International Journal of Instruction
e-ISSN: 1308-1470 ● www.e-iji.net

April 2025 ● Vol.18, No.2
p-ISSN: 1694-609X
pp. 285-308

Article submission code: 20240815100702
Received: 15/08/2024
Revision: 21/11/2024
Accepted: 29/10112024
OnlineFirst: 03/01/2025

Systematic Literature Review of Fourth Industrial Revolution on Higher Education: Implications for Higher Education Sustainability

Yousef Mubrik N Almutairi
Assoc. Prof., University of Ha'il, Saudi Arabia, *yo.almutairi@uoh.edu.sa*

Atheer Farouk Al-Saad
Asst. Prof., University of Ha'il, Saudi Arabia, *a.alsaed@uoh.edu.sa*

Reda Ibrahim Elmelegy
The Applied College, University of Ha'il, Saudi Arabia, *r.salim@uoh.edu.sa*

Amany Abdel Hahez Bakr
The Art College, University of Ha'il, Saudi Arabia, *a.bakr@uoh.edu.sa*

Magdi Abd Elrahman Abdallah
The Applied College, University of Ha'il, Saudi Arabia, *ma.abdallah@uoh.edu.sa*

Khaled Mubark N Almotairi
Prof., University of Ha'il, Saudi Arabia, *k.almitary@uoh.edu.sa*

The current research aims to clarify the relationship between the sustainability in higher education and the fourth industrial revolution through acknowledging the factors contribute to the sustainability of the Fourth Industrial Revolution (4IR) in higher education, defining the effect of Fourth Industrial Revolution (4IR) on higher education, particularly in terms of sustainability, and the challenges that higher educational institutions face in implementing Fourth Industrial Revolution (4IR) technologies. It utilizes the PRISMA guidelines; a selection process narrowed down 127 initially identified articles to 39 relevant studies for in-depth analysis. The results of the research confirms that the characteristics of the 4th industrial revolution have been reflected on higher education and hence require its speedy response for it to cope with the digital innovations and the integration of advanced technologies including the artificial intelligence, blockchain and internet of things into educational frameworks to ensure the the sustainability of 4IR in higher education institutions .Moreover, it elucidates that Higher education teaching has changed significantly due to the Fourth Industrial Revolution and the traditional teaching methods have been revolutionized through the application of technologies like virtual reality (VR), augmented reality (AR) and machine learning (ML).

Keywords: higher education, industrial revolution, higher education sustainability, teaching and learning in higher education, advanced technology

Citation: Almutairi, Y. M. N., Al-Saad, A. F., Elmelegy, R. I., Bakr, A. A. H., Abdallah, M. A. E., & Almotairi, K. M. N. (2025). Systematic literature review of fourth industrial revolution on higher education: Implications for higher education sustainability. *International Journal of Instruction*, *18*(2), 285-308. https://doi.org/10.29333/iji.2025.18216a

INTRODUCTION

Technologies have the potential to increase inequality in terms of social stability even though they have also been shown to increase access to education and equality. The problem in this case is that while new technologies democratize employment and entrepreneurship, they also present new difficulties, such as the dominance of multinational technical giants, which exacerbates social fragmentation and inequality (World Economic Forum, 2017). While prior research has indicated a decline in inequality, inequality has actually increased, leading to new illnesses like social media addiction, which is a growing concern among the younger generation (Andreassen et al., 2017). In the context of education, we should design learning systems that cater for digital literacies to be spread out to the community as a whole in order to aim for the public to be digital literate.

The concept of the Fourth Industrial Revolution (FIR) is one that is frequently discussed in business leadership circles and at events like the World Economic Forum in Davos. According to recent white papers, the FIR will "shape the future of education, gender, and work" and will necessitate "accelerating workforce reskilling" (World Economic Forum, 2017). As demonstrated in (World Economic Forum, 2017), the fourth industrial revolution is bringing about rapid transformations that are affecting a number of major areas, including disruption to jobs and skills, innovation and productivity, inequality, agile governance, security and conflict, business disruption, fusing technologies, and ethics and identity.

The goals of industry 4.0, which link technology and people to enable new possibilities, are met by education 4.0. While Education 4.0 is a crucial tool for countries transitioning to Industry 4.0, the approach and execution of this initiative should be customized for each individual nation. Stated differently, one-size-fits-all policies and roadmaps for Education 4.0 are not appropriate for every country (Puriwat & Tripopsakul, 2020)

Global productivity might rise dramatically with the implementation of Higher Education 4.0, an idea that was developed in cooperation with top education professionals from the public and business sectors (Advani, 2023). To fully realize this 4IR change, HEI investments should focus on three essential areas: teacher empowerment, new learning technology, and new evaluation methods (Maj-Waśniowska et al., 2023). To fully realize the potential of Higher Education 4.0, educators, corporations, investors, parents, and caregivers, in addition to students themselves, are all critical stakeholders. Future 4IR operations will require a new set of expertise.

