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Original Article

Navigating the Impediments and Challenges of Integrating Artificial Intelligence Technologies within the Framework of Education 4.0: A Systematic Review

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Abstract *- Implementation of Fourth Industrial Revolution (4IR) techniques are needed for long-term sustainability and automation in the Industrial and education sector processes. Rapid advancement in information technology and other engineering technologies demands more proactive steps in education institutes. In the post-pandemic world, there is an increasing demand for changes in teaching and learning methodologies with the support of modern digital technologies. So, all teaching institutes need to make significant changes in learning and teaching. The impact of 4 IR is more critical on the education sector than the previous generation's industrial revolution. Keeping track of essential technologies can be challenging as they evolve quickly. The fourth Industrial Revolution is the current technological digital revolution in which the primary focus is on cyber-physical and biological systems such as Artificial Intelligence, Robotics, the Internet of Things, and Virtual Reality, etc. educators and institutions should establish pedagogies and teaching with the aid of Industry 4.0 techniques to evolve education 4.0. So, it is essential to understand the challenges and competencies required for implementing 4IR by the faculty members and students currently studying in Higher Education Institutes (HEIs). This paper aims to systematically review industry 4.0 techniques and their application to online learning and teaching, pedagogies change, data management enhancement in HEIs, digital and virtual laboratories, etc. This work explores various fields in education 4.0 and the challenges involved in the implementation and execution of HEIs. This study contributes a systematic overview of digital technology application in HEIs based on existing literature, current trends, and research gaps and accordingly gives the future direction of education 4.0.*

Keywords *- Industry 4.0, Education 4.0, Artificial Intelligence, Robotics, Virtual reality, Blockchain technology, Gamification, Digital laboratories.*

1. Introduction

Industrial revolutions are evolving due to trade development, increasing demand, society's requirements, and the requirement to enhance business. The first Industrial Revolution began in the 18th century in Britain and then spread worldwide. The first industrial revolution started in about 1760 and extended up to 1830. The first industrial revolution was the transition from manual production to mechanization. The first industrial revolution mainly focused on steam power, machine tools using iron technology, and the requirements raised in the mechanization of the factory system. The first industrial revolution was the primary one, which changed textile technology, iron technology, chemicals, cement production, paper production, agriculture, mining, and transportation. The Second Industrial Revolution began in the 19th century due to inventions in electricity, electrical machines, and the development of assembly line production. Henry Ford (1863-1947) took the idea of mass production and carried it over to the automobile production field because of the advantages of faster production and lower cost.

The primary source of this revolution was the development of a production system using electrical energy as a primary power source. Many advantages like efficiency, ease of operation, automation, faster production, and electrical machines led to the second Industrial Revolution from 1870 to 1914.

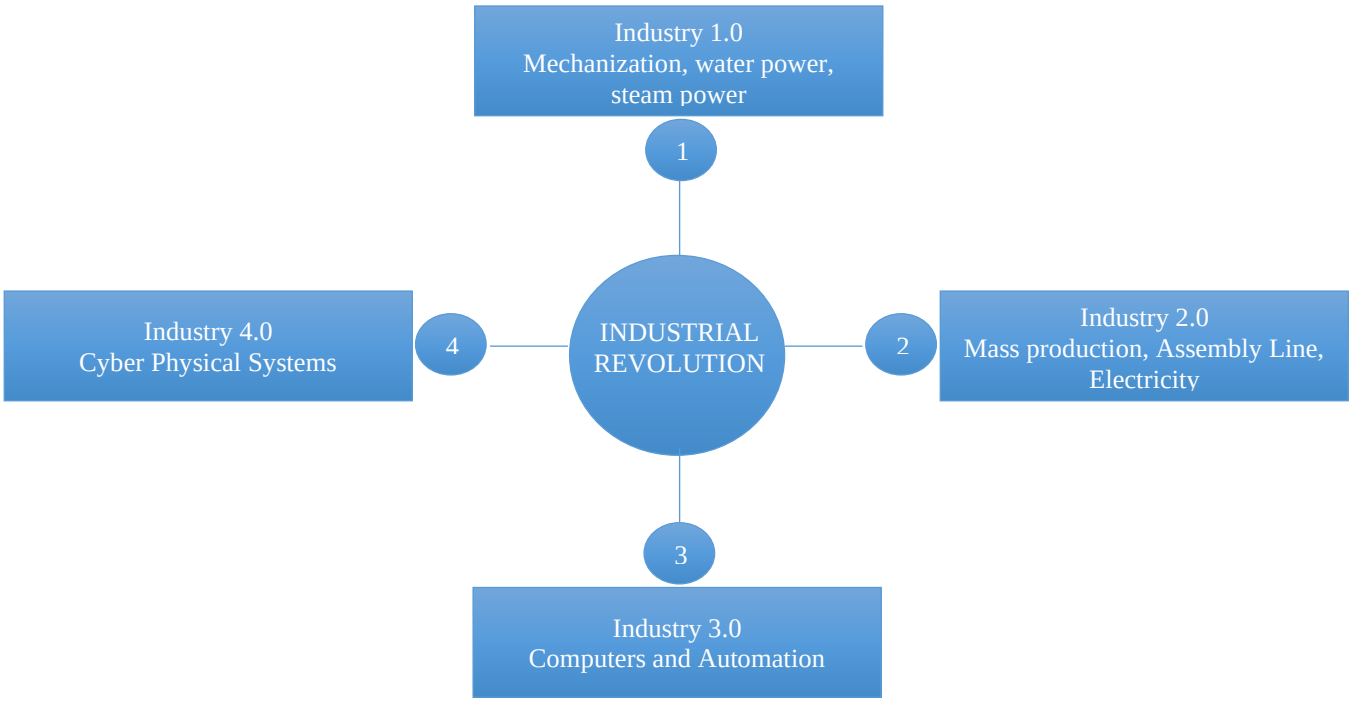

Fig. 1 History of industrial revolution (Latnovic and Sikman, L 2022) [1]

The Third Industrial Revolution began in the mid-20th century because of silicon technology's development in memory-programmable controls and computers. The fast development of computers started many changes in high-precision technology in many fields. In Industry 3.0, electronics and computers played a vital role, mainly in the addition of networking technologies. The development of software technology and the internet in early 2000 in Industry 3.0 opened a path for Industry 4.0 and revolutionized many management processes in the industrial sector.

Industry 4.0 is based on the concept of a smart factory, where the machines are integrated with men through Cyber-Physical Systems (CPS). CPS is the integration of IT systems with mechanical and electronic components connected to online networks that allow communication between machines similar to social networks. These innovative technologies enable factories to become "smart," producing customized products on an industrial scale while providing many opportunities for operational flexibility and efficiency improvements. Digitalization is the most crucial element in Industry 4.0 because it connects man and technology. The central theme of the industrial revolution is given in Figure 1. Education is undergoing vast changes due to the upcoming Industrial Revolution –Industry 4.0. Engineers must possess the hard and soft skills to operate within the intelligent factory [2]. Only in this way will it be possible to implement the new Industry 4.0 practices properly and to make technological advances for companies and the whole society [3]. Industry 4.0 is an initiative to change culture, education, economy, and trade significantly. The study made by the authors (Oztemel, E. and Gursev, S., 2020) focuses on various aspects of Industry 4.0, such as big data, IoT, virtual manufacturing, intelligent robotics, and cloud computing. It emphasizes the importance of a sustainable economy, innovative manufacturing, and cloud computing in achieving Industry 4.0 goals. The study also highlights the benefits and drawbacks of Industry 4.0, the need for a taxonomy of Industry 4.0, and areas for further research. There were 250 companies involved in the study [4].

Like the Industrial Revolution, education evolved from Education 1.0 to Education 4.0. The education 1.0 framework focuses on transforming information from teacher to student; the student receives information passively. Education 2.0 responds to education related to the needs of the industrial society with the concept of "teaching technology." The education 3.0 framework aims to solve the needs of the developing technology society. It promotes the production of knowledge by supporting self-learning. Education 4.0 is beyond the traditional education system. Education 4.0 supports individuals in keeping up with the innovative age.

Education 4.0 helps students improve themselves to face societal changes and encourages them to develop the applicability of modern technologies [5]. The use of 4IR technologies combined with contemporary learning and teaching methodologies, such as gamification, online teaching, virtual labs, and blended learning, has been identified as a trending research topic within the education sector. [6]. The Industry 4.0 technologies and the systematic implementation in HEIs are shown in Figure 2. This paper aims to do systematic review synthesizing research about how technology dominates learning, teaching styles, and administrative systems in education institutes.

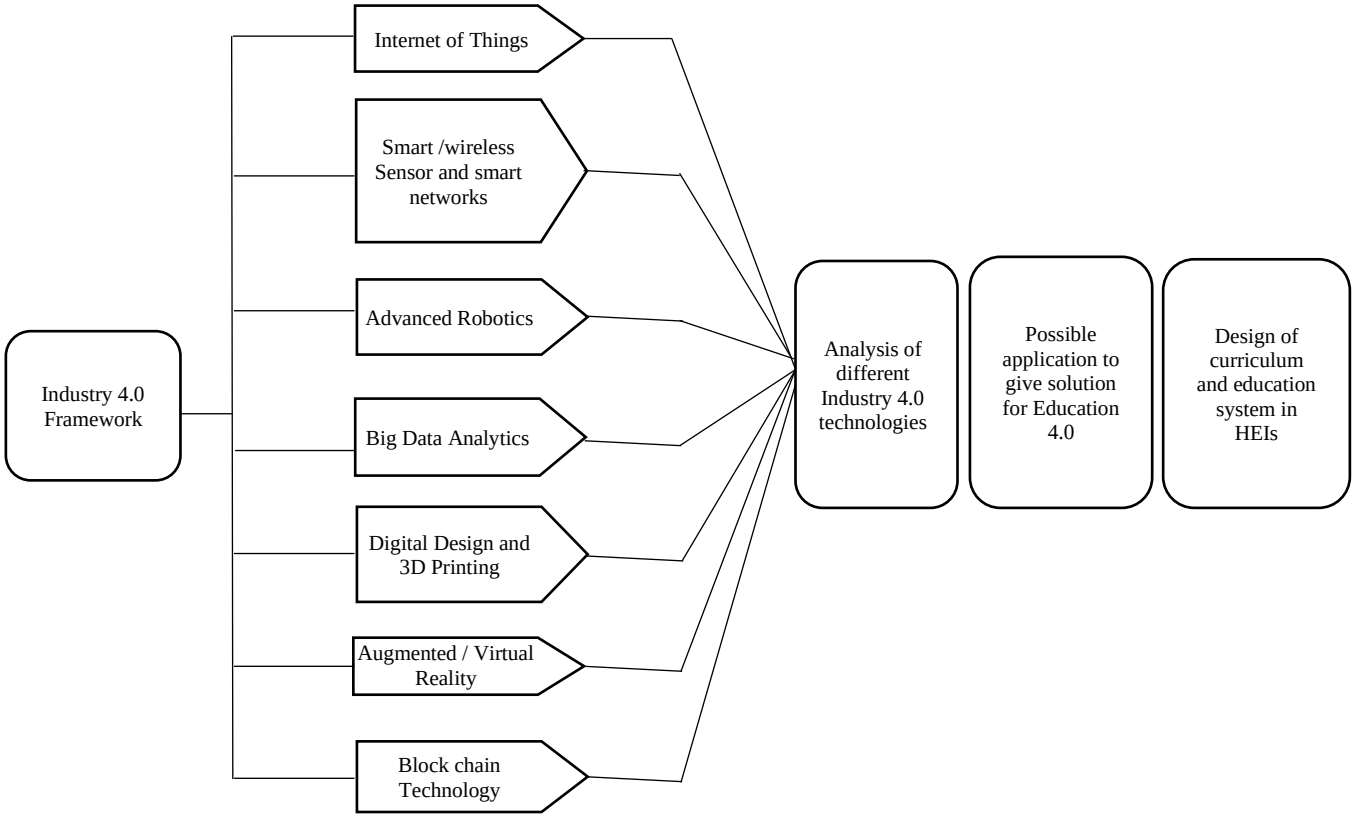

Fig. 2 Application of Digital Technologies in the Fourth Industrial Revolution to Education 4.0

In this study, we strive to bridge the gap and contribute to analyzing existing literature encompassing all research about learning analytics and industry 4.0 technologies. This paper investigates the characteristics and findings of technology applications, research methods, and their analysis, performance prediction, and learning analytics in the automation of education 4.0. The novelty of the paper is that it investigates all of the Industry 4.0 techniques applied in education 4.0, which was not done in a single paper by previous researchers.

