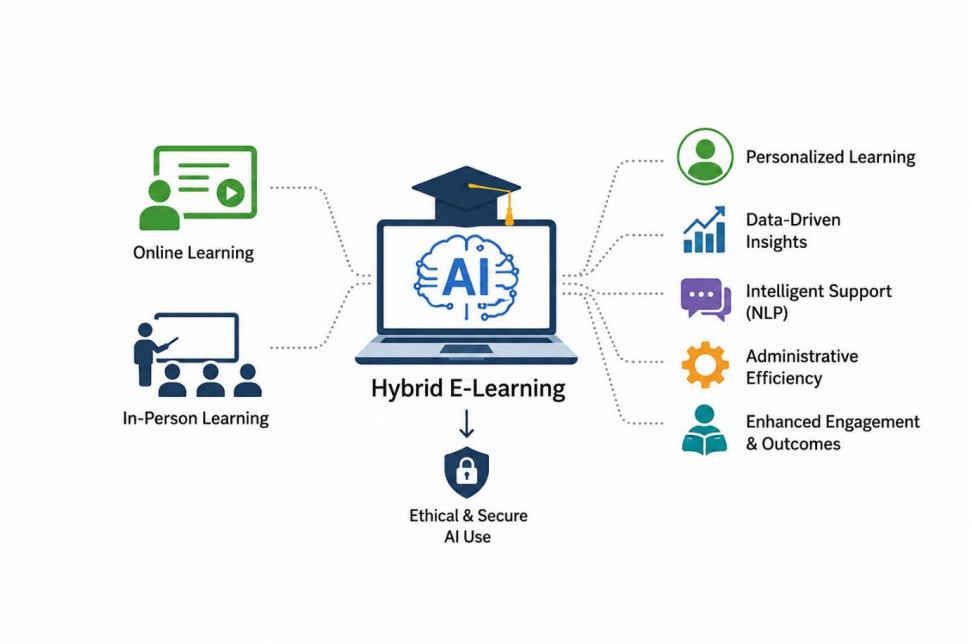
Graphical Abstract



Caption - Artificial Intelligence enhances hybrid education through personalized instruction, student engagement, automated support, and ethical data-driven learning environments

References

1. Lee, G., Yun, M., Zhai, X., & Crippen, K. (2026). Artificial intelligence in science education research: Current states and challenges. Journal of Science Education and Technology, 35, 110–127. https://doi.org/10.1007/s10956-025-10239-8
2. Hasan MK. How AI quietly undermines the joy and effort of learning: a call for rebalancing education in the digital age. Ann Med Surg (Lond). 2025 Jun 10;87(8):4693-4694. doi: 10.1097/MS9.0000000000003456. PMID: 40787558; PMCID: PMC12333830.
3. Rodríguez-Ortiz MÁ, Santana-Mancilla PC, Anido-Rifón LE. Machine Learning and Generative AI in Learning Analytics for Higher Education: A Systematic Review of Models, Trends, and Challenges. Applied Sciences. 2025; 15(15):8679. https://doi.org/10.3390/app15158679
4. Lee, K., Fanguy, M., Bligh, B., & Lu, X. S. (2022). Adoption of online teaching during the COVID-19 Pandemic: a systematic analysis of changes in university teaching activity. Educational Review, 74(3), 460–483. https://doi.org/10.1080/00131911.2021.1978401
5. Wu J, Tlili A, Salha S, Mizza D, Saqr M, López-Pernas S and Huang R (2025) Unlocking the potential of artificial intelligence in improving learning achievement in blended learning: a meta-analysis. Front. Psychol. 16:1691414. doi: 10.3389/fpsyg.2025.1691414
6. Chen Y. Evaluation of the impact of AI-driven personalized learning platform on medical students' learning performance. Front Med (Lausanne). 2025 Sep 12;12:1610012. doi: 10.3389/fmed.2025.1610012. PMID: 41020237; PMCID: PMC12465117.
7. Rincón EHH, Jimenez D, Aguilar LAC, Flórez JMP, Tapia ÁER, Peñuela CLJ. Mapping the use of artificial intelligence in medical education: a scoping review. BMC Med Educ. 2025 Apr 12;25(1):526. doi: 10.1186/s12909-025-07089-8. PMID: 40221725; PMCID: PMC11993958.
8. Wang, S., Sun, Z., Wang, H., Yang, D., & Zhang, H. (2025). Enhancing student acceptance of artificial intelligence-driven hybrid learning in business education: Interaction between self-efficacy, playfulness, emotional engagement, and university support. The International Journal of Management Education, 23(2), Article 101184. https://doi.org/10.1016/j.ijme.2025.101184
9. Vistorte AOR, Deroncele-Acosta A, Ayala JLM, Barrasa A, López-Granero C, Martí-González M. Integrating artificial intelligence to assess emotions in learning environments: a systematic literature review. Front Psychol. 2024 Jun 19;15:1387089. doi: 10.3389/fpsyg.2024.1387089. PMID: 38966729; PMCID: PMC11223560.
10. Hamilton J, Costello M, Barr L, Cooper S, Jones M. Application of generative artificial intelligence by nurse academics in higher education: A scoping review. Nurse Educ Pract. 2026 Jan;90:104669. doi: 10.1016/j.nepr.2025.104669. Epub 2025 Dec 5. PMID: 41353944.
11. Adewale MD, Azeta A, Abayomi-Alli A, Sambo-Magaji A. Impact of artificial intelligence adoption on students' academic performance in open and distance learning: A systematic literature review. Heliyon. 2024 Nov 1;10(22):e40025. doi: 10.1016/j.heliyon.2024.e40025. PMID: 39605813; PMCID: PMC11600083.

12. Zou Y, Kuek F, Feng W and Cheng X (2025) Digital learning in the 21st century: trends, challenges, and innovations in technology integration. Front. Educ. 10:1562391. doi: 10.3389/feduc.2025.1562391
13. Mukul, E., & Büyüközkan, G. (2023). Digital transformation in education: A systematic review of Education 4.0. Technological Forecasting and Social Change, 194, 122664. https://doi.org/10.1016/j.techfore.2023.122664
14. Dritsas E, Trigka M. Methodological and Technological Advancements in E-Learning. Information. 2025; 16(1):56. https://doi.org/10.3390/info16010056
15. Faizan Siddiqui M, Jabeen S, Alwazzan A, Vacca S, Dalal L, Al-Haddad B, Jaber A, Ballout FF, Abou Zeid HK, Haydamous J, El Hajj Chehade R, Kalmatov R. Integration of Augmented Reality, Virtual Reality, and Extended Reality in Healthcare and Medical Education: A Glimpse into the Emerging Horizon in LMICs-A Systematic Review. J Med Educ Curric Dev. 2025 May 29;12:23821205251342315. doi: 10.1177/23821205251342315. PMID: 40452894; PMCID: PMC12123137.