Mudau & Sikhosana (2024) investigated how the Fourth Industrial Revolution affected teaching and learning during the COVID-19 pandemic in some selected schools in the South African provinces of Gauteng and Mpumalanga. It was verified that teachers faced difficulties with regard to socioeconomic background, limitless internet access, and teaching and learning resources. The absence of support from the School Management Teams and the instructors' lack of experience with the Fourth Industrial Revolution presented further difficulties.

Moreover, Mhlanga and Moloi (2020) claim that the majority of South Africa's public schools, particularly those in townships and rural areas, were affected by the lockdown due to the 4IR infrastructural challenge. Additionally, no workable interventions were put in place to address these situations, so universities and traditional schools without 4IR instruments were forced to close as soon as the COVID-19 lockdown began. Mhlanga and Moloi (2020) predict that this will happen frequently throughout Africa because of problems with infrastructure, broadband availability, and data costs. Butler-Adam (2018) notes that 4IR has implications for many aspects of life, which presents both opportunities and challenges for the educational system.

The achievements of the previous industrial revolutions especially the third, which led to a rise in the use of computers, electronics, and telecommunications are interwoven with the fourth (Oke & Fernandes, 2020). This suggests that elements that were essential to the previous revolutions such as electricity and access to computers and the internet may have an impact on the 4IR's future. Similar to other developing nations in Asia and South America, people believe that the digital divide is greatest in African nations. Africa's population does not have access to the same level of affordable and functional technology infrastructure as those living in developed North American and European nations. The digital divide, according to Antonio and Tuffley (2014), is the difference in access to essential ICT resources between those who have them and those who do not, such as those who lack access to electronic devices, the internet, or inadequate infrastructure.

Research Problem

In fact, society of twenty-first century has witnessed alarming changes that may affect all aspect of life. These progressions have made us remain near the very edge of an innovative upheaval that will on a very basic level adjust the way we live, work, and identify with each other. Thus, higher education will need to increase its capacity for ethical and intercultural understanding due to the societal changes brought about by the Fourth Industrial Revolution (4IR). This will place a premium on liberal arts education modified to address the unique concerns highlighted by 4IR technologies and their disruptions to society(Penprase, 2018).

This research sheds light on the multifaceted relationship between the fourth industrial revolution and higher education sustainability. The following research question guides the study:

1. What factors contribute to the sustainability of the Fourth Industrial Revolution (4IR) in higher education?
2. How does the Fourth Industrial Revolution (4IR) affect higher education, particularly in terms of sustainability?
3. What challenges do higher educational institutions face in implementing Fourth Industrial Revolution (4IR) technologies?
4. What are the impacts of the Fourth Industrial Revolution (4IR) on teaching and learning in higher education?

Research Objevtives

This research aims to clarify how the fourth industrial revolution contributes to achieving the sustainability of higher education. This can be done through:

1. Acknowledging the factors contribute to the sustainability of the Fourth Industrial Revolution (4IR) in higher education.
2. Clarifying the impact of the Fourth Industrial Revolution (4IR) on the sustainability of higher education and teaching and learning.
3. Acknowledging the challenges that higher educational institutions face in implementing Fourth Industrial Revolution (4IR) technologies.

METHOD

The SLR defines future research directions and offers up-to-date data on a research focus area (Kunisch, 2018). It assisted the researchers in determining the crucial voids and unanswered concerns in the body of current literature. By producing accessible scientific evidence based on recent literature, the SLR is also recognized as the approach that helps researchers respond to the research question (Lame, 2019).

The preferred reporting items for systematic review and meta-analysis (PRISMA) were used in the SLR process for this study in the framework of 4IR approaches to support higher education and its role in enhancing educational sustainability in tertiary institution. Because it allowed the researchers to provide a comprehensive analysis of the corpus of data pertaining to how 4IR is being incorporated into educational practices within higher institutions, this technique was also deemed relevant to the current study.

Search Strategy, Inclusion and Exclusion Criteria

Three databases were used to find the literature for this study: Google Scholar, Science Direct, Web of Science, Semantic Scholar and Scopus. Studies the Fourth Industrial Revolution and Higher Educational Institutions (HEIs), teaching and learning, and 4IR technologies are all included in the literature. The literature search was conducted using the following search terms: "4IR tools in HEIs," "4IR and teaching and learning," and "4IR and sustainability in HEIs." Articles, book chapters, and conference papers were the document types that were ordered in the search by language (English). The review was restricted to 2013-2023.

It was discovered that these search engines predominate in the academic research papers published on the sustainability of 4IR in Higher Education Institutions. The search yielded 126 documents at first. Duplicate documents (articles, book chapters, and conference papers) were removed once the search was finished. After the removal of 10 duplicate documents, 108 documents remained.