2. Problem Background

The automation of the education process includes interconnectivity between processes, the use of technologies, data transparency, and autonomous learning to boost the quality of learning and teaching. The advancement of digital technologies forced universities to undergo a significant phase change in learning and education, which is highly challenging and requires more competencies than the previous generation's industrial revolution [7]. Learning critical technologies before learning the core content from the faculty and students is challenging as they keep growing/changing rapidly. The fourth industrial revolution refers to this era wherein new technological breakthroughs will cause disruptions in several industries. It will be marked by robotics, Artificial Intelligence (AI), and blockchain, among other technologies. Dr. Hilal Al Hanaei - Secretary General of The Research Council, Sultanate of Oman (TRC), added that "ability to cope with the rapid automation and it is required to prepare our students (Oman) with the competitive skills to cope up 4IR in the global labor market in years to come". (Source: Times News service: https://timesofoman.com/article/59068-oman-ready-for-fourth-industrial-revolution-trc) [8].

In the future, students and faculty will never be done with their educations within the universities and colleges. Instead, they must constantly engage with their colleagues and outside experts to renew and update their skills [9]. More proactive and creative forms of faculty development will also be required to enable faculty to maintain expertise based on the latest discoveries and technologies. The 4IR campus must become a constantly renewing collaborative hub of activity to keep itself within the fast-paced environment of the future [10]. Laptinovic, T and Sikman, L described that virtual joint laboratory for advanced technology (VALIP) and its feasible solution in university teaching is highly challenging [1]. They explored the challenges faced by the University of Banja Luka, Bosnia, Faculty of Mechanical Engineering while implementing digital laboratories. Reza Ghaney Gheshlagh discussed the challenges of online education from the perspective of the University of Medical Sciences students in Iran, which resulted in the following challenges:

1. Inadequacy for practical learning
2. Inadequacy of internet and web services

3. Barriers related to educational content
4. Interaction between teacher and student [11].

Caratozzolo, P et al. explained Problem-Based Learning (PBL) and Challenge-Based Learning (CBL) approaches, which are essential requirements for adapting the curriculum to meet the labor market requirements [12]. Al-Ghamdi et al. addressed the cyberattacks in HEIs due to poor IT infrastructures. Their study designs a novel search and rescue optimization with a deep learning-based learning authentication technique for cyber security in higher education institutions. They have proposed a deep learning-based fingerprint identification technique called SRODL-LAC to avoid cyberattacks in accessing university materials [13].

Overall, we can say that numerous challenges are there in implementing modern technologies, which is taken as the main objective of this paper and analyzed using various outstanding publications. After reviewing numerous articles, we have selected 118 papers relevant to the paper's aim and objective. Among this, we categorized according to the different themes and extracted the core work the researchers explored. Figure 3 shows the paper's numbers, which are topics that we have referred to in this review work.

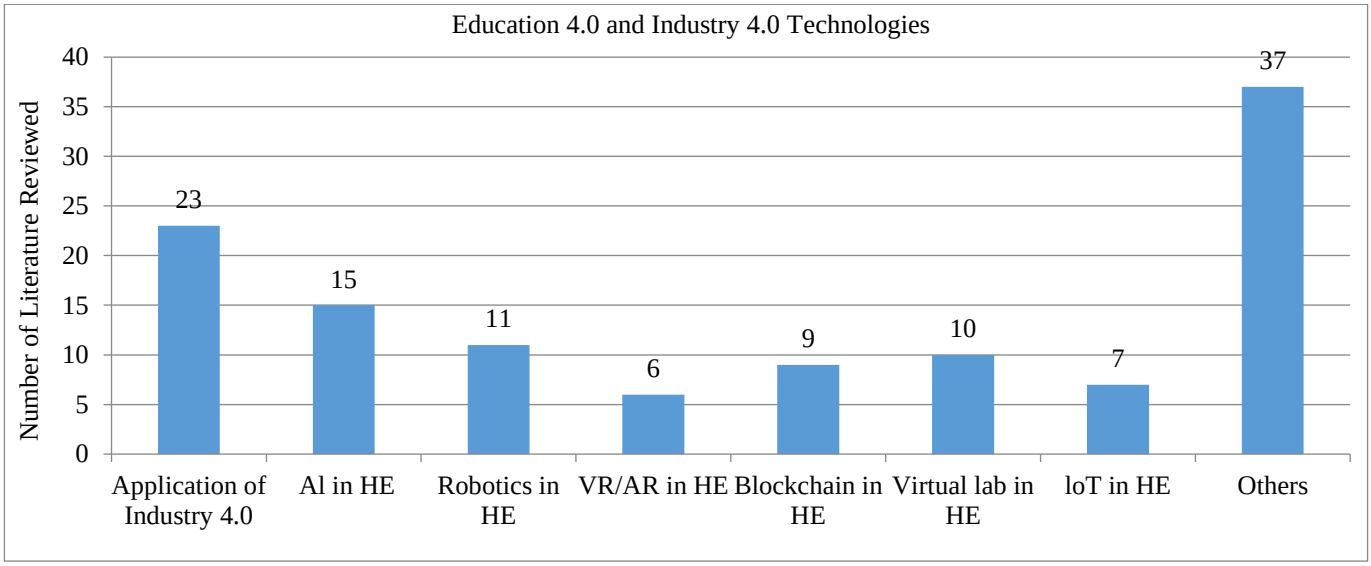

Fig. 3 Filtered literature for the automation of Education 4.0 using Industry 4.0 Technologies

3. Literature Review

Digital technology in Education 4.0 becomes a more realistic and practical approach to personalized learning for problem-solving, innovation, creativity, and collaboration. This is the future trend in the education system to enhance the quality of HEIs and students' knowledge. Figure 4 shows the central perspective of Education 4.0, which shows its main characteristics [14]. Yuefan Xia et al. presented in their paper the challenges faced in learning before COVID-19 during COVID-19, and the changes in students' relationships with others in online education. The research gap in this paper is the sample size, which is small. The study reveals that the level of agreement should be between students and staff to improve online teaching and learning experience [15]. As per Wheatley and Greer, technology-based learning saves time when many students are in a teaching session. They analyzed the time conflict and concluded that online platforms would solve the issues in time management and teach more students three decades ago [16]. Emad Mushtaha et al. discussed the challenges and opportunities of online learning and teaching at engineering and theoretical colleges during the pandemic. He conducted a study with 1713 participants at the University of Sharjah, and 77.2% of users gave positive feedback about flexibility in place and time. However, the authors concluded that the sudden implementation of online mode had implications for users, including mental health, which is a negative part of the study. The authors recommended Hybrid-flexible (Hyflex), which is more effective for the university to apply based on the nature of the courses [17].

Akturk, C., Talan, T and Cerasi, C.C explored the requirement for a super bright society (society 5.0) from education 4.0 and university 4.0 using industry 4.0 techniques. The digital transformation experienced in the world and Turkey was stated in this work [18]. Anshari, M., Almunawar, M.N., and Razzaq, A. discussed talent management by the universities to face Industry 4.0. A qualitative method was deployed in this paper to extract primary data from educators' perspectives on talent management through Education 4.0. He added that talent management is an essential aspect of HEIs to satisfy the industrial needs of modern industries [19]. Bakker, M.N. and Axmann, M. explained the meaning of learning analysis in Industry 4.0 and education. The application of AI and related areas in education has been explored in this book chapter [20].

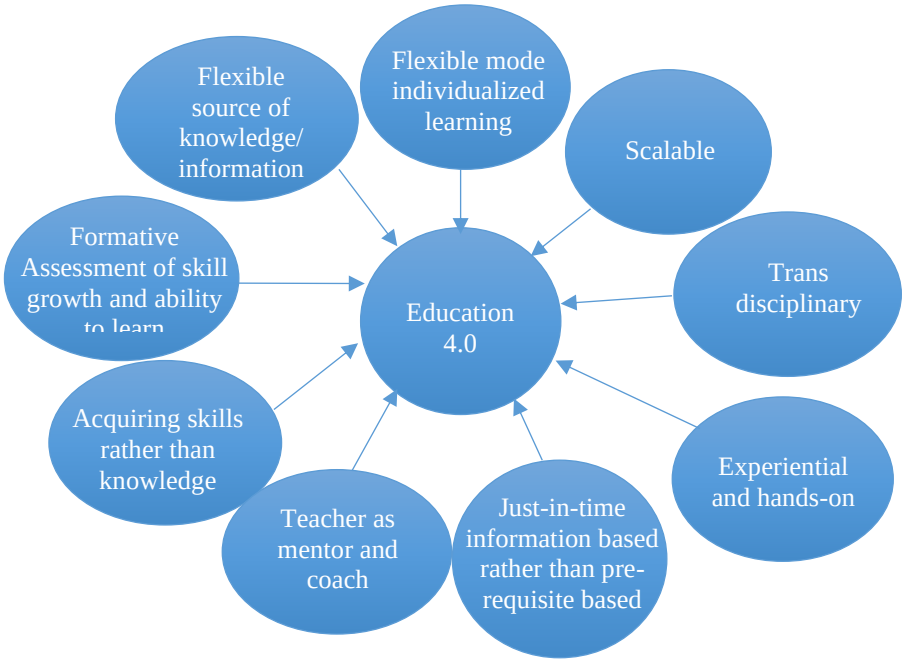

Fig. 4 Perspective of education 4.0 (Das, Shuvra & Kleinke, Darrell & Pistrui, David, 2020) [14]

Caratozzolo, P. and Alvarez-Delgado, A. have given an education 4.0 framework to enrich active learning using virtual and AI tools to enhance the quality of the education sector. This paper explains the importance of AI in future education systems to improve curriculum and learning experience [21]. Chen Z et al. proposed a student performance analysis using a Hybridized Deep Neural Network (HDNN), which can be used to monitor, predict, and evaluate the student's performance with more accuracy in an education 4.0 environment [22]. Ivanciu and Sipos concluded in their paper that electronic devices and circuit labs can transform to online or hybrid-based learning using industry 4.0 techniques to transform education 4.0 [23]. The impact of Industry 4.0 techniques in education has not only proven its advantages in engineering education, but it has also proved in learning other subjects. Laurent, A. and Fabiano, B. discussed a critical perspective on the impact of Industry 4.0 techniques in developing professional safety management skills in safety education [24]. Similarly, Mourtzis, D. published a paper discussing the development of skills and competencies in manufacturing towards education 4.0: a teaching factory approach [25]. Mourtzis, D et al. presented how adopting cyber-physical systems and industry 4.0 technologies under the teaching factory paradigm will reshape manufacturing education, addressing the requirement for highly skilled employees [26].