16. Vergara D, Lampropoulos G, Antón-Sancho Á, Fernández-Arias P. Impact of Artificial Intelligence on Learning Management Systems: A Bibliometric Review. Multimodal Technologies and Interaction. 2024; 8(9):75. https://doi.org/10.3390/mti8090075
17. Matos, T., Santos, W., Zdravevski, E., Coelho, P. J., Pires, I. M., & Madeira, F. (2025). A systematic review of artificial intelligence applications in education: Emerging trends and challenges. Decision Analytics Journal, 15, 100571. https://doi.org/10.1016/j.dajour.2025.100571
18. Istenič, A. Blended learning in higher education: the integrated and distributed model and a thematic analysis. Discov Educ 3, 165 (2024). https://doi.org/10.1007/s44217-024-00239-y
19. Gudoniene D, Staneviciene E, Huet I, Dickel J, Dieng D, Degroote J, Rocio V, Butkiene R, Casanova D. Hybrid Teaching and Learning in Higher Education: A Systematic Literature Review. Sustainability. 2025; 17(2):756. https://doi.org/10.3390/su17020756
20. Wang X, Liu J, Jia S, Hou C, Jiao R, Yan Y, Ma T, Zhang Y, Liu Y, Wen H, Wang YF, Zhu H, Liu XY. Hybrid teaching after COVID-19: advantages, challenges and optimization strategies. BMC Med Educ. 2024 Jul 12;24(1):753. doi: 10.1186/s12909-024-05745-z. PMID: 38997704; PMCID: PMC11241882.
21. Li KC, Wong BTM, Kwan R, Chan HT, Wu MMF, Cheung SKS. Evaluation of Hybrid Learning and Teaching Practices: The Perspective of Academics. Sustainability. 2023; 15(8):6780. https://doi.org/10.3390/su15086780
22. Arfat, Y., Shahid, M. K., Al-Tayyar, R. S., Mahmood, K., & Alghamdi, A. (2025). Building inclusive learning environment through hybrid learning system: Role of technology and corresponding engagement. Sustainable Futures, 10, 100887. https://doi.org/10.1016/j.sftr.2025.100887
23. Sanders CK, Scanlon E. The Digital Divide Is a Human Rights Issue: Advancing Social Inclusion Through Social Work Advocacy. J Hum Rights Soc Work. 2021;6(2):130-143. doi: 10.1007/s41134-020-00147-9. PMID: 33758780; PMCID: PMC7973804.
24. Shah, S., Mahboob, U., Junaid, S.M. et al. Challenges faced by teachers of postgraduate health professions blended learning programs: a qualitative analysis. BMC Med Educ 24, 251 (2024). https://doi.org/10.1186/s12909-024-05213-8
25. Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. Sustainable Operations and Computers, 3, 275–285. https://doi.org/10.1016/j.susoc.2022.05.004
26. Lin H, Chen Q. Artificial intelligence (AI) -integrated educational applications and college students' creativity and academic emotions: students and teachers' perceptions and attitudes. BMC Psychol. 2024 Sep 16;12(1):487. doi: 10.1186/s40359-024-01979-0. PMID: 39285268; PMCID: PMC11403842.
27. Shahzad MF, Xu S, Lim WM, Yang X, Khan QR. Artificial intelligence and social media on academic performance and mental well-being: Student perceptions of positive impact in the age of smart learning. Heliyon. 2024 Apr 15;10(8):e29523. doi: 10.1016/j.heliyon.2024.e29523. PMID: 38665566; PMCID: PMC11043955.
28. Zhang J, Lin T, Shi Y, Wu Y, Yu F. A comprehensive perspective of the innovation and reflection on virtual reality in the teaching and learning of anesthesiology. Front Med (Lausanne). 2025 Nov 26;12:1626292. doi: 10.3389/fmed.2025.1626292. PMID: 41384126; PMCID: PMC12689290.
29. Burke, D., Crompton, H. & Nickel, C. The Use of Extended Reality (XR) in Higher Education: A Systematic Review. TechTrends 69, 998–1011 (2025). https://doi.org/10.1007/s11528-025-01092-y
30. Stracke, C.M., Bothe, P., Adler, S. et al. Immersive virtual reality in higher education: a systematic review of the scientific literature. Virtual Reality 29, 64 (2025). https://doi.org/10.1007/s10055-025-01136-x
31. Mittal, K., & Srivastava, S. (2025). Hybrid learning in higher education system: A new frontier in pedagogical innovation. International Journal of Humanities and Education Research, 7(2), 138–142. https://doi.org/10.33545/26649799.2025.v7.i2b.248
32. Schuetze, H. G., de Vries, W., & Álvarez Mendiola, G. (2024). Digitalization of higher education: An introduction. Journal of Comparative & International Higher Education, 16(2), 6–12. https://doi.org/10.32674/jcihe.v16i2
33. Khadidos, A.O., Manoharan, H., Khadidos, A.O. et al. Personalized learning in hybrid education. Sci Rep 15, 18176 (2025). https://doi.org/10.1038/s41598-025-03361-5
34. Nazyrova, A., Miłosz, M., Bekmanova, G., Omarbekova, A., Aimicheva, G., & Kadyr, Y. (2025). The Digital Transformation of Higher Education in the Context of an AI-Driven Future. Sustainability, 17(22), 9927. https://doi.org/10.3390/su17229927
35. Luo, J., Zheng, C., Yin, J. et al. Design and assessment of AI-based learning tools in higher education: a systematic review. Int J Educ Technol High Educ 22, 42 (2025). https://doi.org/10.1186/s41239-025-00540-225

36. Rodrigues, B., Pinto, R., & Gonçalves, G. (2025). A systematic literature review of AI-driven intelligent tutoring systems in engineering education: Emphasizing personalization, feedback, and student monitoring. IEEE Access, 13, 190152–190177. https://doi.org/10.1109/ACCESS.2025.3626473
37. Wang, S., Wang, F., Zhu, Z., Wang, J., Tran, T., & Du, Z. (2024). Artificial intelligence in education: A systematic literature review. Expert Systems with Applications, 252, 124167. https://doi.org/10.1016/j.eswa.2024.124167
38. Gusenbauer M, Haddaway NR. Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources. Res Synth Methods. 2020 Mar;11(2):181-217. doi: 10.1002/jrsm.1378. Epub 2020 Jan 28. PMID: 31614060; PMCID: PMC7079055.
39. Marín, Y.R., Caro, O.C., Rituay, A.M.C. et al. Ethical Challenges Associated with the Use of Artificial Intelligence in University Education. J Acad Ethics 23, 2443–2467 (2025). https://doi.org/10.1007/s10805-025-09660-w
40. Zawacki-Richter, O., Bai, J.Y.H., Lee, K. et al. New advances in artificial intelligence applications in higher education?. Int J Educ Technol High Educ 21, 32 (2024). https://doi.org/10.1186/s41239-024-00464-3
41. Li, S., Zeng, C., Liu, H. et al. A meta-analysis of AI-enabled personalized STEM education in schools. IJ STEM Ed 12, 58 (2025). https://doi.org/10.1186/s40594-025-00566-y
42. Du, X., Du, M., Zhou, Z. et al. Facilitator or hindrance? The impact of AI on university students' higher-order thinking skills in complex problem solving. Int J Educ Technol High Educ 22, 39 (2025). https://doi.org/10.1186/s41239-025-00534-0
43. Labadze, L., Grigolia, M. & Machaidze, L. Role of AI chatbots in education: systematic literature review. Int J Educ Technol High Educ 20, 56 (2023). https://doi.org/10.1186/s41239-023-00426-1
44. Timotheou S, Miliou O, Dimitriadis Y, Sobrino SV, Giannoutsou N, Cachia R, Monés AM, Ioannou A. Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. Educ Inf Technol (Dordr). 2023;28(6):6695-6726. doi: 10.1007/s10639-022-11431-8. Epub 2022 Nov 21. PMID: 36465416; PMCID: PMC9684747.