In order to guarantee that pertinent publications about the 4IR technology themes, education, sustainability and Higher Education Institutions were included in the study, the researchers went over the abstracts of all 33 papers and classified them as either included or omitted. Of the 75 research publications, thirty-seven were deemed irrelevant and unrelated to the current study; hence, they were removed.

Methodological Quality Assessment

A six-item checklist created by Pitchforth et al. (2017) was used to evaluate the methodological quality of the 39 documents that were kept. Finding out if these documents fit the inclusion or an exclusion criterion for this study was the goal. When implementing the checklist, a component method based on PRISMA was utilized. Six research criteria are evaluated by the checklist with a "yes" or "no" score. The quality assessment was carried out separately by three authors, and one author further validated the results to support the assessment.

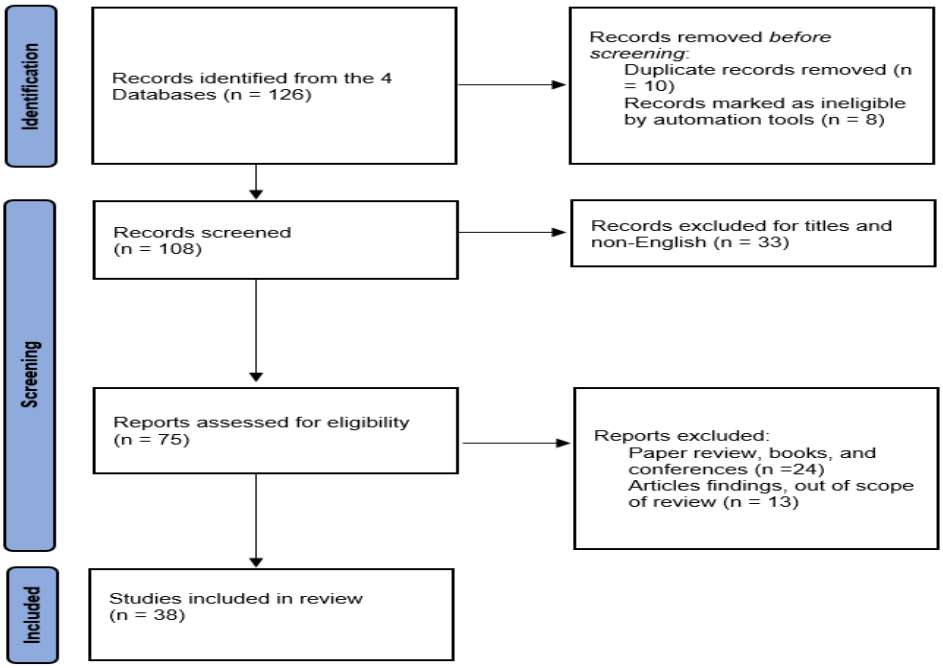


Figure 1
PRISMA flow diagram

Data Extraction and Descriptive Analysis

A data extraction table was drawn up to aid in the analysis of the selected journals, aiding in the systematic review process. Captured in the table are vital specifics comprising of author individualities and journal publication and the year of publication, geographical origins, methodological frameworks employed, and the respective journals of publication. These extracted data were influential in carrying out the descriptive analyses for the study.

Table 1
Data extraction table

S/N	Author Name & Year	Methodology	Country	Journal
1	Ahmed, T. T. (2013)	Qualitative	Developing	International Journal of Academic Research in Business and Social Sciences
2	Alakrash, H. M., & Razak, N. A. (2020)	Qualitative	Asia	The Asian ESP Journal
3	Al-Fraihat, D., Joy, M., & Sinclair, J. (2020)	Mixed	Mixed	Computers in Human Behavior
4	Ali, W. (2020)	Qualitative	Global	Higher Education Studies
5	Ally, M. (2019)	Qualitative	Canada	International Review of Research in Open and Distributed Learning
6	Anderson, A. (2008)	Qualitative	Sri Lanka	International Journal of Education and Development using ICT
7	Andreassen, C. S., Pallesen, S., & Griffiths, M. D. (2017)	Quantitative	Norway	Addictive Behaviors
8	Antonio, A., & Tuffley, D. (2014)	Qualitative	Developing	Future Internet
9	Aziz Hussin, A. (2018)	Qualitative	Malaysia	International Journal of Education and Literacy Studies
10	Bhattacharjee, D., Paul, A., Kim, J. H., & Karthigaikumar, P. (2018)	Quantitative	India	Computers & Electrical Engineering
11	Block, C., Kreimeier, D., & Kuhlenkötter, B. (2018)	Mixed	Germany	Procedia Manufacturin
12	Bosch, N., Härkki, T., & Seitamaa-Hakkarainen, P. (2022)	Mixed	Finland	Design and Technology Education: An International Journal
13	Bucciarelli, L., & Drew, D. (2015)	Qualitative	USA	Engineering Studies
14	Butler-Adam, J. (2018)	Qualitative	South Africa	South African Journal of Science
15	Cezzar, J. (2020)	Qualitative	USA	She Ji: The Journal of Design, Economics, and Innovation
16	Chai, C. S., & Kong, S. C. (2017)	Qualitative	China	Journal of Computers in Education
17	Chang, V. (2016)	Qualitative	Global	International Journal of Information Management
18	Chatti, M. A., Dyckhoff, A. L., Schroeder, U., & Thüs, H. (2012)	Mixed	Germany	International Journal of Technology Enhanced Learning
19	Chen, G., Xu, B., Lu, M., & Chen, N.-S. (2018)	Qualitative	China	Smart Learning Environments
20	Daniel, B. K. (2015)	Qualitative	Global	British Journal of Educational Technology
21	Grodotzki, J., Ortelt, T. R., & Tekkaya, A. E. (2018)	Mixed	Germany	Procedia Manufacturing
22	Kunisch, S., Menz, M., Bartunek, J.M., Cardinal, L.B., & Denyer, D. (2018)	Qualitative	German	Organizational Research Methods
23	Lame, G. (2019)	Qualitative	UK	Proceedings of the Design Society: International Conference on Engineering Design
24	López-León, R., & Valdez, G.G. (2018)	Mixed	Mexico	International Journal of Educational Research and Innovation
25	Lou, Y. (2018)	Qualitative	USA	She Ji: The Journal of Design, Economics, and Innovation
26	Mhlanga, D., & Moloi, T. (2020)	Mixed	South Africa	Education Sciences