Jedaman P. et al. discussed the change in education plans and the challenges they pose in Thailand. They discussed transition, dynamics, strategic management, and strategic leadership to reform the policies in Thailand [27]. Moraes, E.B et al. addressed integrating industry 4.0 techniques with education 4.0 and analyzed the advantages of innovative teaching and the improvements in learning [28]. Saragih et al. discussed blended learning in executing education 4.0 using digital technologies. This paper examined the different technologies that can be integrated into university learning and teaching and its challenges and opportunities [29]. As per Toma, M.V., and Turcu, C.E, "By 2025, two billion people will be part of Gen Alpha who will get the most significant access to modern technologies. This paper proposes a solution supporting technology integration in regular textbooks. Connecting learning materials with the technologies can lead to a better understanding and involvement in the classroom [30]. Verma, A. and Singh, A. have done a systematic review in their work to discuss the new era of technology in education 4.0 and the trends and future directions [31].

Education 4.0 helps develop competencies for reasoning for complexity. Ramírez-Montoya et al. analyzed complex thinking as a significant competency with critical, systematic, scientific, and innovative thinking as part of it in the education environment by reviewing 35 articles. Education 4.0 provides an opportunity to improve training practices that build these competencies. It also impacts education research through various study methods, including quantitative and mixed methods, for higher insights [32]. Silva, D.E. et al. investigated and identified initiatives in Education 4.0 and Industry 4.0 to promote the advancement in education, with 78 articles reviewed. The results revealed that the number of searches on this topic has risen in recent years due to increasing interest. The study also says that the initiatives that promote Education 4.0 are seeking the student's protagonism,

incentivizing active learning, proposing practical activities, developing 21st-century skills, and enabling experience with advanced computing resources and processes [33]. Similarly, many notable and latest publications deal with the review of the latest trends in education 4.0. The authors of this paper collected many review papers from the digital library and then filtered them according to the theme of this paper based on qualitative and quantitative analysis, which are presented in Table 1. Table 1 shows the direct and allied review papers of Industry 4.0, in which we can understand that numerous researchers are working on applying modern technologies to change the HEI's current system. The following section will detail the technologies that can be applied in education 4.0, their important phases, and HEIs' challenges.

Table 1. Review papers related to the application of industry 4.0 in HEIs

No	Author	Year	Title	Journal / Conference	Theme
1	Alex Sander Clemente de Souza, Luciana Debs, [6]	2024	Concepts, innovative technologies, learning approaches and trend topics in education 4.0: A scoping literature review	Social Sciences & Humanities Open	Education 4.0 - Review paper
2	Butt, R., Siddiqui, H., Soomro, R.A. and Asad, M.M. [34]	2020	Integration of Industrial Revolution 4.0 and IOTs in academia: a state-of-the-art review on the concept of education 4.0 in Pakistan [Review]",	Interactive Technology and Smart Education	Education 4.0 - Review paper
3	González-Pérez, L.I. and Ramírez-Montoya, M.S.[35]	2022	Components of Education 4.0 in 21st-century skills frameworks: a systematic review.	Sustainability, MDPI	Education 4.0 - Review paper
4	Hariharasudan, A. and Kot, S., 2018[36]	2018	A scoping review on Digital English and Education 4.0 for Industry 4.0	Social Sciences, MDPI	Digital English and Education 4.0 - Review paper
5	Huk, T. [37]	2021	From education 1.0 to education 4.0 – challenges for the contemporary school	The New Educational Review	Education 1.0 to Education 4.0 – review and analysis
6	Krstikj, A., Sosa Godina, J., García Bañuelos, L., González Peña, O.I., Quintero Milián, H.N., Urbina Coronado, P.D. and Vanoye García, A.Y. [38]	2022	Analysis of competency assessment of educational innovation in upper secondary school and higher education: a mapping review	Sustainability, MDPI	Competency assessment – mapping review
7	Lai, J.W.M. and Bower, M. [39]	2020	Evaluation of technology use in education: findings from a critical analysis of systematic literature reviews	Journal of Computer Assisted Learning	Use of technology in education- Review and analysis - Review paper
8	Liu, C., Zowghi, D., Kearney, M. and Bano, M. [40]	2021	Inquiry-based mobile learning in secondary school science education: a systematic review	Journal of Computer Assisted Learning	Mobile learning – Review paper
9	Müller F, Denk A, Lubaway E, Sälzer C, Kozina A, Perše TV, et al. [41]	2020	We are assessing social, emotional, and intercultural competencies of students and school staff: A systematic literature review.	Educational Research Review, Elsevier	Competency analysis of students - Review paper
10	Parmaxi, A. and Demetriou, A.A. [42]	2020	Augmented reality in language learning: a state-of-the-art review of 2014–2019."	Journal of Computer Assisted Learning	Augmented reality in learning - Review paper
11	Qureshi, M.I., Khan, N., Raza, H., Imran, A. and Ismail, F.[43]	2021	Digital technologies in education 4.0. Does it enhance the effectiveness of learning? A systematic literature review	International Journal of Interactive Mobile Technologies	Digital technologies in Education 4.0 - Review paper

12	Ramírez-Montoya, M.S., Castillo-Martínez, I.M., Sanabria-Z, J. and Miranda, J. [32]	2022	Complex thinking in the framework of Education 4.0 and Open Innovation-A systematic literature review	Journal of Open Innovation: Technology	Framework of Education 4.0- Review paper
13	Silva, D.E., Lopes, T., Sobrinho, M.C. and Valentim, N.M.C., 2021. [33]		Investigating initiatives to promote the advancement of education 4.0: A systematic mapping study.	13th International Conference on Computer-Supported Education (CSEDU 2021)	Advancement of education 4.0 – Review and mapping study
14	Verma, A. and Singh, A. [31]	2021	A new era of technology-empowered education: education 4.0 a systematic review.	9th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO)	Education 4.0 - Review paper
15	Costan,E.;Gonzales, G.; Gonzales, R.;Enriquez,L.;Costan, F.; Suladay, D.; Atibing,N.M.;Aro,J.L.;Evangelista,S.S.; Maturan, F.; et al [44]	2021	Education 4.0 in Developing Economies: A Systematic Literature Review of Implementation Barriers and Future Research Agenda.	Sustainability, MDPI	Education 4.0 in economy development - Review paper
16	Arnold, M.G.; Vogel, A.; Ulber, M. [45]	2021	Digitalizing Higher Education in Light of Sustainability and Rebound Effects-Surveys in Times of the COVID-19 Pandemic.	Sustainability, MDPI	Digitizing Higher Education
17	Chiu, W.K. [46]	2021	Pedagogy of Emerging Technologies in Chemical Education during the Digitalization and Artificial Intelligence Era: A Systematic Review.	Education Sciences, MDPI	AI in education - Review paper
18	Tselegkaridis, S.; Sapounidis, T. [47]	2021	Simulators in Educational Robotics: A Review. Educ. Sci.	Education Science, MDPI	Education robots – Review paper
19	López-Chila, R.; Llerena-Izquierdo, J.; Sumba-Nacipucha, N.; Cueva-Estrada, J. [48]	2024	Artificial Intelligence in Higher Education: An Analysis of Existing Bibliometrics.	Education Science, MDPI	AI in higher education – Review paper
20	Thurzo, A.; Strunga, M.; Urban, R.; Surovková, J.; Afrashtehfar, K.I. [49]	2023	Impact of Artificial Intelligence on Dental Education: A Review and Guide for Curriculum Update.	Education Science, MDPI	AI in dental education – Review paper
21	Mukul,E Büyüközkan,G, [5]	2023	Digital transformation in education: A systematic review of education 4.0,	Technological Forecasting and Social Change, Elsevier	Education 4.0 – Review Paper

22	Laura Icela, G. P., María Soledad, R. M., & Juan Antonio, E. G. [50]	2023	Education 4.0 Maturity Models for Society 5.0: Systematic literature review.	Cogent Business & Management	Education 4.0 and Society 5.0 – Review Paper
23	Ghobakhloo, M., Iranmanesh, M., Tseng, M. L., Grybauskas, A., Stefanini, A., & Amran, A. [51]	2023	Behind the definition of Industry 5.0: a systematic review of technologies, principles, components, and values.	Journal of Industrial and Production Engineering	Industry 5.0 – Review paper

4. Review of Technologies in Industry 4.0

The rapid development in Internet technologies and telecommunication transformed our lives with more connectivity between people, between machines, and even between men and machines the new technologies changed the industry operations to the physical and the virtual world. Cyber-Physical Systems (CPSs) have further improved numerous rapid technological developments in many fields [52]. CPSs allow machines to communicate more intelligently with each other. Some of the critical technologies involved in Industry 4.0 are as follows.

- Cyber-physical systems
- Big data
- Internet of things
- Artificial intelligence
- Additive manufacturing
- Cloud computing
- Virtual reality
- Robotics
- Blockchain technology

Since introducing these technologies, we can now automate an entire production in industrial processes without human assistance. Similarly, these technologies are having an impact in all fields, including in the education field [53]. Known examples of this are robots that perform programmed sequences without human intervention, which is possible in learning and teaching. AI-driven technologies have already proved their impact on primary-level teaching and higher education teaching [54]. AI-driven devices are used for google search, teaching in primary education, teaching languages, conducting online exams, etc.