45. Crompton, H., Burke, D. Artificial intelligence in higher education: the state of the field. Int J Educ Technol High Educ 20, 22 (2023). https://doi.org/10.1186/s41239-023-00392-8
46. AlDhaen, F. (2022). The Use of Artificial Intelligence in Higher Education – Systematic Review. In: Alaali, M. (eds) COVID-19 Challenges to University Information Technology Governance. Springer, Cham. https://doi.org/10.1007/978-3-031-13351-0_13
47. Du Plooy, E., Casteleijn, D., & Franzsen, D. (2024). Personalized adaptive learning in higher education: A scoping review of key characteristics and impact on academic performance and engagement. Heliyon, 10(21), e39630. https://doi.org/10.1016/j.heliyon.2024.e39630
48. Itani, A., Gronseth, S.L., Musaad, S. et al. Ethical considerations for teaching with artificial intelligence: a scoping review in medical education settings. Int J Educ Technol High Educ 22, 68 (2025). https://doi.org/10.1186/s41239-025-00563-9
49. Garzón J, Patiño E, Marulanda C. Systematic Review of Artificial Intelligence in Education: Trends, Benefits, and Challenges. Multimodal Technologies and Interaction. 2025; 9(8):84. https://doi.org/10.3390/mti9080084
50. Hariyanto, Kristianingsih, F.X.D. & Maharani, R. Artificial intelligence in adaptive education: a systematic review of techniques for personalized learning. Discov Educ 4, 458 (2025). https://doi.org/10.1007/s44217-025-00908-6
51. Tan, L. Y., Hu, S., Yeo, D. J., & Cheong, K. H. (2025). Artificial intelligence-enabled adaptive learning platforms: A review. Computers and Education: Artificial Intelligence, 9, 100429. https://doi.org/10.1016/j.caeai.2025.100429
52. Guan, R., Raković, M., Chen, G. et al. How educational chatbots support self-regulated learning? A systematic review of the literature. Educ Inf Technol 30, 4493–4518 (2025). https://doi.org/10.1007/s10639-024-12881-y
53. Qadir, H.M., Suleman, M.T., Khan, R.A. et al. Optimizing learning outcomes: a deep dive into hybrid AI models for adaptive educational feedback. J Big Data 12, 144 (2025). https://doi.org/10.1186/s40537-025-01187-6
54. Lin, CC., Huang, A.Y.Q. & Lu, O.H.T. Artificial intelligence in intelligent tutoring systems toward sustainable education: a systematic review. Smart Learn. Environ. 10, 41 (2023). https://doi.org/10.1186/s40561-023-00260-y
55. Schmidt, D. A., Alboloushi, B., Thomas, A., & Magalhaes, R. (2025). Integrating artificial intelligence in higher education: Perceptions, challenges, and strategies for academic innovation. Computers and Education Open, 9, 100274. https://doi.org/10.1016/j.caeo.2025.100274
56. Usher, M. (2025). Generative AI vs. instructor vs. peer assessments: a comparison of grading and feedback in higher education. Assessment & Evaluation in Higher Education, 50(6), 912–927. https://doi.org/10.1080/02602938.2025.2487495
57. Usher, M. (2025). Generative AI vs. instructor vs. peer assessments: a comparison of grading and feedback in higher education. Assessment & Evaluation in Higher Education, 50(6), 912–927. https://doi.org/10.1080/02602938.2025.2487495
58. Palanci, A., Yılmaz, R.M. & Turan, Z. Learning analytics in distance education: A systematic review study. Educ Inf Technol 29, 22629–22650 (2024). https://doi.org/10.1007/s10639-024-12737-5
59. Zhou M, Peng S. The Usage of AI in Teaching and Students' Creativity: The Mediating Role of Learning Engagement and the Moderating Role of AI Literacy. Behav Sci (Basel). 2025 Apr 27;15(5):587. doi: 10.3390/bs15050587. PMID: 40426365; PMCID: PMC12109026.

60. Mohamed, A.M., Shaaban, T.S., Bakry, S.H. et al. Empowering the Faculty of Education Students: Applying AI's Potential for Motivating and Enhancing Learning. Innov High Educ 50, 587–609 (2025). https://doi.org/10.1007/s10755-024-09747-z
61. Mahafdah R, Bouallegue S, Bouallegue R. Enhancing e-learning through AI: advanced techniques for optimizing student performance. PeerJ Comput Sci. 2024 Dec 23;10:e2576. doi: 10.7717/peerj-cs.2576. PMID: 39896364; PMCID: PMC11784796.
62. Idowu, J. A., Koshiyama, A. S., & Treleaven, P. (2024). Investigating algorithmic bias in student progress monitoring. Computers and Education: Artificial Intelligence, 7, 100267. https://doi.org/10.1016/j.caeai.2024.100267
63. Tan, X., Cheng, G., & Ling, M. H. (2025). Artificial intelligence in teaching and teacher professional development: A systematic review. Computers and Education: Artificial Intelligence, 8, 100355. https://doi.org/10.1016/j.caeai.2024.100355
64. Renta-Davids, A.-I., Camarero-Figuerola, M., & Camacho, M. (2025). Navigating the challenges and opportunities of artificial intelligence in educational leadership: A scoping review. Review of Education, 13(2), e70101. https://doi.org/10.1002/rev3.70101
65. Gligorea I, Cioca M, Oancea R, Gorski A-T, Gorski H, Tudorache P. Adaptive Learning Using Artificial Intelligence in e-Learning: A Literature Review. Education Sciences. 2023; 13(12):1216. https://doi.org/10.3390/educsci13121216
66. Rincon-Flores, E.G., Castano, L., Guerrero Solis, S.L. et al. Improving the learning-teaching process through adaptive learning strategy. Smart Learn. Environ. 11, 27 (2024). https://doi.org/10.1186/s40561-024-00314-9
67. Sharma, S., Mittal, P., Kumar, M. et al. The role of large language models in personalized learning: a systematic review of educational impact. Discov Sustain 6, 243 (2025). https://doi.org/10.1007/s43621-025-01094-z
68. Sayeed Salih, S., Husain, O., Hamdan, M., Abdelsalam, S., Elshafie, H., & Motwakel, A. (2025). Transforming education with AI: A systematic review of ChatGPT's role in learning, academic practices, and institutional adoption. Results in Engineering, 25, Article 103837. https://doi.org/10.1016/j.rineng.2024.103837
69. Roy, P., Pandit, R., & Naskar, S. K. (2026). AI in education: Transforming learning and enhancing student well-being. In S. Mahajan, D. S. Kapoor, & K. J. Singh (Eds.), Intelligent systems for neurocognition and human-robot-computer interaction (pp. 183–201). Academic Press. https://doi.org/10.1016/B978-0-443-41660-6.00002-8
70. Konstantinidou, A., Nisiforou, E. A., & Vrasidas, C. (2026). Enhancing personalized learning with Artificial Intelligence and analytics: university staff's insights. Interactive Learning Environments, 1–21. https://doi.org/10.1080/10494820.2026.2619907
71. Alfredo, R., Echeverria, V., Jin, Y., Yan, L., Swiecki, Z., Gašević, D., & Martinez-Maldonado, R. (2024). Human-centred learning analytics and AI in education: A systematic literature review. Computers and Education: Artificial Intelligence, 6, Article 100215. https://doi.org/10.1016/j.caeai.2024.100215
72. Sakr, A., & Abdullah, T. (2024). Virtual, augmented reality and learning analytics impact on learners, and educators: A systematic review. Education and Information Technologies, 29, 19913–19962. https://doi.org/10.1007/s10639-024-12602-5
73. Li, G., Luo, H., Chen, D., Wang, P., Yin, X., & Zhang, J. (2025). Augmented Reality in Higher Education: A Systematic Review and Meta-Analysis of the Literature from 2000 to 2023. Education Sciences, 15(6), 678. https://doi.org/10.3390/educsci15060678
74. Al-Zahrani, A.M., Alasmari, T.M. Exploring the impact of artificial intelligence on higher education: The dynamics of ethical, social, and educational implications. Humanit Soc Sci Commun 11, 912 (2024). https://doi.org/10.1057/s41599-024-03432-4
75. Stöhr, C., Ou, A. W., & Malmström, H. (2024). Perceptions and usage of AI chatbots among students in higher education across genders, academic levels and fields of study. Computers and Education: Artificial Intelligence, 7, 100259. https://doi.org/10.1016/j.caeai.2024.100259
76. Zainuddin Z. Integrating ease of use and affordable gamification-based instruction into a remote learning environment. Asia Pac Educ Rev. 2023 Feb 22:1–12. doi: 10.1007/s12564-023-09832-6. Epub ahead of print. PMCID: PMC9946286.