27	Mitra, S. (2014)	Qualitative	India	Prospects
28	Mourtzis, D., Boli, N., Dimitrakopoulos, G., Zygomalas, S., & Koutoupes, A. (2018)	Mixed	Greece	Procedia Manufacturing
29	Naidoo, J., & Reddy, S. (2023)	Mixed	South Africa	Sustainability
30	Ng'Ambi, D., Brown, C., Bozalek, V., Gachago, D., & Woos, D. (2016)	Mixed	South Africa	British Journal of Educational Technology
31	Jordin, N., & Norman, H. 2018)	Qualitative	Malaysia	Journal of Sustainable Development Education and Research
32	Oke, A., & Fernandes, F. A. P. (2020)	Qualitative	Nigeria	Journal of Open Innovation: Technology, Market, and Complexity
33	Oyediran, W. O., Omoare, A. M., Owoyemi, M. A., Adejobi, A. O., & Fasasi, R. B. (2020)	Mixed	Nigeria	Heliyon
34	Popenici, S. D., & Kerr, S. (2017)	Qualitative	Global	Research and Practice in Technology Enhanced Learning
35	Qureshi, I. A., Ilyas, K., Yasmin, R., & Whitty, M. (2012)	Mixed	Pakistan	Knowledge Management & E-Learning: An International Journal
36	Rana, H., & Lal, M. (2014)	Qualitative	Global	International Journal of Computer Applications
37	Rosa, W. (Ed.). (2017)	Qualitative	Global	A new era in global health
38	Woodcock, B., & Yang, L. (2019)	Mixed	Global	Digital Learning Journal
39	Ray Schroeder (2026)	Qualitative	Global	UCPEA

Research Methodology

For this study, the article reviewed made use of the three major research methodologies; Two studies employed quantitative methods, twenty-six studies employed qualitative approaches, and Ten studies made use the mixed-methods design. The representation of the aforementioned distribution is seen in Figure 2 below.

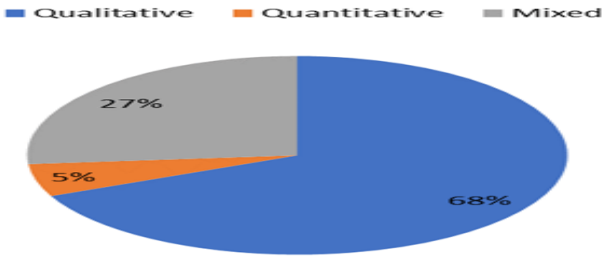


Figure 2
Research methodology analysis

Research Country Analysis

A chart was created to show a well detailed distribution of the studies by location the study was carried out. It is important to note that the scope of the study is global, nevertheless there is an obvious concentration of articles from certain regions/countries. This distribution is comprehensively depicted in Figure 3.