4.1. Review of Artificial Intelligence in Online Learning and Teaching

General AI is machine intelligence and the type of adaptable intellect found in humans, a flexible form of intelligence capable of learning how to carry out different tasks in industry and our day-to-day lives. Artificial Intelligence (AI) allows machines to learn from experience, adjust to new inputs, and perform human-like tasks with more intelligence. Artificial intelligence was coined in 1956. Still, AI has become more popular today because of the advanced facilities in increased data volumes, advanced algorithms, and improvements in computing power and storage. Because of the development of neural networks, machine learning, and deep learning, many fields have adopted artificial intelligence to provide unimaginable performance. AI is important because of computerized intelligence automation, adding intelligence to existing products, adapting the progressive learning algorithms to form new structures and regularities, analyzing more and deeper data, and incredible accuracy. Artificial intelligence is giving the most innovative tech inventions in almost all sectors that humans find challenging to achieve. AI also plays a significant role in learning and teaching for education and helps automate many teaching and learning processes to enhance the experience for educators and students. E-learning and online learning hugely influence educational delivery tools, and AI is leading the race. AI helps students receive highly engaging lectures and take part in intuitive aptitude tests so that students can find the best method to address their learning requirements. Recent Artificial Intelligence teaching software can identify areas where students are lacking and focus on that content.

Advanced AI software can generate new problems from the source material. These online systems generate better material and more comprehensive testing methods than typical classroom teaching. Artificial Intelligence (AI) is transforming the landscape of Online Learning and Teaching (L&T) by offering advanced tools and solutions that enhance both the student learning experience and the improvement efficiency of teaching processes [55]. AI-powered systems can personalize the learning journey for each student by analyzing their learning patterns, preferences, and performance data. Through adaptive learning algorithms, AI can provide customized content recommendations, quizzes, and assessments tailored to individual needs, maximizing engagement and knowledge retention [56].

Moreover, AI-driven chatbots / chatGPTs and virtual assistants can offer immediate support to students, answering queries, providing feedback, and guiding them through their learning journey in real-time [57]. On the teaching side, AI can automate administrative tasks such as grading, plagiarism detection, scheduling, and content creation, allowing instructors to focus more on delivering high-quality instruction. Natural Language Processing (NLP) technologies enable AI to analyze and understand text-based interactions, facilitating intelligent tutoring systems that can provide interactive and responsive learning experiences. Additionally, AI-powered data analytics tools can generate insights from large volumes of learner data, helping educators identify

trends, assess learning outcomes, and optimize instructional strategies. Overall, AI holds the potential to transform online learning and teaching by making education more personalized, accessible, and effective for learners and instructors alike. Artificial Intelligence (AI) has revolutionized online Learning and Teaching (L&T) by offering personalized and adaptive educational experiences [58]. Through AI-powered algorithms, online platforms can analyze vast amounts of student data to identify individual learning styles, preferences, and areas of difficulty.

This enables the customization of learning pathways and content delivery to suit each student's needs, enhancing engagement and comprehension [59]. Moreover, AI facilitates the creation of interactive and immersive learning environments through technologies such as Virtual Reality (VR) and Augmented Reality (AR), enabling students to visualize complex concepts and scenarios in a more tangible way [36]. Overall, AI integration in online learning and teaching offers unprecedented opportunities for personalized, efficient, and practical education delivery, transforming how we acquire knowledge and skills in the digital era [60]. This data-driven approach enables educators to tailor instruction and content delivery to meet the unique needs of each student, fostering more engaging and effective learning experiences [61]. Virtual tutors powered by AI can also assist students with personalized learning paths, answering questions and providing additional resources or explanations as needed [62].

Furthermore, AI-enhanced chatbots can offer 24/7 support for students, addressing common queries and concerns instantly. Intelligent tutoring systems utilize AI to deliver personalized feedback and guidance, helping students navigate complex concepts and improve their understanding [63]. Virtual Reality (VR) and Augmented Reality (AR) technologies powered by AI create immersive and interactive learning experiences, enabling learners to explore complex concepts, simulate real-world scenarios, and engage in hands-on training activities [64]. AI-powered platforms can analyze vast amounts of data learners generate, including interactions with course materials, assessment performance, and engagement with online resources, to tailor learning experiences to individual needs [65]. Through machine learning algorithms, these platforms can adapt content delivery in real-time, recommendations, remedial exercises, or additional resources based on each learner's strengths, weaknesses, and learning preferences. AI is helping in many ways in online learning and teaching. Some potential fields in which AI techniques can be applied are listed in Figure 5. The I4Tech laboratory at the Technical University of Catalonia aims to educate students on Industry 4.0 technologies through hands-on practice. The laboratory provides a collaborative learning environment for students to interact with digital technologies in the industrial sector. The laboratory helps students develop their competencies in flexible automation, the Internet of Things, cyber-physical systems, and augmented reality to work in the future industrial sector. [66]

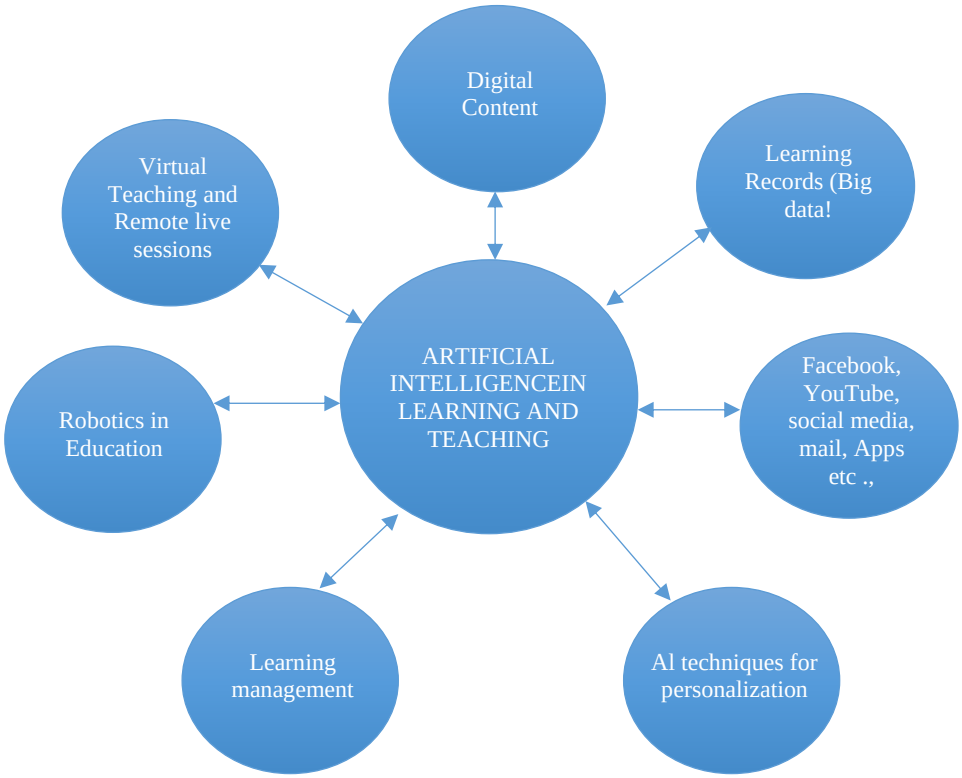

Fig. 5 Artificial intelligence in education systems

4.1.1. Smart Learning Content

AI can create innovative learning content with digitized study materials to help students get customized solutions [67]. Using Artificial Intelligence, the textbook content is changed to many subgroups, like interactive content through audios, practice sessions, feedback-based learning, and also for academic assessment. Also, it is possible to create study materials for intelligent simulations. Innovative learning content can also be used to design a digital course and intelligent content across various devices, including video, audio, Apps, and an online assistant.

4.1.2. Real-time Questioning

Artificial Intelligence can be used as a virtual or online tutor to help students clear their doubts. Students can ask the AI engine; the AI Engine will recognize the question and receive the appropriate answer for the questions raised by the student. Many AI engines are available to learn many topics in the university syllabus. These AI-based engines will bridge the gap in learning and help students create an improved learning environment.

4.1.3. Natural Language Processing

People are trying to learn foreign languages for different reasons and benefits. People take up learning a foreign language because they move to a country to do business, live, work, or study. In multi-lingual education institutions, teachers must learn two or three languages to better connect with the students. Learning languages has many advantages, including social, economic, and mental benefits. However, learning many foreign languages is difficult and time-consuming. With an AI system, it is easy to process natural language. By integrating AI into online learning and teaching, it is possible to interact with the system in the languages of students'/ teachers' choice [68]. The AI engine makes it easy to learn foreign languages without the language teacher's assistance by saving time. Artificial intelligence can be used in natural language processing to facilitate effective communication with learners so that they can learn more quickly in their language. Processing different human languages is becoming a more manageable task with the use of artificial intelligence and other modern technologies. Integrating language processing and online learning content will save time and help efficient learning.

4.1.4. Fresh Learning Content Generation

Online learning course creation is a challenging part requiring several skills. With AI, it is possible to prepare innovative content that can help to combine all the skills needed to deliver a practical online course. This allows trainers or university teachers to focus more on creating an engaging digital learning experience for their learners.

4.1.5. Gamification

Gamification is essential in eLearning or online learning to engage and motivate learners to get more interest and in-depth knowledge. Creating different tactical games for the course content with AI is more accessible than any other software. AI helps to process large amounts of data, which is then used to determine learners' behavior and to provide them with updates about their learning progress. Gamification has more influence on learning mathematics, science, grammar, etc. [69].

4.1.6. Intelligent Tutoring System

Innovative tutoring systems use extensive data from specific learners to give them feedback and work with them directly. While this AI application is still in its infant stage, it will soon be able to work as a full-fledged digital platform that helps learners with their educational needs and problem-solving. Also, these platforms are more flexible and able to adapt to various learning styles to help faculty and learners. The AI system will generate many questions and answers, which may help students get ready for their exams [70].

4.1.7. Challenges in the Implementation of AI in HEIs

In the use of AI in HEIs, there will be a chance of unintended consequences. The reliability of implementing AI may not be accurate from case to case. Akinwalere, S.N. and Ivanov, V.T. pointed out that "AI learning systems in a particular kind of college or university in California may not have the same outcomes for students in another part of the country. They have added challenges in comprehensiveness, accuracy, output, and implementation [71]. AI may reduce the cost of many operations in university processes, which may pose threats to humans, like unemployment, salary cuts, and misunderstandings between employees and employers. This may lead to an unhealthy working environment on university campuses. There may be a chance of conflict in the results obtained from AI-assisted laboratories compared with human-assisted laboratories. In the assessment process, AI-based result prediction may vary from human evaluation, which is a highly challenging job by university exam offices.

Also, there are ethical concerns while adopting AI in higher education to ensure its responsible and equitable use. There are challenges in biased information, privacy in data management, digital literacy, and training for both student and faculty integration of AI in curriculum, etc. Security is another big challenge in AI implementation that needs to be addressed in all HEIs before adopting AI. Sirghi et al. addressed challenges in AI on the learning process in Romanian universities, such as perceived usefulness, attitude towards learning technologies, expected performance, degree of compatibility, and interactivity of the application [72]. So, it can be concluded that there are challenges in accessibility, preparedness of teachers, students, and HEIs, ethical issues, high cost of implementation, technology addition ethical issues, and updating of rapid change in technologies. Table 2 shows the review papers on the application of Artificial Intelligence in HEIs.