77. Cortés-Pérez I, Zagalaz-Anula N, López-Ruiz MDC, Díaz-Fernández Á, Obrero-Gaitán E, Osuna-Pérez MC. Study Based on Gamification of Tests through Kahoot!™ and Reward Game Cards as an Innovative Tool in Physiotherapy Students: A Preliminary Study. Healthcare (Basel). 2023 Feb 15;11(4):578. doi: 10.3390/healthcare11040578. PMID: 36833112; PMCID: PMC9957048.
78. Sichterman, B., Noroozi, O., Boetje, J., van Ginkel, S., Khosravi, H., & Versendaal, J. (2025). Supporting peer learning with artificial intelligence: A systematic literature review. Innovations in Education and Teaching International, 62(5), 1648–1664. https://doi.org/10.1080/14703297.2025.2530118
79. Hassan B, Raza MO, Siddiqi Y, Wasiq MF, Siddiqui RA. CONNECT: An AI-Powered Solution for Student Authentication and Engagement in Cross-Cultural Digital Learning Environments. Computers. 2025; 14(3):77. https://doi.org/10.3390/computers14030077
80. Villegas-Ch, W., Buenano-Fernandez, D., Navarro, A.M. et al. Adaptive intelligent tutoring systems for STEM education: analysis of the learning impact and effectiveness of personalized feedback. Smart Learn. Environ. 12, 41 (2025). https://doi.org/10.1186/s40561-025-00389-y
81. Kittredge AK, Hopman EWM, Reuveni B, Dionne D, Freeman C and Jiang X (2025) Mobile language app learners' self-efficacy increases after using generative AI. Front. Educ. 10:1499497. doi: 10.3389/feduc.2025.1499497

82. Settles, B., LaFlair, G. T., & Hagiwara, M. (2020). Machine learning–driven language assessment. Transactions of the Association for Computational Linguistics, 8, 247–263. https://doi.org/10.1162/tacl_a_00310
83. Lechuga, C. G., Matayoshi, J., & Doroudi, S. (2025). Looking Beyond a Single Score: Examining Student Mathematical Strengths Using ALEKS Data. Educational Assessment, 30(3), 219–247. https://doi.org/10.1080/10627197.2025.2485928
84. Yang, J., Shi, G., Zhu, W., et al. (2025). Intelligent technologies in smart education: A comprehensive review of transformative pillars and their impact on teaching and learning methods. Humanities and Social Sciences Communications, 12, 1239. https://doi.org/10.1057/s41599-025-05444-0
85. Saqr RR, Al-Somali SA, Sarhan MY. Exploring the Acceptance and User Satisfaction of AI-Driven e-Learning Platforms (Blackboard, Moodle, Edmodo, Coursera and edX): An Integrated Technology Model. Sustainability. 2024; 16(1):204. https://doi.org/10.3390/su16010204
86. Celik, I., Dindar, M., Muukkonen, H. et al. The Promises and Challenges of Artificial Intelligence for Teachers: a Systematic Review of Research. TechTrends 66, 616–630 (2022). https://doi.org/10.1007/s11528-022-00715-y
87. Heine, S., & König, J. (2025). Applying artificial intelligence in teacher education: preservice teachers' attitudes and reflections in using ChatGPT for teaching and learning. European Journal of Teacher Education, 48(5), 934–963. https://doi.org/10.1080/02619768.2025.2540791
88. Kalniņa D, Nīmante D and Baranova S (2024) Artificial intelligence for higher education: benefits and challenges for pre-service teachers. Front. Educ. 9:1501819. doi: 10.3389/feduc.2024.1501819
89. Bernardo, B. M. V., Mamede, H. S., Barroso, J. M. P., & dos Santos, V. M. P. D. (2024). Data governance & quality management—Innovation and breakthroughs across different fields. Journal of Innovation & Knowledge, 9(4), Article 100598. https://doi.org/10.1016/j.jik.2024.100598
90. Verano-Tacoronte, D., Bolívar-Cruz, A. & Sosa-Cabrera, S. Are university teachers ready for generative artificial intelligence? Unpacking faculty anxiety in the ChatGPT era. Educ Inf Technol 30, 20495–20522 (2025). https://doi.org/10.1007/s10639-025-13585-7
91. Hazzan-Bishara, A., Kol, O. & Levy, S. The factors affecting teachers' adoption of AI technologies: A unified model of external and internal determinants. Educ Inf Technol 30, 15043–15069 (2025). https://doi.org/10.1007/s10639-025-13393-z
92. Oncioiu I, Bularca AR. Artificial Intelligence Governance in Higher Education: The Role of Knowledge-Based Strategies in Fostering Legal Awareness and Ethical Artificial Intelligence Literacy. Societies. 2025; 15(6):144. https://doi.org/10.3390/soc15060144
93. Batool, A., Zowghi, D. & Bano, M. AI governance: a systematic literature review. AI Ethics 5, 3265–3279 (2025). https://doi.org/10.1007/s43681-024-00653-w
94. Al-kfairy M, Mustafa D, Kshetri N, Insiew M, Alfandi O. Ethical Challenges and Solutions of Generative AI: An Interdisciplinary Perspective. Informatics. 2024; 11(3):58. https://doi.org/10.3390/informatics11030058
95. Tolentino R, Baradaran A, Gore G, Pluye P, Abbasgholizadeh-Rahimi S. Curriculum Frameworks and Educational Programs in AI for Medical Students, Residents, and Practicing Physicians: Scoping Review. JMIR Med Educ. 2024 Jul 18;10:e54793. doi: 10.2196/54793. PMID: 39023999; PMCID: PMC11294785.
96. Baker, R.S., Hawn, A. Algorithmic Bias in Education. Int J Artif Intell Educ 32, 1052–1092 (2022). https://doi.org/10.1007/s40593-021-00285-9
97. Mazurova E, Standaert W, Penttinen E, Tan FTC. Paradoxical Tensions Related to AI-Powered Evaluation Systems in Competitive Sports. Inf Syst Front. 2022;24(3):897-922. doi: 10.1007/s10796-021-10215-8. Epub 2021 Nov 29. PMID: 34867076; PMCID: PMC8628033.
98. Memarian, B., & Doleck, T. (2023). Fairness, accountability, transparency, and ethics (FATE) in artificial intelligence (AI) and higher education: A systematic review. Computers and Education: Artificial Intelligence, 5, Article 100152. https://doi.org/10.1016/j.caeai.2023.100152
99. Zhai, C., Wibowo, S. & Li, L.D. The effects of over-reliance on AI dialogue systems on students' cognitive abilities: a systematic review. Smart Learn. Environ. 11, 28 (2024). https://doi.org/10.1186/s40561-024-00316-7
100. Chan, C.K.Y. A comprehensive AI policy education framework for university teaching and learning. Int J Educ Technol High Educ 20, 38 (2023). https://doi.org/10.1186/s41239-023-00408-3
101. Nguyen A, Ngo HN, Hong Y, Dang B, Nguyen BT. Ethical principles for artificial intelligence in education. Educ Inf Technol (Dordr). 2023;28(4):4221-4241. doi: 10.1007/s10639-022-11316-w. Epub 2022 Oct 13. PMID: 36254344; PMCID: PMC9558020.