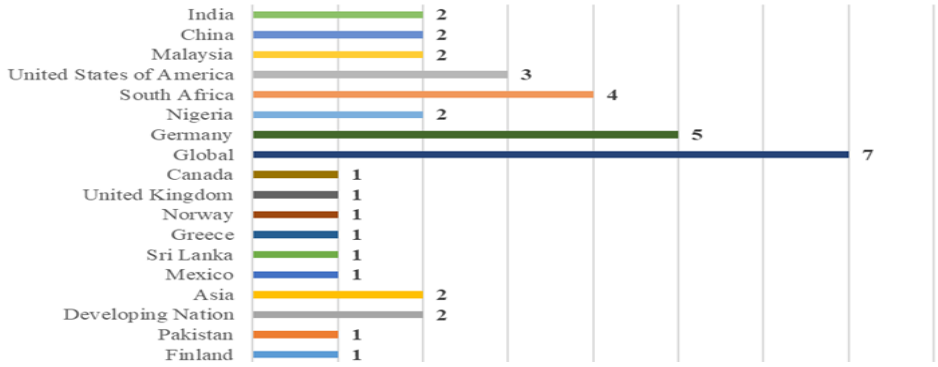
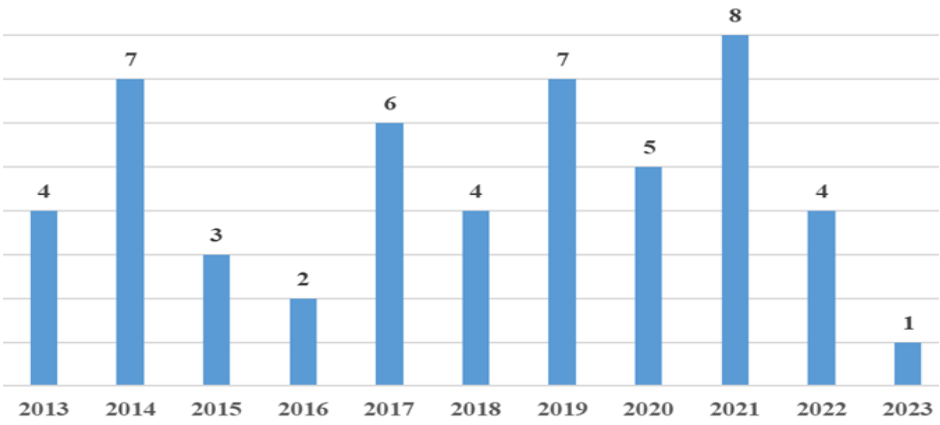


Figure 3
Study location analysis

Article Publication by Year

The table below shows a distribution of the various years the articles used in this review were published from 2013-2023. From the table it is clear that the year with the highest number of publication was 2021, with a total of 8 publications, which is followed by 2019 and 2014, with 7 publications each, 2017 is the third on the list, with a total of 6 publications. The year with the least number of publications is 2023, with just a single publication, followed by 2016 and 2015, with 2 and 3 respectively.



FINDINGS & DISCUSSION

The discussion section here presents the findings relevant to the research question posed in this study.

Research Question 1: What factors contribute to the sustainability of the Fourth Industrial Revolution (4IR) in higher education?

Shortage of skills needed for the new professions that will arise will be the problem in the future, not a shortage of employment prospects (Ruminar & Gayatri, 2018). This

insight highlights how crucial it is to acquire the abilities required to guarantee sustainability in the setting of 4IR. By enabling people and organizations to think critically, communicate effectively, collaborate effectively, and generate creative solutions to solve the complex issues of sustainable development, the 4Cs abilities may play a significant role in accomplishing the SDGs. These competencies are crucial for accomplishing global goals because they are interconnected and applicable to different SDGs. Students have the ability to actively contribute to sustainable development by realizing the connection between the SDGs and the 4Cs skills.

By encouraging efficient communication and information sharing in educational settings, communication skills may support SDG 4 (Quality Education) and guarantee that everyone has access to education. Effective communication of ideas, thoughts, and solutions is made possible by having good communication skills. Achieving the SDGs in the 4IR, where a variety of stakeholders work together across national boundaries and professional domains, depends critically on effective communication (Armstron et al., 2018; Mhlanga & Moloi, 2020).

By helping students to express their ideas verbally, visually, and in writing, design education fosters good communication (Zande, 2011; Cezzar, 2020). Any design process must include effective communication, as poor communication can lead to mistakes, delays, and even the project's complete failure (Eckert et al., 2005; Sandeep et al., 2021). Usually, the goal of the designer is to convey a particular design concept through one or more drawings that show the artifact in its entirety and highlight key elements. By pushing students to investigate other viewpoints, question presumptions, and think outside of the box, design education fosters creativity (Zande, 2011; Zhongbin, 2023).

Interdisciplinary methods and teamwork are promoted by design education (Zande, 2011; McDermott et al., 2014; Kaygan & Demir, 2017; Cohen & Mule, 2019; Petrova et al., 2022). By offering chances for interdisciplinary projects, teamwork, and stakeholder engagement, design education fosters collaboration. It promotes teamwork among students, makes use of a variety of viewpoints, and accepts the idea of solving problems collectively.