Table 2. Review papers related to the application of artificial intelligence in HEIs

No	Author	Year	Title	Journal / Conference	Theme
1	Caratozzolo, P. and Membrillo-Hernández, J., [12]	2021	Challenge-based learning approaches for Education 4.0 in Engineering	In Proceedings of the 2021 SEFI Conference	Education 4.0 in engineering
2	Ciolacu, M., Tehrani, A.F., Binder, L. and Svasta, P.M., [56]	2018	Education 4.0-Artificial Intelligence assisted higher education: early recognition system with machine learning to support students' success.	In 2018 IEEE 24th International Symposium for Design and Technology in Electronic Packaging(SIITME)	AI in higher education
3	Eichinger, P., Hofig, B. and Richter, C [59]	2017	Education 4.0 for mechatronics-agile and smart.	In 2017 International Conference on Research and Education in Mechatronics (REM)	Education 4.0 for Mechatronics
4	Adel, A.; Ahsan, A.; Davison, C. [57]	2024	ChatGPT Promises and Challenges in Education: Computational and Ethical Perspectives.	Education Sciences, MDPI	Challenges of Chatgpt in Education
5	Ahmad, S.F. et al.,[58]	2021	Artificial Intelligence and Its Role in Education	Sustainability, MDPI	AI in education
6	Parmaxi and Demetriou[42]	2020	Augmented reality in language learning: a state-of-the-art review of 2014-2019	Journal of Computer Assisted Learning	AR in education – Review
7	Ellahi, R.M., Ali Khan, M.U. and Shah, A. [60]	201`9	“Redesigning curriculum in line with industry 4.0”,	Procedia Computer Science,	Change of curriculum using Industry 4.0 techniques
8	Hussin, A.A., [61]	2018	Education 4.0 made simple: Ideas for teaching.	International Journal of Education and Literacy Studies	Education 4.0 implementation
9	Hımmetoglu, B., Aydug, D. and Bayrak, C., [62]	2020	Education 4.0: Defining the teacher, the student, and the school manager aspects of the revolution.	Turkish Online Journal of Distance Education.	Education 4.0 for schools
10	Haderer, B. and Ciolacu, M., [63]	2022	Education 4.0: Artificial intelligence assisted task-and time planning system.	Procedia computer science.	AI-based Education 4.0
11	Sonntag, D et al.,[64]	2019	Hybrid learning environments by data-driven augmented reality	Procedia Manufacturing	AR in Education
12	Lye, C.Y. and Lim, L. [65]	2024	Generative Artificial Intelligence in Tertiary Education: Assessment Redesign Principles and Considerations	Education Sciences	AI in Education
13	Zairon, I.Y., Wook, T.S.M.T., Salleh, S.M., Dahlan, H.A. and Rahmat, M., [69]	2021	Analysis of Behaviour and Learning Style on Education 4.0 in Virtual Mentoring using Gamification.	In 2021 International Conference on Electrical Engineering and Informatics (ICEEI)	Analysis of Education 4.0
14	Akinwalere, Susan & Ivanov, Ventsislav. [71]	2022	Artificial Intelligence in Higher Education: Challenges and Opportunities.	Border Crossing.	Challenges of AI in Education

15	Sîrghi, Nicoleta; Voicu, Mirela-Catrinel; Noja, Gratiela Georgiana; Socoliuc, OanaRamona [72]	2024	Challenges of artificial intelligence on the learning process in higher education,	Amfiteatru Economic, The Bucharest University of Economic Studies, Bucharest.	Challenges of AI in Education

5. Review of Robotics in Online Learning and Teaching

Growing technology provides many challenges and opportunities in learning and teaching [73]. Robot technologies are fast-growing technologies that offer a range of possibilities within online education to give various solutions for every student according to their need [74]. Artificial intelligence and the growth of online learning and teaching have opened a system to use school robots to prepare learners for assignments, quizzes, online exams, etc. Engineers are developing various education robots and related information processing to assist students and teachers in practical and improved academic abilities using robots [75]. Many novel robotic competitions are held globally for students within industry 4.0 concepts, including the robots for education 4.0 [76]. Ferreira T et al. discussed the application of robots and their importance in their paper titled “Robot at Factory 4.0: An Auto Referee Proposal based on the Artificial Vision” [77]. So, it is clearly understood that the importance and need of robots in all fields are increasing in the modern world. The need for "smarter" personnel with a more excellent range of competencies to cope with higher-level work opened a path for educational robots. The research world believes now that technology is replacing traditional types of talk-based teaching by teachers, and there was a noticeable increase in speech, language, and thinking problems using robots. Robotic and simulation technologies have proven themselves to be worthy components of available educational resources [78]. These technologies have shown their value in everyday learning and the specialized education of students with disabilities.

In healthcare education, specialized knowledge is the key to understanding the reality of the background and giving special treatment. Many students benefit from using robotics when receiving a healthcare or medical education. A human subject isn't feasible when learning to perform complicated medical procedures, so educators use robots as stand-ins. Robots can be created and programmed to give off all indications of human life, including breath and heartbeat. Robots can be used in procedures like injections, surgeries, and even delivering children. Students with special requirements are reaching new levels of learning through the use of robotics in the classroom. Using robotics technologies, children with autism learn communication and social skills, and students with developmental issues and attention disorders are learning focus. Individuals with severe physical disabilities are also offered a constant companion and health monitoring system - all through the use of robotics. Robots can be programmed to suit each child's needs, offering exceptional education in a more straightforward, accessible format [79].

5.1 Major Reasons for Using Robots in Online Learning and Teaching

- Robots, therefore, act as additional support for teachers to improve learning and teaching. Robot teaching tools are gaining popularity in teaching for four significant reasons:
- The present Jobs are completely technology-oriented and require higher-level creative thinking, broader knowledge, and communicative collaboration for complex problem-solving. Robot-based delivery will build new confidence and the introduction of new technology to the learners
- Robots with artificial intelligence will serve more information than a traditional delivery in teaching
- Robot-structured tasks for learners enable them to work with minimal contact with faculty input
- Robot-based learning and teaching will increase student control over learning and give more time for teachers to prepare their content

5.2. Advantages of Using Robots in Online Learning and Teaching

There are many advantages of using Robots in online learning and teaching.

- Robots can be used to bring students into the classroom and can increase attendance and direct learning.
- Robots can be used as intelligent personnel in learning and teaching with the help of artificial intelligence.
- Robotics is very good for school-level students and will attract students to learn technologies in parallel with their regular curriculum.
- Robotics-based online learning and teaching is one of the best solutions for physically challenged students.
- Robotics are suitable for healthcare sector students to get more information on the latest medicine, developments in health care, etc.

5.3. Various Robots Used in Learning and Teaching

Different types of Robots used in learning and teaching are given in the following subsections.

5.3.1. Emotional Robots

Emotional robots are used to bridge the gap between learner and teacher. At present, emotional robots are used for kids’ education, psychology sessions, storytelling, etc. In

storytelling, this robot assistant can play a role assigned in advance and cooperate with the teacher and parent to react to some events or replace the sound of the teacher and parent; the robot can talk to the students or children. The robot can be a faithful audience within the conversation of teachers and students or parents and children.

5.3.2. Casual Robots

Casual robots can be used as service robots to deliver items and also for gaming purposes. Casual robots can provide teaching aids to the students in the classroom. It will serve to teach subjects through games and animation. This may be fun for school-level students and give them enthusiasm for learning.

5.3.3. Walk, Dance, and Singing Robots

This robot will be under Lego robots and mobile robots. These robots are used to learn dance, songs, and music. These robots are beautiful for kids, and we can use them for learning and teaching. This kind of robot will be helpful in arts colleges and will create a teacher-free environment.

This may allow students to learn by themselves whenever they need training. In the future, these robots can be used in HEIs for laboratory experiment teaching.

5.3.4. Programmable Robots

Programmable robots have the flexibility to be used in various activities. These reprogrammable robots can easily accommodate new things and stimulate learner's imagination and creativity. Programmable robots can be used in virtual laboratories, which may enhance the students' practical understanding. This kind of robot can be extended to help with campus tours for stakeholders inside the HEI campuses.

5.3.5. Humanoid Robots

A humanoid robot has a body shape built to resemble the human body. The design may be for functional purposes, such as interacting with human tools and environments, for experimental purposes. These robots are highly suitable for instructing students and can be used for question-and-answer sessions by integrating with smart speakers like Alexa or Siri. Humanoid robots can be used for intelligent tutoring systems and academic advising roles.

5.3.6. Training Robotics

Robots can be utilized as trainers in Education systems. With the integration of artificial intelligence and robotic technology, using robots as university trainers is possible. It is possible to teach maths, science, and technology using robots [80].

5.4. Challenges in the Implementation of Robots in HEIs

The main challenge in implementing robots in classrooms is high-cost involvement. Universities need a big budget to implement robotic technology in learning and teaching. The second big challenge is integration into the curriculum. The teachers may not get enough time and training to operate/integrate robots during their allotted class hours/working hours. As per the article by Makers' Muse [81], the challenges in implementing robots are

- Scarcity of resources
- Funding for equipment, software, and trained educators
- Accessibility to all
- The financial gap between institutes
- Integrating robotics into the curriculum
- Teacher readiness
- Staying updated

Marcial, C.H. et al. discussed educational robots' challenges from the teacher's home perspective. They added that implementing robots becomes a great challenge for teachers to be at the forefront of technical proposals and generate strategies for incorporation into the classroom [82]. Ahmad Khanlari discussed the benefits and challenges of integrating educational robots into primary/elementary curricula in teachers' perceptions. In his paper, he concluded that teachers perceive robotics to positively affect students' lifelong learning skills, which is overshadowed by the number of barriers and challenges [83]. Integration of education robots in primary education has advantages and many challenges. Even though kids will have more fun learning, there are safety issues in allowing robots to be teachers. Also, primary teachers will face more challenges when operating the robots and learning the techniques. There may be a chance of a digital divide between primary schools [84]. Table 3 shows the review papers on robotics and its challenges in higher education institutes.