102. Ifenthaler, D., Majumdar, R., Gorissen, P. et al. Artificial Intelligence in Education: Implications for Policymakers, Researchers, and Practitioners. Tech Know Learn 29, 1693–1710 (2024). https://doi.org/10.1007/s10758-024-09747-0
103. Papagiannidis, E., Mikalef, P., & Conboy, K. (2025). Responsible artificial intelligence governance: A review and research framework. The Journal of Strategic Information Systems, 34(2), Article 101885. https://doi.org/10.1016/j.jsis.2024.101885
104. Shahzad, M.F., Xu, S. & Zahid, H. Exploring the impact of generative AI-based technologies on learning performance through self-efficacy, fairness & ethics, creativity, and trust in higher education. Educ Inf Technol 30, 3691–3716 (2025). https://doi.org/10.1007/s10639-024-12949-9
105. Manganello F, Nico A, Boccuzzi G. Theoretical Foundations for Governing AI-Based Learning Outcome Assessment in High-Risk Educational Contexts. Information. 2025; 16(9):814. https://doi.org/10.3390/info16090814

106. Sposato, M. Artificial intelligence in educational leadership: a comprehensive taxonomy and future directions. Int J Educ Technol High Educ 22, 20 (2025). https://doi.org/10.1186/s41239-025-00517-1
107. An Q, Yang J, Xu X, Zhang Y, Zhang H. Decoding AI ethics from Users' lens in education: A systematic review. Heliyon. 2024 Oct 12;10(20):e39357. doi: 10.1016/j.heliyon.2024.e39357. PMID: 39640624; PMCID: PMC11620203.
108. Nguyen, A., Ngo, H.N., Hong, Y. et al. Ethical principles for artificial intelligence in education. Educ Inf Technol 28, 4221–4241 (2023). https://doi.org/10.1007/s10639-022-11316-w
109. Tzirides, A. O. (Olnancy), Zapata, G., Kastania, N. P., Saini, A. K., Castro, V., Ismael, S. A., You, Y.-L., Santos, T. A., Searsmith, D., O'Brien, C., Cope, W., & Kalantzis, M. (2024). Combining human and artificial intelligence for enhanced AI literacy in higher education. Computers and Education Open, 6, Article 100184. https://doi.org/10.1016/j.caeo.2024.100184
110. Kalantzis, M., & Cope, B. (2025). Literacy in the time of artificial intelligence. Reading Research Quarterly, 60(1), e591. https://doi.org/10.1002/rrq.591
111. Khairullah SA, Harris S, Hadi HJ, Sandhu RA, Ahmad N and Alshara MA (2025) Implementing artificial intelligence in academic and administrative processes through responsible strategic leadership in the higher education institutions. Front. Educ. 10:1548104. doi: 10.3389/feduc.2025.1548104
112. Renick, T. M. (2023). Predictive analytics, artificial intelligence and the impact of delivering personalized supports to students from underserved backgrounds. In P. D. Moskal, C. D. Dziuban, & A. G. Picciano (Eds.), Data analytics and adaptive learning: Research perspectives (pp. 1–14). Routledge, New York. https://doi.org/10.4324/9781003244271
113. Strielkowski, W., Grebennikova, V., Lisovskiy, A., Rakhimova, G., & Vasileva, T. (2025). AI-driven adaptive learning for sustainable educational transformation. Sustainable Development, 33(2), 1921–1947. https://doi.org/10.1002/sd.3221
114. Kooli C. Chatbots in Education and Research: A Critical Examination of Ethical Implications and Solutions. Sustainability. 2023; 15(7):5614. https://doi.org/10.3390/su15075614
115. Xu, Y., Liu, X., Cao, X., Huang, C., Liu, E., Qian, S., Liu, X., Wu, Y., Dong, F., Qiu, C.-W., Qiu, J., Hua, K., Su, W., Wu, J., Xu, H., Han, Y., Fu, C., Yin, Z., Liu, M., Roepman, R., Dietmann, S., Virta, M., Kengara, F., Zhang, Z., Zhang, L., Zhao, T., Dai, J., Yang, J., Lan, L., Luo, M., Liu, Z., An, T., Zhang, B., He, X., Cong, S., Liu, X., Zhang, W., Lewis, J. P., Tiedje, J. M., Wang, Q., An, Z., Wang, F., Zhang, L., Huang, T., Lu, C., Cai, Z., Wang, F., & Zhang, J. (2021). Artificial intelligence: A powerful paradigm for scientific research. The Innovation, 2(4), 100179. https://doi.org/10.1016/j.xinn.2021.100179
116. Matz, S.C., Bukow, C.S., Peters, H. et al. Using machine learning to predict student retention from socio-demographic characteristics and app-based engagement metrics. Sci Rep 13, 5705 (2023). https://doi.org/10.1038/s41598-023-32484-w
117. Gill, S. S., Xu, M., Patros, P., Wu, H., Kaur, R., Kaur, K., Fuller, S., Singh, M., Arora, P., Parlikad, A. K., Stankovski, V., Abraham, A., Ghosh, S. K., Lutfiyya, H., Kanhere, S. S., Bahsoon, R., Rana, O., Dustdar, S., Sakellariou, R., … Buyya, R. (2024). Transformative effects of ChatGPT on modern education: Emerging era of AI chatbots. Internet of Things and Cyber-Physical Systems, 4, 19–23. https://doi.org/10.1016/j.iotcps.2023.06.002
118. Mustafa, M.Y., Tlili, A., Lampropoulos, G. et al. A systematic review of literature reviews on artificial intelligence in education (AIED): a roadmap to a future research agenda. Smart Learn. Environ. 11, 59 (2024). https://doi.org/10.1186/s40561-024-00350-5
119. Halkiopoulos C, Gkintoni E. Leveraging AI in E-Learning: Personalized Learning and Adaptive Assessment through Cognitive Neuropsychology—A Systematic Analysis. Electronics. 2024; 13(18):3762. https://doi.org/10.3390/electronics13183762
120. Gayed, J. M. (2025). Educators' perspective on artificial intelligence: equity, preparedness, and development. Cogent Education, 12(1), 1-21. https://doi.org/10.1080/2331186X.2024.2447169
121. Zhang H, Cao J. From digital disruption to mental health: the impact of AI-induced educational anxiety on teacher well-being in the era of smart education. BMC Public Health. 2025 Nov 17;25(1):4010. doi: 10.1186/s12889-025-25372-7. PMID: 41250007; PMCID: PMC12625245.
122. Samala, A.D., Rawas, S., Rahmadika, S. et al. Virtual reality in education: global trends, challenges, and impacts—game changer or passing trend?. Discov Educ 4, 229 (2025). https://doi.org/10.1007/s44217-025-00650-z
123. Lampropoulos G. Combining Artificial Intelligence with Augmented Reality and Virtual Reality in Education: Current Trends and Future Perspectives. Multimodal Technologies and Interaction. 2025; 9(2):11. https://doi.org/10.3390/mti9020011
124. Bekteshi, L. (2025). Education in the era of AI and immersive technologies – A systematic review. Journal of Research in Engineering and Computer Sciences, 3(1), 1–14. https://doi.org/10.63002/jrecs.31.779
125. Chaudhry MA, Kazim E. Artificial Intelligence in Education (AIEd): a high-level academic and industry note 2021. AI Ethics. 2022;2(1):157-165. doi: 10.1007/s43681-021-00074-z. PMID: 34790953; PMCID: PMC8261391.