In the 4IR era, design education cultivates design thinking, a potent instrument for promoting creativity and problem-solving skills. According to Lor (2017), design thinking is a human-centered approach to problem-solving that fosters original and creative solutions. Students gain the ability to recognize issues, relate to users, and develop creative prototypes of solutions through the application of design thinking approaches. Design thinking can support 4IR sustainability by embracing an empathic and user-centric approach, cultivating an iterative and experimental mindset, fostering multidisciplinary collaboration, igniting creativity and ideation, and placing a strong emphasis on human centered prototyping and testing, according to Lor's (2017) analysis of the application of a design thinking framework.

One significant SDG for education is Goal 4: “to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all” (Rosa, 2017, p. 14). A few nations have begun utilizing 4IR technology in order to promote sustainable

development. According to projections, 4IR technologies will become self-organizing and play a significant part in delivering teaching and helping students (Mitra, 2014, 2019). 4IR technologies, AI, learning analytics, and the Internet of Things will cause learning to become more individualized and learner-centered (Aker, 2020; Chai & Kong, 2017; Mitra, 2014; Popenici & Kerr. 2017). In order to create a personalized learning simulation based on students' responses to stimuli, a study carried out in a developing Commonwealth nation looked at the usage of virtual reality and a mobile learning platform (Bhattacharjee et al., 2017). In order to personalize the virtual lesson simulations, the researchers created an immersive model based on the "innate natural learning process in humans" (p. 236). When it came to improving creativity through reinforced customization of the simulations, their "learning model [was] immersive and [gave] long term retention," they found (p. 236). Teachers' roles will be drastically altered by the 4IR age; many will become "4IR" or "digital" teachers utilizing deep learning technologies like artificial intelligence, robotics, big data, the Internet of Things, etc (Ally, 2019). According to the World Economic Forum (2017), in order for instructors to educate in the 4IR, they will need to use robotics and AI.

Research Question 2: How does the Fourth Industrial Revolution (4IR) impact higher education, particularly in terms of sustainability?

Butler-Adam (2018) asserts that curricula, teaching, and learning rather than robotic tutors are among the consequences of the 4IR for the education sector. Stated differently, cross-sector teaching and learning is essential. The various components that contribute to the successful application of the 4IR are important knowledge for educators and students from a variety of backgrounds. Students studying the humanities and social sciences must comprehend at least the principles and workings of artificial intelligence (AI), as explained by Butler-Adam (2018).

According to Brown-Martin (2017), digital literacy is a fundamental requirement for students to acquire the adaptive skills they need to engage in the global digital society, reap the benefits of the digital economy, and seize new chances for social inclusion, employment, innovation, and creative expression.

Research and development (R&D) is frequently cited as being primarily driven by new technology developments (Xing and Marwala, 2017). Technology-assisted research yields many beneficial results. Technology-driven research and development (R&D) can take many different forms, according to Xing and Marwala (2017). Some examples include utilizing mobile capabilities to increase the accuracy of data acquisition, utilizing advanced big data analytics to identify statistical patterns that may be hidden and utilizing AI techniques to retool information search, collection, organization, and knowledge discovery.

Furthermore, moral and ethical actions may be affected by the 4IR, which is something that needs to be taken into account. Technology has a wide range of effects on people's lives. There are several dynamic changes occurring as a result of the widespread adoption of new technology in business, government, and other areas of life. According to Hooker and Kim (2019), recent technological developments like the AI revolution may have more drastic effects, such as the mass displacement of workers that has never

been witnessed before. A significant portion of the populace may lose work possibilities as a result of this. Regarding the above argument, however, there is disagreement among numerous writers, researchers, academics, and policymakers. On the one hand, some claim that the new revolution will result in a rise in employment opportunities. However, there is a counterargument that the widespread use of technology would lead to the extinction of jobs in the near future.

In several industries, there is evident evidence of machines taking control. It is unclear who should bear more of the blame for the reduction in labor and employment brought on by the adoption of new technology like robotics: the government or private industry. One of the concerns brought up has to do with the human cost of utilizing new technologies. Academics place a high value on ethics when it comes to education. Ethical boundaries should be emphasized as educational materials become more widely available and accessible in order to guarantee that moral principles are instilled in education (Nordin and Norman, 2018).

The Fourth Industrial Revolution, driven by artificial intelligence, will bring about a shift in the workplace from task-based to human-centered characteristics. Due to the convergence of man and machine, there will be less of a subject distance between science and technology and the humanities and social sciences. As a result, higher education will become increasingly important in the Fourth Industrial Revolution. Given the potential for both positive social impacts and devastating environmental damage, higher education will need to adapt quickly. This will require much more interdisciplinary teaching, research, and innovation (Lupanda, 2020).

According to Maringe and Chiramba (2022), instruction in the twenty-first century must support the relevance of college graduates in the four-year interval (fourth industrial revolution). Additionally, Maringe and Chiramba (2022) note that the knowledge-based, competitive, information-age, technology-driven society of the future should be reflected in the skills taught at higher education institutions. For teachers to properly develop their pupils during the 4IR, they require ongoing support.