Table 3. Review papers related to robotics in HEIs

No	Author	Year	Title	Journal / Conference	Theme
1	E.Luiz, L., et al. [73]	2022	Robot at Factory lite-a step-by-step educational approach to the robot assembly	In Iberian Robotics Conference	Robotics in education
2	Karalekas, G. et al[75]	2023	Teaching Machine Learning in K–12 Using Robotics	Education Sciences,MDPI	Robotics in education
3	Braun,J et al. [76]	2022	A robot localization proposal for the Robot at Factory 4.0: A novel robotics competition within the Industry 4.0 concept	Frontiers in Robotics and AI	Robotics and Industry 4.0

4	Ferreira ,T et al [77]	2022	Robot at Factory 4.0: an auto-referee proposal based on artificial vision	At the Iberian Robotics conference	Robotics and Industry 4.0
5	Schiavo, F et al [78]	2024	Educational Robots, Emotion Recognition and ASD: New Horizon in Special Education	Education Sciences	Robotics in education
6	Purdue University Article [79]	2024	The Use of Robotics and Simulators in the Education Environment	https://online.purdue.edu/blog/education/robotics-simulators-education-environment) [79]	Robotics in the education environment
7	Lima, J., Kalbermatter, R.B., Braun, J., Brito, T., Berger, G. and Costa, P., [80]	2022,	A realistic simulation environment as a teaching aid in educational robotics.	In the 2022 Latin American Robotics Symposium (LARS), 2022 Brazilian Symposium on Robotics (SBR), and 2022 Workshop on Robotics in Education (WRE)	Teaching using an education robot.
8	Makers' muse [81]	2023	Overcoming Challenges in Implementing Robotics Education in Schools	https://medium.com/@makermuse3/overcoming-challenges-in-implementing-robotics-education-in-schools-de147ff7b685	Challenges in implementing robots in education.
9	Marcial, C.H et al, (2023), [82]	2023	Challenges of Educational Robotics: A Perspective from the Teacher's Home,	Social science Journal, RES MILITARIS.	Challenges in implementing robots in education.
10	Khanlari, Ahmad. [83]	2015	Teachers' perceptions of the benefits and the challenges of integrating educational robots into primary/elementary curricula.	European Journal of Engineering Education.	Challenges in implementing robots in education.
11	Vivas Fernandez, L., & Sáez López, J. M. [84]	2019	Integration of educational robotics in Primary Education. Latin American Journal of	Educational Technology	Challenges in implementing robots in education.

6. Virtual Reality (VR) and Augmented Reality (AR) in Online Learning and Teaching

Virtual Reality (VR) is a computer-generated simulated environment with text, objects, audio, video and special effects that appear natural, making the user feel immersed in their surroundings with the support of multi-sensory interactions and reactions [85]. There are two different technologies, Augmented Reality (AR) and Hybrid Reality (HR) that are in purview with virtual reality.

So, integrating virtual reality and online learning technologies will enhance the students' learning, training, and instruction in many different contexts [86]. Commonly, a VR environment is perceived through a device known as a Virtual Reality headset or helmet. When students read about something, they often want to experience it. With VR, they aren't limited to word descriptions or book illustrations; they can explore the topic and see how things are put together. So, VR will help students learn beyond text-based and face-to-face classroom-based learning and teaching [87].

VR is a low-risk environment and can offer different communication methods, immersive and reproducible learning environments adaptable for special needs, and a unique perspective that promotes interaction and is low-risk. VR also opens up new perspectives that an educator might offer and gives learners novel opportunities for their responses. So, VR is giving promising hope for the future of online learning and teaching, and more research work is going on in this area, including information security in VR applications [88]. Virtual Reality (VR) has more potential to take learning beyond the traditional online learning experience.

6.1. Five Critical Aspects of VR Learning Experiences

- Immersive: It makes it possible to have real-time feeling in the learning environment.
- Easy to use: It does not require special skills to interact with a VR app.
- Meaningful: The text, video, and audio with visual effects will make for meaningful learning. This is very useful for designers and storytellers.
- Adaptable: Based on feedback from the learners, it is possible to establish complete control over the difficulty level. It is possible to design the course based on how students learn and then use this knowledge to design VR products for effective learning.
- Measurable: Teachers can measure the metrics of education so they can realize the resulting knowledge of a subject. Using this, it is possible to understand the success and failure of the teaching methodology.

6.2. Advantages and Disadvantages of Using VR in Education

6.2.1. Advantages of Using VR in Education

- Enhanced engagement
- improved retention and experiential learning
- Real-time experience – making the experience more memorable
- Visual learning will improve the quality of learners.
- Real-world technical skills
- VR creates an entire digital environment, a 360-degree
- Develop creativity
- Learning by doing
- To make users to adopt new technology
- Design learning students can check out 3D geometric forms from multiple perspectives.

6.2.2. Disadvantages of Using VR in Education

- VR gadgets are so costly
- Need to give more care to VR gadgets since it is made up of glass
- Wearing a VR headset for more time may result in health issues for the learners
- Not valid for long-time learning

Education institutions think that VR and AR tools are costly and unsuitable for the present environment. But Bringing AR and VR tools into the classroom doesn't have to be expensive. Available resources, like Google Cardboard, can connect to smartphones and can be acquired without investing much in costs [89]. Resources for teachers include affordable apps, low prices, or even free apps, such as 360 Cities, which allows students to learn about the world's top cities without visiting there. Many apps will allow you to discover the world's history, different locations, the seven wonders of the world, etc. Developing lesson plans with VR and AR using Immersive VR Education and Nearpod is possible.

6.3. Challenges in VR-Based Teaching

VR transports learners to a different world, allowing people to do something that might be difficult to experience, too expensive, or difficult to repeat in real life. However, the preparation of teaching content is not easy for teachers. Various technical skills are required for teachers to handle a topic through VR. It is necessary to understand the hard and soft skills like the basics of VR gadgets, headsets, specifications, etc. Soft skills like video creation, modeling, and simulation are also needed to prepare the content. According to Caroline Graeske and Sofia Aspling Sjöberg, "VR technology offers many opportunities but cannot exist independently. It must function in accordance with the curricula and educational goals" [90]. Also, VR may affect interpersonal relationships in the classroom since students are in the virtual world; VR may affect interaction between students since students will only interact with virtual persons. Table 4 shows the review papers on Virtual and Augmented reality and its challenges in higher education institutes.

Table 4: Review papers related to virtual reality and augmented reality in HEIs

No	Author	Year	Title	Journal / Conference	Theme
1	Vergara, D et al [85]	2021	Assessment of Virtual Reality as a Didactic Resource in Higher Education.	Sustainability, MDPI	VR in education
2	Hermandez-chavez et al. [86]	2021	Development of Virtual Reality Automotive Lab for Training in Engineering Students.	Sustainability, MDPI	VR in education
3	Adnan, A.H.M et al [87]	2020	360 Degree videos, VR experiences, and the application of education 4.0 technologies in Malaysia for exposure and immersion	Advances in Science, Technology and Engineering Systems Journal	VR in education
4	Hoole, R and Jahankhani, H [88]	2021	Security Framework for Delivery of Training, Using VR Technology	Information Security Technologies for Controlling Pandemics (Book chapter)	VR for Information Security

5	Martin,J., Bohuslava,J and Igor,H [89]	2018	Augmented reality in education 4.0	13th international scientific and technical conference on computer sciences and information technologies	AR in education
6	Caroline Graeske & Sofia Aspling Sjöberg , [90]	2021	VR-Technology in Teaching: Opportunities and Challenges,	International Education Studies; Published by Canadian Center of Science and Education	Challenges in the Implementation of VR in education

7. Block Chain Technology in Education

Blockchain technology provides many benefits in the education sector, mainly allowing the storing and sharing of data with high security. Blockchain can be used to achieve more transparency, accessibility, and traceability in staff and student record management, data sharing, content creation, and management [91]. Blockchain application is a steadily growing concept that offers many advantages to education stakeholders. Atienza-Mendez and Bayyou have identified the possible areas where blockchain can be applied in the education sector, as shown in Figure 6.

Al-Zoubi, Dmour, and Aldmour proposed a blockchain-based remote lab management system. This system has a data management system on the front end in which user login, lab experiment list, scheduling, and experiment data upload to the blockchain are available. The backend consists of a Web3.js library, which acts as a middleware for data flow. The authors claim that this new pedagogical paradigm will eventually lead to education 4.0. [93]. Rahardja, U et al. reviewed blockchain technology in education 4.0, and mapping has been done to see the modern popularity and research subject of the blockchain generation.

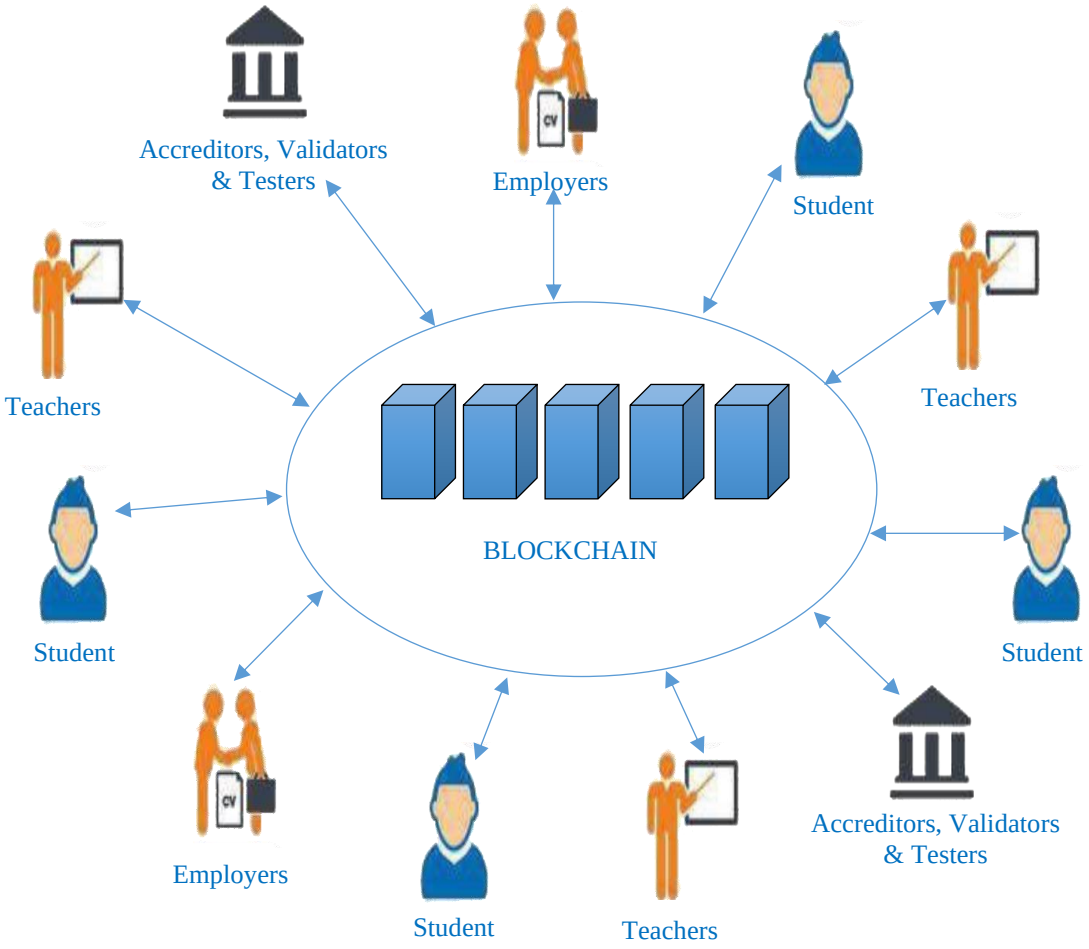

Fig. 6 Block chain in Education Technology (Atienza-Mendez and Bayyou, 2019) [92]

This paper describes the novelty of blockchain technology and the mechanism of its use that can be used in systems in higher education [94]. Cipriani et al. have researched the utilization of blockchain technology's potential for leading education 4.0. The result of this research is blockchain data in the website framework that has a novelty in the form of blockchain implementation on aid proposals and diploma certificates at universities. They concluded that a blockchain can help in terms of high security in the world of education [95].