126. Atchley P, Pannell H, Wofford K, Hopkins M, Atchley RA. Human and AI collaboration in the higher education environment: opportunities and concerns. Cogn Res Princ Implic. 2024 Apr 8;9(1):20. doi: 10.1186/s41235-024-00547-9. PMID: 38589710; PMCID: PMC11001814.
127. Chen Y (2025) Evaluation of the impact of AI-driven personalized learning platform on medical students' learning performance. Front. Med. 12:1610012. doi: 10.3389/fmed.2025.1610012
128. Vieriu, A. M., & Petrea, G. (2025). The Impact of Artificial Intelligence (AI) on Students' Academic Development. Education Sciences, 15(3), 343. https://doi.org/10.3390/educsci15030343

129. Létourneau A, Deslandes Martineau M, Charland P, Karran JA, Boasen J, Léger PM. A systematic review of AI-driven intelligent tutoring systems (ITS) in K-12 education. NPJ Sci Learn. 2025 May 14;10(1):29. doi: 10.1038/s41539-025-00320-7. PMID: 40368938; PMCID: PMC12078640.
130. Ali, O., Murray, P. A., Momin, M., Dwivedi, Y. K., & Malik, T. (2024). The effects of artificial intelligence applications in educational settings: Challenges and strategies. Technological Forecasting and Social Change, 199, Article 123076. https://doi.org/10.1016/j.techfore.2023.123076
131. Cotilla Conceição JM, van der Stappen E. The Impact of AI on Inclusivity in Higher Education: A Rapid Review. Education Sciences. 2025; 15(9):1255. https://doi.org/10.3390/educsci15091255
132. Yu T, Tian Y, Huang Q, Cheng Z, Zhang R. Explaining adoption of AI tools in education: a dual-path model of ethical concern and functional value. Front Psychol. 2026 Jan 21;16:1735913. doi: 10.3389/fpsyg.2025.1735913. PMID: 41646889; PMCID: PMC12868169.
133. Romaios A, Sfikas P, Giannadakis A, Panidis T, Paravantis JA, Skouras ED, Mihalakakou G. Artificial Intelligence for Enhancing Indoor Air Quality in Educational Environments: A Review and Future Perspectives. Sustainability. 2025; 17(22):10117. https://doi.org/10.3390/su172210117
134. Lin H, Chen Q. Artificial intelligence (AI) -integrated educational applications and college students' creativity and academic emotions: students and teachers' perceptions and attitudes. BMC Psychol. 2024 Sep 16;12(1):487. doi: 10.1186/s40359-024-01979-0. PMID: 39285268; PMCID: PMC11403842.
135. Huynh, L., Le, T.H., Dang, B. et al. Mindset matters: Fostering teachers' responsible AI use through professional development. J. New Approaches Educ. Res. 14, 23 (2025). https://doi.org/10.1007/s44322-025-00043-y
136. Sperling, K., Stenberg, C.-J., McGrath, C., Åkerfeldt, A., Heintz, F., & Stenliden, L. (2024). In search of artificial intelligence (AI) literacy in teacher education: A scoping review. Computers and Education Open, 6, Article 100169. https://doi.org/10.1016/j.caeo.2024.100169
137. Sat M. The impact of AI integration in project preparation in education course on pre-service teachers' innovativeness, AI anxiety, attitudes, and acceptance. BMC Psychol. 2025 Nov 24;13(1):1297. doi: 10.1186/s40359-025-03647-3. PMID: 41287118; PMCID: PMC12642211.
138. Kazmaci A, Cek K, Altinay F, Altinay Z, Dagli G. Influence of theoretical and practical artificial intelligence knowledge on the primary school teachers' sustainable AI integration ability: mediating effects of beliefs and attitudes. Front Psychol. 2025 Aug 5;16:1628557. doi: 10.3389/fpsyg.2025.1628557. PMID: 40837268; PMCID: PMC12361219.
139. Kohnke, L., Zou, D., Ou, A. W., & Gu, M. M. (2025). Preparing future educators for AI-enhanced classrooms: Insights into AI literacy and integration. Computers and Education: Artificial Intelligence, 8, Article 100398. https://doi.org/10.1016/j.caeai.2025.100398
140. Rahman, A., Khandakar, A., Ayari, M.A. et al. Artificial intelligence innovations challenges and emerging trends in engineering education. Discov Educ 5, 179 (2026). https://doi.org/10.1007/s44217-026-01137-1
141. Kamali, J., Alpat, M.F. & Bozkurt, A. AI ethics as a complex and multifaceted challenge: decoding educators' AI ethics alignment through the lens of activity theory. Int J Educ Technol High Educ 21, 62 (2024). https://doi.org/10.1186/s41239-024-00496-9
142. Younas, M., Ismayil, I., El-Dakhs, D. A. S., & Anwar, B. (2025). Exploring the impact of artificial intelligence in advancing smart learning in education: A meta-analysis with statistical evidence. Open Praxis, 17(3), 594–610. https://doi.org/10.55982/openpraxis.17.3.842
143. Khan, S., Mazhar, T., Shahzad, T. et al. Harnessing AI for sustainable higher education: ethical considerations, operational efficiency, and future directions. Discov Sustain 6, 23 (2025). https://doi.org/10.1007/s43621-025-00809-6
144. Bhutoria, A. (2022). Personalized education and artificial intelligence in the United States, China, and India: A systematic review using a human-in-the-loop model. Computers and Education: Artificial Intelligence, 3, Article 100068. https://doi.org/10.1016/j.caeai.2022.100068
145. Shi J, Liu W, Hu K. Exploring How AI Literacy and Self-Regulated Learning Relate to Student Writing Performance and Well-Being in Generative AI-Supported Higher Education. Behav Sci (Basel). 2025 May 20;15(5):705. doi: 10.3390/bs15050705. PMID: 40426482; PMCID: PMC12108985
146. Koukaras C, Hatzikraniotis E, Mitsiaki M, Koukaras P, Tjortjis C, Stavrinides SG. Revolutionising Educational Management with AI and Wireless Networks: A Framework for Smart Resource Allocation and Decision-Making. Applied Sciences. 2025; 15(10):5293. https://doi.org/10.3390/app15105293
147. Xu X. AI optimization algorithms enhance higher education management and personalized teaching through empirical analysis. Sci Rep. 2025 Mar 24;15(1):10157. doi: 10.1038/s41598-025-94481-5. PMID: 40128297; PMCID: PMC11933401.
148. Doğan, M., Celik, A., & Arslan, H. (2025). AI in higher education: Risks and opportunities from the academician perspective. European Journal of Education, 60(1), e12863. https://doi.org/10.1111/ejed.12863
149. Rao, G. T., & Suhasini, N. (2025). Integrating artificial intelligence in higher education to enhance teaching and learning. Computer Applications in Engineering Education, 33(6), e70085. https://doi.org/10.1002/cae.70085
150. Bayly-Castaneda K, Ramirez-Montoya M-S and Morita-Alexander A (2024) Crafting personalized learning paths with AI for lifelong learning: a systematic literature review. Front. Educ. 9:1424386. doi: 10.3389/feduc.2024.1424386
151. Kamalov F, Santandreu Calonge D, Gurrib I. New Era of Artificial Intelligence in Education: Towards a Sustainable Multifaceted Revolution. Sustainability. 2023; 15(16):12451. https://doi.org/10.3390/su151612451

152. Mhlongo S, Mbatha K, Ramatsetse B, Dlamini R. Challenges, opportunities, and prospects of adopting and using smart digital technologies in learning environments: An iterative review. Heliyon. 2023 May 18;9(6):e16348. doi: 10.1016/j.heliyon.2023.e16348. PMID: 37274691; PMCID: PMC10238696.