According to Yende (2021), one of the primary reasons for the global improvement in higher education has been the 4IR. Moreover, according to Yende (2021), the 4IR's accompanying technologies have made 21st-century teaching and learning more effective. In addition to focusing on how Africans might use technology to better their communities, we also need to talk about how to establish an engaged university in Africa. Universities play a pivotal role in the advancement of society by means of their teaching, research, and community engagement initiatives. Universities impact their communities by advancing the 4IR agenda in their academic enterprise operations (Madumo, and Kimaro, 2021).

A new curriculum for 4IR liberal arts must take into account the societal dislocations that have occurred throughout this period. The relationship between corporate profits, advances in productivity, and pay increases has already begun to falter. This tendency is projected to pick up speed as sophisticated AI-powered devices and other cutting-edge technology become more prevalent in organizations. The 4IR curriculum must address the paradox of technologies that simultaneously expand democratization and centralize

wealth and political influence, as well as the political and social tensions that will accompany the rising pace of technological development. According to a WEF analysis, there will be significant political ramifications from the growth and convergence of the physical, digital, and biological domains. This development will "enable citizens to engage with governments, voice their opinions, coordinate their efforts, and even circumvent the supervision of public authorities. Simultaneously, governments will gain new technological powers to increase their control over populations" (Schwab, 2016).

The implementation of online learning during the COVID-19 epidemic proved advantageous and was deemed a "lifeline for education during the pandemic" (Oyediran et al., 2020). China created a policy known as "Suspending Classes without Stopping Learning" to ensure that education and learning continued throughout the COVID-19 shutdown (Oyediran et al., 2020).

Research Question 3: What challenges do higher educational institutions face in implementing Fourth Industrial Revolution (4IR) technologies?

Higher education is greatly impacted by the Fourth Industrial Revolution since it removes all barriers to innovation and advances system improvements. According to Barnes, Marateo, and Ferris (2009), e-learning systems have been used by many higher education institutions in an effort to improve the effectiveness of instruction due to the increased development in the use of information and communication technology. These initiatives are encouraging since students in higher education institutions are likely tech-savvy and have spent their entire lives using the internet and other technologies. According to Sivathanu Pillai (2018), it is critical to consider how the technology will be used by the general public and to have a thorough understanding of it while still being able to meet and overcome all of the challenges that this technology will present.

There are several obstacles to overcome while implementing the Fourth Industrial Revolution (4IR), especially in areas where there are substantial impediments to education, culture, and infrastructure already in place. A crucial problem is the lack of a strong infrastructure, as noted by Tarus et al. (2015), Anderson (2008), Rana & Lal (2014), and others. This includes steady internet connections and inexpensive, dependable power. It is challenging to incorporate cutting-edge technology because of this lack of infrastructure, which is further exacerbated by the impediments of social structures, cultural recognition, and financial capability (Qureshi et al., 2012). Furthermore, there is a clear lack of appropriate computer proficiency among students and teachers, which make it difficult to make efficient use of the technical resources that are accessible (Qureshi et al., 2012). According to Wanga and Ngumbuke (2012), a major obstacle to the widespread use of ICTs is the absence of a comprehensive approach, as well as a lack of financial resources, management and technical support, and knowledge. Integration of 4IR technologies is made more difficult by educational obstacles including staff members lacking the necessary training and having insufficient technological abilities (Sife, Lwoga, and Sanga, 2007). The cultural environment also matters; teachers are not well-motivated by incentives or a supportive attitude toward e-learning, and computer skills and internet connectivity are few (Ahmed, 2013). Further disincentives come from the possible hazards connected to 4IR, like loss of

employment, cyber-security dangers, and hacking (Lambert, 2017). According to Anderson and Grönlund (2009), a number of elements, including content design, transit sequences, individual physical traits, and technology and background influences, such as managerial, cultural, and societal aspects, contribute to the complexity of these difficulties. The effective use of the small amount of technology that is accessible is hampered in emerging nations by staff members' lack of training and frequent lack of access to technology (Naidu, 2003). Naresh and Reddy (2015) have highlighted the importance of greater financial assistance, government e-learning procedures, suitable technology training, and enhanced knowledge and readiness among students.

Technology is behind the fourth industrial revolution, which specifically offers new problems and solutions for raising the level of living. The use of technology has caused problems for Malaysian educators. The current study focuses on these concerns because they need to be examined and brought to light. While it has occasionally helped educational institutions enhance teaching and learning, it has also occasionally caused problems and obstacles due to student distraction, a lack of technological know-how, and a host of other factors. Another problem for instructors is the amount of time it takes to setup hardware and software; this prevents them from having adequate time to teach. The use of technology in the classroom might be intimidating if proper planning and execution aren't done in terms of material distribution, teacher responsibilities, and facility conditions (Alakrash & Razak, 2020a).