7.1. Challenges in the Implementation of Blockchain in HEIs

Abdulghafour Mohammad and Sergio Vargas have conducted a qualitative study on the barriers affecting higher education institutions' adoption of blockchain technology. Academic and administrative staff from the European Union and Canada are interviewed to conduct the study. The key finding of this study includes 15 challenges in adopting blockchain in HEIs, categorized as technological, organization, and environmental framework [96].

The authors found that the technological challenges are more compared to others that are, (1) immaturity, (2) poor usability, (3) security issues, (4) privacy, (5) lack of scalability; (6) limited interoperability; (7) integration complexity; (8) immutability and lack of flexibility; and (9) unavailability. In the organizational context, there is (10) a lack of adequate skills, (11) financial barriers, and (12) a lack of management commitment and support. In the environmental context, there are (13) legal issues and a lack of regulatory compliance, (14) market and ecosystem readiness, and (15) sustainability concerns. The review made by Ricardo Raimundo and Albérico Rosário includes 37 articles highlighting the implications of using blockchain for improving higher education processes. The findings of this study mention the challenges involved in adopting blockchain in higher education, including compatible digital platforms to safely share and organize data, flexible smart contracts, affordable, innovative projects, and privacy/learning issues for all the stakeholders involved in the administrative and learning processes in higher education [97].

Dwivedi, S., and Vig, S. have investigated blockchain adoption in higher education institutions in India to identify the main challenges. In India, block chain technology is in the growing stage in the educational sector. This investigation highlights ten main challenges categorized under three dimensions [98]. Challenges under the technological dimension include operational issues, security concerns, hardware-related issues, and the cost of new technology. Organizational dimensions include attitudinal issues, human resource-related challenges, and financial challenges. The third dimension, i.e., the environmental dimension, covered the challenges relating to the regulatory environment, stakeholders, and the competitive environment. Solutions must be found to overcome these challenges and achieve the full potential of technology adoption in higher education. The performance of blockchain technology in learning methods becomes more fun and practical with an optimal system. The main challenge in applying technology in education is data security, such as archiving and document authenticity. However, the transparent result allows blockchain certificates to be verified and validated easily [99]. Table 5 shows the review papers related to the blockchain and its challenges in higher education institutes.

Table 5. Review papers on related Blockchains in HEIs

No	Author	Year	Titles	Journals / Conferences	Theme
1	Nazari, Z.; Vahidi, A.R. and Musilek, P [91]	2024	Artificial Intelligence Non-Formal Education System	Education Sciences	Blockchain and AI in education
2	Atienza-Mendez and Bayyou [92]	2019	Blockchain technology applications in education	International Journal of Computing and Technology	Blockchain in education
3	Al–Zoubi, Dmour and Aldmour Al-Zoubi, A. Y., Dmour, M., & Aldmour, R. [93]	2022	Blockchain as a Learning Management System for Laboratories 4.0.	International Journal of Online and Biomedical Engineering	Blockchain in education
4	Rahardja, U et al [94]	2022	A mapping study research on block chain technology in education 4.0.	IEEE Creative Communication and Innovative Technology	Blockchain in education

5	Supriati et al. [95]	2022	We are utilizing the potential of blockchain technology for leading education 4.0.	International Conference on Science and Technology	Blockchain in education
6	Mohammad, A.; Vargas, S. [96]	2022	Barriers Affecting Higher Education Institutions' Adoption of Blockchain Technology: A Qualitative Study.	Informatics 2022, 9, 64. https://doi.org/10.3390/informatics9030064	Challenges in applying blockchain in learning and teaching
7	Raimundo R, Rosário A. [97]	2021	Blockchain System in the Higher Education.	Eur J Investing Health Psychol Educ. 2021 Mar 16;11(1):276-293. doi: 10.3390/ejihpe11010021. PMID: 34542464; PMCID: PMC8314340.	Challenges in applying blockchain in learning and teaching
8	Dwivedi, S., & Vig, S. [98]	2023	Blockchain adoption in higher education institutions in India: Identifying the main challenges.	Cogent Education, 11(1). https://doi.org/10.1080/2331186X.2023.2292887	Challenges in applying blockchain in learning and teaching
9	Ninda Lutfiani , Qurotul Aini , Untung Rahardja , Lidya Wijayanti , Efa Ayu Nabila , Mohammed Iftequar Ali [99]	2021	Transformation of block chain and opportunities for education 4.0,	International Journal of Education and Learning, Vol. 3, No. 3, December 2020, pp. 222-231, DOI:10.31763/ijele.v3i3.283	Challenges in applying blockchain in learning and teaching

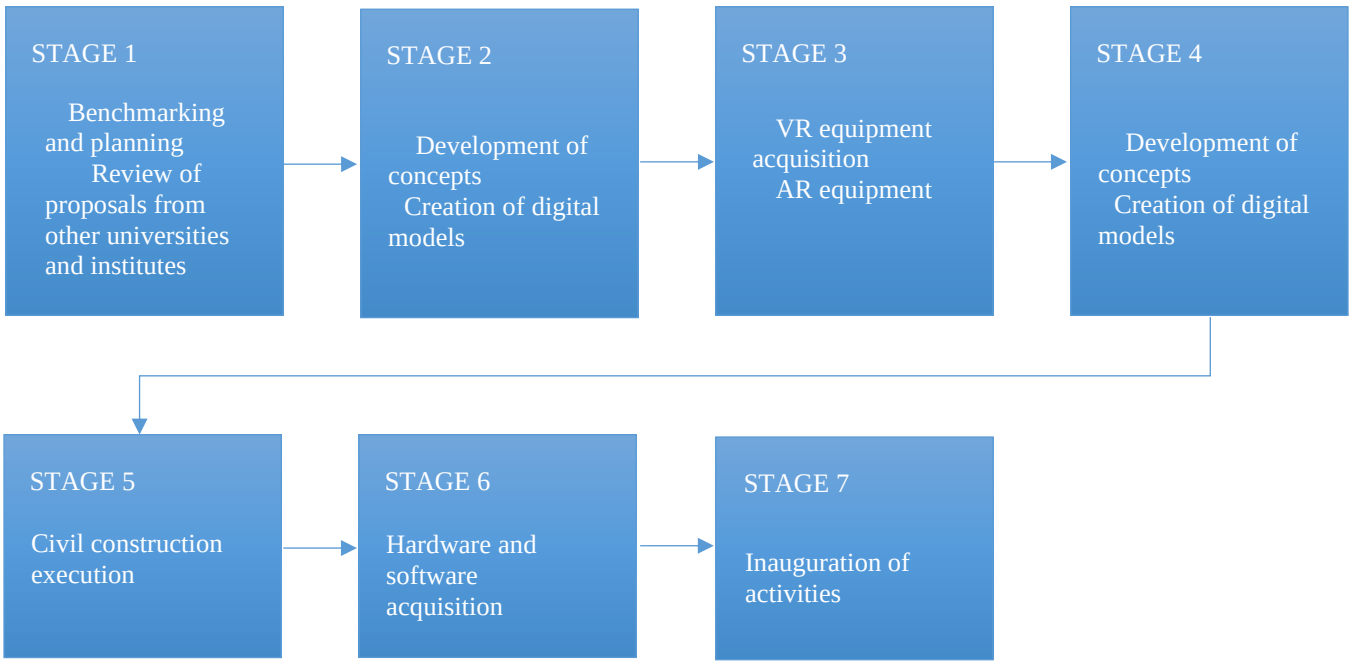

Fig. 7 Implementation of the digital laboratory (Cordero-Guridi et al., 2022) [104]

8. Online or Digital Laboratories

Online or virtual laboratories have been a crucial tool in providing practical activities. Online laboratories offer unique features and advantages that may fill the gap between education and industry in the 4.0 paradigm [100]. It is believed that digital laboratories are essential in higher education, particularly in engineering education, and that the theoretical knowledge imparted to the students in the classroom should be adequately accompanied by practical experience through laboratory experiments [101]. Grodotzki, J., Ortelt, T.R. and Tekkaya, A. implemented virtual labs at the TU Dortmund University as a part of their research project and explained the methodology, execution, and advantages of implementing the virtual labs [102]. Ciolacu, M.I et al. discussed hardware and software concepts for an education 4.0 innovation learning lab for Artificial Intelligence. Authors claimed that this digital laboratory concept can be used in higher education and for further research projects [103]. Cordero-Guridi et al. describe the development of a virtual reality laboratory to support learning, training, and collaborative ventures related to additive manufacturing for the 4.0 automotive industry [104]. The authors have given seven stages in the implementation of digital laboratories in the education sector, as shown in Figure 7. Miranda J et al. described how open innovation laboratories are used to enable resources to reach the vision of education 4.0 and represent a case of implementation at a Mexico-based university. The authors explained the implementation of a digital laboratory using a case study [105]. So, an active learning-based laboratory in higher education will unavoidably change all HEIs by applying industry 4.0 techniques.

8.1. Challenges in the Implementation of Virtual Laboratories in HEIs

Deriba, Fitsum & Saqr, Mohammed & Tukiainen, Markku identified four significant barriers: technological, infrastructural, pedagogical, and cultural. To enable all students to have equal opportunities to develop their practical skills, from a technological perspective, security threats and compatibility issues are significant barriers that make it challenging to conduct experiments in the labs [106]. Students who lack technical expertise face the issue of technical complexity and difficulty in following complicated setups. Additionally, due to technological problems, students may struggle to apply the theoretical concepts without real-time feedback and assessment.

Further, design-related issues such as the lack of reliable design, limited customization, and failure to include design principles in the configuration are also found. Different solutions and strategies were proposed and implemented to address these issues, including universal design principles incorporating realistic simulations and integrating various technologies and frameworks for realistic feedback and compatibility issues. The studies identified limited funding for laboratory development as an infrastructural challenge, resulting in outdated and less effective VL environments that negatively impact student learning due to the unavailability of the latest technology and equipment. Additionally, the lack of high-specification servers with massive processing capabilities to host all the virtual machines results in slow performance and response delays due to limited internet connectivity and bandwidth. To address these issues, some studies proposed offering VL that does not require expensive hardware or infrastructure and increasing the number of physical laboratory spaces available as the best solution [107]

Pedagogically, a lack of well-specified pedagogical approaches and principles was identified as a hindrance to the learning process when teaching complex concepts. Similarly, the reliance on mathematical models and a long learning curve were critical issues. These challenges restrict students from opportunities for exploration and experimentation and make it difficult to assess their performance. To solve the problems, primary studies proposed a variety of solutions, for instance, integrating VL experiences into existing courses and curricula [108]. Some studies also identified cultural barriers related to misconceptions and trust issues with laboratory platforms. To address these issues, studies proposed promoting the benefits of VL and encouraging experimentation with technology. Table 6 shows the review papers on virtual digital laboratories and their challenges in higher education institutes.