153. Zhou T, Colomer J. Cooperative Learning Promoting Cultural Diversity and Individual Accountability: A Systematic Review. Education Sciences. 2024; 14(6):567. https://doi.org/10.3390/educsci14060567
154. Mhlongo, S., Mbatha, K., Ramatsetse, B., & Dlamini, R. (2023). Challenges, opportunities, and prospects of adopting and using smart digital technologies in learning environments: An iterative review. Heliyon, 9(6), e16348. https://doi.org/10.1016/j.heliyon.2023.e16348
155. Piccialli, F., Chiaro, D., Qi, P., Bellandi, V., & Damiani, E. (2025). Federated and edge learning for large language models. Information Fusion, 117, 102840. https://doi.org/10.1016/j.inffus.2024.102840
156. Vidal, J. C., Rabelo, T., Lama, M., & Amorim, R. (2018). Ontology-based approach for the validation and conformance testing of xAPI events. Knowledge-Based Systems, 155, 22–34. https://doi.org/10.1016/j.knosys.2018.04.035
157. Zhang, T., Liu, H., Tao, J., Wang, Y., Yu, M., Chen, H., & Yu, G. (2023). Enhancing dropout prediction in distributed educational data using learning pattern awareness: A federated learning approach. Mathematics, 11(24), 4977. https://doi.org/10.3390/math11244977
158. Bai, Y., Zhao, J., Wei, T. et al. A survey of explainable knowledge tracing. Appl Intell 54, 6483–6514 (2024). https://doi.org/10.1007/s10489-024-05509-8
159. Liu, T. (2022). Knowledge tracing: A bibliometric analysis. Computers and Education: Artificial Intelligence, 3, 100090. https://doi.org/10.1016/j.caeai.2022.100090
160. Zhou, X., Zhang, Z., Xie, X. et al. Deep learning based knowledge tracing in intelligent tutoring systems. Sci Rep 15, 21395 (2025). https://doi.org/10.1038/s41598-025-07422-7
161. Nurpeisova, A., Shaushenova, A., Mutalova, Z., Ongarbayeva, M., Niyazbekova, S., Bekenova, A., Zhumaliyeva, L., & Zhumasseitova, S. (2023). Research on the development of a proctoring system for conducting online exams in Kazakhstan. Computation, 11(6), 120. https://doi.org/10.3390/computation11060120
162. Mukred, M., Mokhtar, U. A., Hawash, B., AlSalman, H., & Zohaib, M. (2024). The adoption and use of learning analytics tools to improve decision making in higher learning institutions: An extension of technology acceptance model. Heliyon, 10(4), e26315. https://doi.org/10.1016/j.heliyon.2024.e26315
163. Verma, N., Bhutani, P., Lalit, R. et al. Map Reduce Framework-Assisted Feature Analysis and Adaptive Multiplicative Bi-RNN Using Big Data Analytics for Decision-Making. Int J Comput Intell Syst 18, 252 (2025). https://doi.org/10.1007/s44196-025-00977-3
164. Wang A, Wu X. Building a triadic model of technology, motivation, and engagement: a mixed-methods study of AI teaching assistants in design theory education. Front Psychol. 2025 Jul 2;16:1624182. doi: 10.3389/fpsyg.2025.1624182. PMID: 40672855; PMCID: PMC12265309.
165. Neufeld A. Putting Self-Determination Theory Into Practice: A Practical Tool for Supporting Medical Learners' Motivation. Clin Teach. 2025 Aug;22(4):e70140. doi: 10.1111/tct.70140. PMID: 40641189; PMCID: PMC12263349.
166. Ma Y and Chen M (2025) The human touch in AI: optimizing language learning through self-determination theory and teacher scaffolding. Front. Psychol. 16:1568239. doi: 10.3389/fpsyg.2025.1568239
167. Tan, L. Y., Hu, S., Yeo, D. J., & Cheong, K. H. (2025). Artificial intelligence-enabled adaptive learning platforms: A review. Computers and Education: Artificial Intelligence, 9, 100429. https://doi.org/10.1016/j.caeai.2025.100429
168. Mahafdah R, Bouallegue S, Bouallegue R. Enhancing e-learning through AI: advanced techniques for optimizing student performance. PeerJ Comput Sci. 2024 Dec 23;10:e2576. doi: 10.7717/peerj-cs.2576. PMID: 39896364; PMCID: PMC11784796.
169. Petridou, E., & Lao, L. (2024). Identifying challenges and best practices for implementing AI additional qualifications in vocational and continuing education: a mixed methods analysis. International Journal of Lifelong Education, 43(4), 385–400. https://doi.org/10.1080/02601370.2024.2351076
170. Zhang, K., & Aslan, A. B. (2021). AI technologies for education: Recent research & future directions. Computers and Education: Artificial Intelligence, 2, Article 100025. https://doi.org/10.1016/j.caeai.2021.100025
171. Ren, X., Wu, M.L. Examining Teaching Competencies and Challenges While Integrating Artificial Intelligence in Higher Education. TechTrends 69, 519–538 (2025). https://doi.org/10.1007/s11528-025-01055-3
172. Shi L, Ding A-C, Choi I. Investigating Teachers' Use of an AI-Enabled System and Their Perceptions of AI Integration in Science Classrooms: A Case Study. Education Sciences. 2024; 14(11):1187. https://doi.org/10.3390/educsci14111187
173. Weidener L, Fischer M. Proposing a Principle-Based Approach for Teaching AI Ethics in Medical Education. JMIR Med Educ. 2024 Feb 9;10:e55368. doi: 10.2196/55368. PMID: 38285931; PMCID: PMC10891487.
174. Hanna, M. G., Pantanowitz, L., Jackson, B., Palmer, O., Visweswaran, S., Pantanowitz, J., Deebajah, M., & Rashidi, H. H. (2025). Ethical and bias considerations in artificial intelligence/machine learning. Modern Pathology, 38(3), 100686. https://doi.org/10.1016/j.modpat.2024.100686
175. Reuben JS, Meiri H, Arien-Zakay H. AI's pivotal impact on redefining stakeholder roles and their interactions in medical education and health care. Front Digit Health. 2024 Nov 5;6:1458811. doi: 10.3389/fdgth.2024.1458811. PMID: 39564581; PMCID: PMC11573760.
176. Knopp MI, Warm EJ, Weber D, Kelleher M, Kinnear B, Schumacher DJ, Santen SA, Mendonça E, Turner L. AI-Enabled Medical Education: Threads of Change, Promising Futures, and Risky Realities Across Four Potential Future Worlds. JMIR Med Educ. 2023 Dec 25;9:e50373. doi: 10.2196/50373. PMID: 38145471; PMCID: PMC10786199.

177. Kinney, M., Anastasiadou, M., Naranjo-Zolotov, M., & Santos, V. (2024). Expectation management in AI: A framework for understanding stakeholder trust and acceptance of artificial intelligence systems. Heliyon, 10(7), e28562. https://doi.org/10.1016/j.heliyon.2024.e28562
178. Khakpaki A. Advancements in artificial intelligence transforming medical education: a comprehensive overview. Med Educ Online. 2025 Dec;30(1):2542807. doi: 10.1080/10872981.2025.2542807. PMID: 40798935; PMCID: PMC12351741.
179. Wang, Y. Artificial intelligence in student management systems to enhance academic performance monitoring and intervention. Sci Rep 15, 35122 (2025). https://doi.org/10.1038/s41598-025-19159-4
180. Chiu, T. K. F. (2024). Future research recommendations for transforming higher education with generative AI. Computers and Education: Artificial Intelligence, 6, 100197. https://doi.org/10.1016/j.caeai.2023.100197
181. Klimova B and Pikhart M (2025) Exploring the effects of artificial intelligence on student and academic well-being in higher education: a mini-review. Front. Psychol. 16:1498132. doi: 10.3389/fpsyg.2025.1498132
182. Xu, S., Khan, K.I. & Shahzad, M.F. Examining the influence of technological self-efficacy, perceived trust, security, and electronic word of mouth on ICT usage in the education sector. Sci Rep 14, 16196 (2024). https://doi.org/10.1038/s41598-024-66689-4
183. Merino-Campos, C. (2025). The impact of artificial intelligence on personalized learning in higher education: A systematic review. Trends in Higher Education, 4(2), 17. https://doi.org/10.3390/higheredu4020017
184. Sriram A, Ramachandran K, Krishnamoorthy S. Artificial Intelligence in Medical Education: Transforming Learning and Practice. Cureus. 2025 Mar 19;17(3):e80852. doi: 10.7759/cureus.80852. PMID: 40255837; PMCID: PMC12007958.
185. Ahsan Z. Integrating artificial intelligence into medical education: a narrative systematic review of current applications, challenges, and future directions. BMC Med Educ. 2025 Aug 23;25(1):1187. doi: 10.1186/s12909-025-07744-0. PMID: 40849650; PMCID: PMC12374307.
186. Chen, Z. Ethics and discrimination in artificial intelligence-enabled recruitment practices. Humanit Soc Sci Commun 10, 567 (2023). https://doi.org/10.1057/s41599-023-02079-x
187. Deep, P. D., Edgington, W. D., Ghosh, N., & Rahaman, M. S. (2025). Evaluating the effectiveness and ethical implications of AI detection tools in higher education. Information, 16(10), 905. https://doi.org/10.3390/info16100905
188. Riahi, I., Battikh, W. & Khanchel, H. Exploring the impact of smart learning technologies on student engagement, e-trust, and satisfaction in higher education institutions: the moderating role of ethical perceptions. J. New Approaches Educ. Res. 14, 21 (2025). https://doi.org/10.1007/s44322-025-00039-8
189. Yan, Z., Qianjun, T. Integrating AI-generated content tools in higher education: a comparative analysis of interdisciplinary learning outcomes. Sci Rep 15, 25802 (2025). https://doi.org/10.1038/s41598-025-10941-y
190. Arango-Vasquez, L. (2026). Education in the Digital Age: Ethical and Inclusive Information Technologies. In: Rocha, A., Adeli, H., Poniszewska-Marańda, A., Moreira, F., Bianchi, I. (eds) Emerging Trends in Information Systems and Technologies. WorldCIST 2025. Lecture Notes in Networks and Systems, vol 1578. Springer, Cham. https://doi.org/10.1007/978-3-032-00701-8_4
191. Sahar, R., Munawaroh, M. Artificial intelligence in higher education with bibliometric and content analysis for future research agenda. Discov Sustain 6, 401 (2025). https://doi.org/10.1007/s43621-025-01086-z
192. Yuan Y, Fu J, Leng L, Wen Z, Wei X, Han D, Hu X, Liang Y, Luo Q, Zhang X, Hu R. The strengths, weaknesses, opportunities, and threats of generative artificial intelligence: a qualitative study of undergraduate nursing students. Front Public Health. 2025 Sep 4;13:1672140. doi: 10.3389/fpubh.2025.1672140. PMID: 40977793; PMCID: PMC12443828.
193. Schmidt, D. A., Alboloushi, B., Thomas, A., & Magalhaes, R. (2025). Integrating artificial intelligence in higher education: Perceptions, challenges, and strategies for academic innovation. Computers and Education Open, 9, 100274. https://doi.org/10.1016/j.caeo.2025.100274
194. Song, Y., Weisberg, L. R., Zhang, S., Tian, X., Boyer, K. E., & Israel, M. (2024). A framework for inclusive AI learning design for diverse learners. Computers and Education: Artificial Intelligence, 6, 100212. https://doi.org/10.1016/j.caeai.2024.100212
195. Lin, Z., Guan, S., Zhang, W. et al. Towards trustworthy LLMs: a review on debiasing and dehallucinating in large language models. Artif Intell Rev 57, 243 (2024). https://doi.org/10.1007/s10462-024-10896-y
196. Chen, Y., Huang, C., Gao, S., Lyu, Y., Chen, X., Liu, S., Bao, D., & Lv, C. (2025). A multimodal deep learning approach for legal English learning in intelligent educational systems. Sensors, 25(11), 3397. https://doi.org/10.3390/s25113397
197. Bala, A., Rashid, R.Z.J.A., Ismail, I. et al. Artificial intelligence and edge computing for machine maintenance-review. Artif Intell Rev 57, 119 (2024). https://doi.org/10.1007/s10462-024-10748-9
198. Wang, T., Guo, J., Zhang, B., Yang, G., & Li, D. (2025). Deploying AI on edge: Advancement and challenges in edge intelligence. Mathematics, 13(11), 1878. https://doi.org/10.3390/math13111878
199. Abbass, W., Abbas, N., Javed, M. et al. Secure and adaptive authentication in fog-assisted smart homes using personalized federated learning. J Supercomput 81, 1570 (2025). https://doi.org/10.1007/s11227-025-08055-3
200. Shahin, M., Hosseinzadeh, A., & Chen, F. F. (2025). A two-stage hybrid federated learning framework for privacy-preserving IoT anomaly detection and classification. IoT, 6(3), 48. https://doi.org/10.3390/iot6030048
201. Martínez-Martínez, A., Gómez-Cambronero, Á., Montoliu, R., & Remolar, I. (2025). Towards the Adoption of Recommender Systems in Online Education: A Framework and Implementation. Big Data and Cognitive Computing, 9(10), 259. https://doi.org/10.3390/bdcc9100259

202. Villegas-Ch, W., Gutierrez, R., García-Ortiz, J. et al. Explainable educational assistant integrated in Moodle: automated semantic assessment and adaptive tutoring based on NLP and XAI. Discov Artif Intell 5, 191 (2025). https://doi.org/10.1007/s44163-025-00438-y
203. Ma H, You Q, Jin Z, Liu X and Chen Z (2025) Exploring the role of generative AI in international students' sociocultural adaptation: a cognitive-affective model. Front. Artif. Intell. 8:1615113. doi: 10.3389/frai.2025.1615113
204. Gkintoni E, Antonopoulou H, Sortwell A, Halkiopoulos C. Challenging Cognitive Load Theory: The Role of Educational Neuroscience and Artificial Intelligence in Redefining Learning Efficacy. Brain Sci. 2025 Feb 15;15(2):203. doi: 10.3390/brainsci15020203. PMID: 40002535; PMCID: PMC11852728.
205. Adams MCB, Clauw DJ. Open data sharing: what could possibly go wrong? Pain. 2025 Nov 1;166(11):2487-2489. doi: 10.1097/j.pain.0000000000003696. PMID: 40623226; PMCID: PMC12413199.
206. Hamzah, H. A., Abu Seman, M. S., & Ahmed, M. (2025). The impact of artificial intelligence in enhancing online learning platform effectiveness in higher education. Information Development, 41(3), 794-810. https://doi.org/10.1177/02666669251315842