Table 6. Review papers related to virtual laboratories in HEIs

No	Author	Year	Title	Journal / Conference	Theme
1	Garcia-Loro, F., Plaza, P., Quintana, B., San Cristobal, E., Gil, R., Perez, C., Fernandez, M. and Castro, M., [100]	2021	Laboratories 4.0: Laboratories for emerging demands under the Industry 4.0 paradigm	2021 IEEE Global Engineering Education Conference (EDUCON)	Digital Laboratories 4.0;
2	Soni, K.M., Hasteer, N. and Bhardwaj, A., [101]	2020	Aspects of fostering competencies for engineering graduates: Education 4.0 paradigm.	In 2020, the 9th International Conference System Modeling and Advancement in Research Trends (SMART)	Competencies requirement in the implementation of Digital Laboratories 4.0;

3	Grodotzki, J., Ortelt, T.R. and Tekkaya, A.E. [102]	2018	Remote and virtual labs for engineering education 4.0: achievements of the ELLI project at the TU Dortmund university",	Procedia Manufacturing,	Remote and virtual labs – a case study
4	Ciolacu, M.I., Binder, L. and Popp, H., [103]	2019	We are enabling IoT in Education 4.0 with biosensors from wearables and artificial intelligence.	In 2019, the IEEE 25th international symposium for design and technology in electronic packaging (SIITME)	IoT and AI-based laboratories.
5	Cordero-Guridi, J.D.J., Cuautle-Gutiérrez, L., Alvarez-Tamayo, R.I. and Caballero-Morales, S.O. [104]	2022.	Design and development of an i4. 0 engineering education laboratory with virtual and digital technologies based on iso/iec tr 23842-1 standard guidelines.	Applied Sciences	Engineering Education Laboratory-Design and development
6	Miranda, J., López, C.S., Navarro, S., Bustamante, M.R., Molina, J.M. and Molina, A., [105]	2019	Open innovation laboratories as enabling resources to reach the vision of education 4.0.	In the 2019 IEEE International Conference on Engineering, Technology and Innovation	Digital Laboratories in education 4.0;
7	Prieto, M.D., Sobrino, Á.F., Soto, L.R., Romero, D., Biosca, P.F. and Martínez, L.R., [66]	2019	Active learning-based laboratory towards engineering education 4.0.	In 2019, the 24th IEEE international conference on emerging technologies and factory automation (ETFA)	Digital Laboratories 4.0;
8	Deriba FG, Saqr M and Tukiainen M (2024) [106]	2024	Assessment of accessibility in virtual laboratories: a systematic review.	Front. Educ. 9:1351711.	Virtual laboratories-Review
9	Alnagrat, A. J. A., Ismail, R. C., and Idrus, S. Z. S [107]	2021	Extended reality (XR) in virtual laboratories: a review of challenges and future training directions.	J. Phys. Conf. Ser.	Virtual laboratories-Review
10	Misiejuk, K., Khalil, M., and Wasson, B. [108]	2023	Tackling the challenges with data access in learning analytics research: a case study of virtual labs	Proceedings of the Technology-Enhanced Learning in Laboratories workshop (TELL 2023).	Challenges in implementation of Virtual laboratories-case study

9. IoT in Education

The Internet of Things (IoT) plays an essential position in the context of information and communication technologies. Using IoT technology, HEIs can enhance learning outcomes by providing a practical learning experience, improving operational efficiency, and gaining real-time, actionable insight into student performance [109]. Ciolacu, M.I., Binder, L., and Popp, H. discussed the application of IoT in education 4.0 with biosensors from wearables and artificial intelligence.

This paper examined the advantages of using IoT in data sharing, data management, and control of data using compact digital gadgets [110]. There is a possibility of framing IoT-based learning and teaching models for better teaching environments, which is discussed in the paper published by Som, S., and Rana, A. [111]. The variations in the implementation of IoT in education, addressed by Ramlowat D.D and Pattanayak B.K are IoT Courses and Tools in Computer Science Education, Current Status and Overview of IoT in Education, IoTFLiP Platform for Medical Education, Consumer Green Education and Green Marketing via IoT, Interrelations of Cloud Computing, Connectivism and IoT, IoT Manpower Training Using HOPPING and ESIC, IoT in Distance Education, IoT in Education Model, Green IoT in Engineering Education [112]. The researchers Alex de Souza and Luciana Debs reviewed 528 selected papers on Education 4.0 that focus on competency-based learning and technologies like AI and IoT. The review highlights the importance of collaboration between industry, governments, universities, and society and the need for a strong partnership between industry and academia to align technology with workforce training.

9.1. Challenges in the Implementation of IoT in HEIs

There are many challenges in implementing the IoT in HEIs, such as privacy and data security, the high price to implement IoT technology, the Involvement of many hardware and software, the requirement of skillset because of the large amount of hardware and software required, and lack of infrastructure to store and process data.

Nur Fitria et al. highlighted the key challenges as high price, security, and safety issues, inadequate internet access for IoT devices, and blue light (Since most IoT devices require users to be exposed to a blue screen, this can impact students' eyes) [113]. Saudamini Mowade discussed the Internet of Things (IoT) challenges and opportunities in the Education Sector.

The application of IoT is in many areas, such as Smart Classrooms, Remote Learning, Smart Campuses, Asset Tracking, Safety and Security, Personalized Learning, Personalized Learning, virtual Laboratories, Student Attendance and Engagement, and Research Collaboration. The authors highlighted challenges such as infrastructure Requirements, Cost, Data Privacy and Security, Interoperability: Technical Expertise, Resistance to Change, Ethical Considerations, and the digital Divide [114]. So, implementing IoT in education systems has many challenges and advantages. If we overcome the challenges, there is no doubt that the transformation that will be enabled will reinvent the education system in HEIs. The selected papers in the "IoT in education" area have been listed in Table 7.

Table 7. Review papers related to IoT in HEIs

No	Author	Year	Title	Journal/Conference	Theme
1	Aldowah, H., Rehman, S.U., Ghazal,S and Umar, I.N., [109]	2017	Internet of Things in Higher Education: A Study on Future Learning	Journal of Physics, Conference Series, The 6th International Conference on Computer Science and Computational Mathematics (ICCSCM 2017)	IoT in higher education
2	Ciolacu, M.I., Binder, L. and Popp, H.,[110]	2019	We are enabling IoT in Education 4.0 with biosensors from wearables and artificial intelligence.	In 2019, the IEEE 25th international symposium for design and technology in electronic packaging (SIITME)	IoT in higher education
3	Som, S. and Rana, A., [111]	2020	IoT-Based Educational Model for Better Teaching-Learning Environment.	In 2020, the 8th International Conference on Reliability, Info com Technologies and Optimization (Trends and Future Directions) (ICRITO).	IoT-based education model
4	Ramlowat, Dosheela & Pattanayak, Binod.[112]	2019	Exploring the Internet of Things (IoT) in Education: A Review:	Proceedings of Fifth International Conference INDIA 2018.	IoT in higher education – review paper
5	Souza, A. S. C. de, & Debs, L.[113]	2024	Concepts, innovative technologies, learning approaches and trend topics in education 4.0: A scoping literature review	Social Sciences & Humanities Ope	IoT and AI in higher education – review paper
6	Nur Fitria, Tira & Simbolon, Nurmala & Afdaleni,.[114]	2023	Internet of Things (IoT) in Education: Opportunities and Challenges.	Conference: Teknologi Informasi Sebagai Sebuah Peluang atau Ancaman Bagi Dunia Usaha di Indonesia at Institut Teknologi Bisnis AAS Indonesia, December 2023	Challenges in implementing IoT in HEIs
7	Saudamini Mowade, [115]	2024	Internet of Things (IoT) in the Education Sector: Challenges and Opportunity,	International Journal of Scientific Engineering and Research (IJSER)	Challenges and opportunities in implementing IoT in HEIs

10. Conclusion and Future of Education 4.0

Many studies and reviews confirm that new-generation students will benefit from integrating Industry 4.0 technologies and innovations into classrooms. Digital Technologies make a significant impact on many industries. Education 4.0 is changing the world of education drastically, and it is essential for society. Qureshi, M.I., Khan, N., Raza, H., Imran, A. and Ismail, F. commented that it is essential for teachers and students to adopt digital technologies for educational purposes. Also, the authors reflect that teachers are not showing a deep interest in adopting these new technologies, whereas students are positive towards them [43]. So, students and faculty must enhance their competitive skills to cope with 4IR in the global labor market in the coming years. The following are the expected tasks to develop the university students to face the 4IR world.

- Best prepare the university learners for the new careers that 4IR drives
- Redefining Classroom culture: Online delivery (flipped Classes) and blended learning,
- Using AI to assist learning
- Develop institutional agility for the 4IR target area
- Capacity building: Provide an opportunity for staff to develop in the focus area of 4IR
- Train and provide opportunities for students to improve their learning experience and qualifications through online courses, credentialed certificate programs, self-teaching, and entrepreneurship.
- need to encourage students to take charge of their self-learning ability
- Moving out with a traditional degree within the academic four walls is widely considered the standard requirement for career success.
- Forging stronger linkages between industry and academia.
- Encourage the development of real-world skills through project-based/ case studies learning.

The assessment of social, emotional, and intercultural competencies of students and staff is more critical while implementing new technologies or new systems in educational institutions [41]. Rojas, Carolina & Alomía, Gustavo & Loaiza, Diego & Romero, Carlos describe the relationship between innovations based on science, technologies, and societal changes. This paper reveals the current works in the area of automation in education 4.0 to face the challenging society 5.0. The authors further discussed the implementation of industry 4.0 technologies and their impact on the Japanese concept of society 5.0. The authors concluded, "A comprehensive educational system at different levels is needed, and professionals are required to develop and acquire skills related to data management and processing" [115]. Oliveira K.K.D.S., Souza R.A. proposed a holistic approach to digital transformation in education. This method equips students with technical, social, cognitive, and interpersonal skills. The process was applied in teaching and learning experiences with positive outcomes, helping students develop soft skills and awareness of climate change. Students and educators in primary and higher education are involved in the study, showing promising outcomes for Education 4.0 objectives [116].

In the future, the methodology of learning will be reformed in that learners will automatically acquire skills using AI-enabled systems. AI is redeveloping the program and learning methodologies, and teachers and learners need to cope with the success of Education 4.0 to develop Society 5.0. This paper contributes to understanding the concept, structure, and impact of implementing modern digital technologies to form Society 5.0 with a sustainability approach. Adopting technologies and pedagogical approaches will enhance Innovation, safety and sustainability within local and global society. However, ethical consideration is essential, which is discussed by Swartz, B., 2021 [117] With the dilemmas of (1) the unintended negative, consequences of using technology, (2) discrimination as a result of the use of technology, and (3) educator agency in the Engineering Education 4.0. As per Swartz, B.'s paper [117], research was conducted at the University of Technology, South Africa, and the results of this study show that engineering educators will benefit from engagement in robust discussion around ethical considerations for Engineering Education 4.0. So, Automation of Education 4.0 proposes digital innovation; the challenges of modern society are faced with increasing the potential of the student–technology relationship to promote improving HEIs' quality through an innovative, intelligent society.

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