It is still unclear what protocols and techniques HEIs should follow to ensure that teaching practices improve 4IR capabilities. Despite the potential advantages of technology for learners' growth through collaborative learning, our analysis reveals that little is known about the factors that influence the adoption and diffusion of the 4IR in the educational sector and how they impact the process of teaching and learning (Chang, 2016; Ng'Ambi et al., 2016; Oke & Fernandes, 2020).

The utility and efficacy of technology, particularly online teaching and learning, have not yet been demonstrated, despite its dissemination and acceptance in other industries. As a result of platforms or tutors assisting students with tests and other exam solutions, there is evidence of deeper threats to intellectual integrity, such as contract cheating (Lubinga et al., 2022). Furthermore, digital technologies have not significantly altered the nature of teaching and learning, especially in higher education. For example, Ng'Ambi et al. (2016) discovered that teaching and learning, particularly in South Africa, stayed substantially the same despite the usage of technology in the classroom.

Research Question 4: What are the impacts of the Fourth Industrial Revolution (4IR) on teaching and learning in higher education?

The Third Industrial Revolution has placed educators in a setting where information is readily available and free of cost, which has caused a shift in emphasis toward active learning pedagogies that emphasize teamwork among varied members of a project-based, peer-led learning environment (Mazur, 2009). A more multidisciplinary curriculum with a stronger emphasis on liberal arts and interpersonal skills is the outcome of many of the most intelligent reactions to recent reforms in STEM education. The American Physical Society SPIN-UP project, Liberal Studies in Engineering,

Project Kaleidoscope Science, and the HHMI Scientific Foundations for Future Physician report are a few examples (Elrod & Kezar, 2016 and Bucciarelli & Drew, 2015; Hilborn, Howes, & Krane, 2003 and AAMC, 2009).

The "digital revolution" has both beneficial and detrimental consequences on student learning, according to the findings. While instructors made use of all available resources to educate during the pandemic, student learning suffered in environments with limited resources while it benefitted greatly in environments with an abundance of resources. Through the encouragement of sustainable education and the development of critical thinking and problem-solving abilities in mathematics education, technology-based learning improved student learning. Additionally, it enhanced instruction and produced additional chances for student participation, teamwork, and conversation in the classroom (Naidoo and Reddy, 2023).

There are certain useful technologies that may be employed to enhance the teaching and learning processes in order to deal with this digital revolution. These consist of: digital exam papers that are immediately available to reviewers; interactive classrooms; access to interactive whiteboards; video conferencing; online meetings and lectures; practical methods of coding and engineering integrated into the curriculum; and the ability to remove bias by neutralizing responses and automating the assessment of multiple-choice answers. creating study guides and courses appropriate for digit-supported models(Abduvakhidov et al,2021).

Modern technology can also increase workplace safety by preventing individuals from entering hazardous areas. For example, by identifying patterns in human behavior from security camera feeds, a deep learning algorithm can be used to track worker accidents or chemical leaks in real time. Oke and Fernandes (2020, p. 22) state that computer-based learning, especially e-learning, provides the opportunity to enable training and teaching anywhere and anytime, thereby reducing operating costs and the logistical difficulties occasionally associated with in-person classroom instruction.

It is important to note that one of the key impacts of the fourth industrial revolution on education is the amplified emphasis on digital literacy and technology incorporation in core curriculum. HEIs are taking the needed steps after integrating the main details so as to ensure that students are well equipped to solve problems in our digitally driven economy (World Economic Forum, 2018). As a result of the aforementioned incorporation the learning is more flexible and tailored to fit the needs of the learner, thanks to the extensive implementation of e-learning platforms. Employing e-learning platforms such as Moodle and Blackboard has made it possible for educationalists to teach proficiently, track learner development, and nurture collaborative learning atmosphere (Al-Fraihat, Joy, & Sinclair, 2020).

Following the Fourth Industrial Revolution, there has been a graduation to data-driven education. As a result of the usage of big data and analytics in HEI, enormous amounts of data have been analyzed to develop teaching and learning results. The data gotten can be employed in the personalization of learning paths, recognition of at-risk learners and make learned decisions with regards resource allocation and curriculum development (Daniel, 2015). Learning analytics have since become a very vital instrument in

providing valued discernments into student engagement and the level of academic performance, thus improving the general learning experience (Chatti, et al., 2012).

To create immersive MR learning experiences, AI, XR, and ICT are being used in MOOC contexts and holistic, immersive learning environments. Mavrikios et al. (2019) describe how students interacted with staff members and instructional materials using finger tracking, mobile technology, and holograms in an all-encompassing, immersive learning environment.
As they discussed tasks, Mavrikios' team showed how holograms might be concurrently watched and handled by several people in a classroom or industrial setting from any position. Any component could be "exploded" to reveal its individual pieces to the audience.

Additionally, on-demand content, features, and annotations were displayed on the consumers' mobile devices. Using a combination of MOOC, AR, remote and VR labs, and additive manufacturing technologies, students were able to visually explore and test complex engineering procedures. Grodotzki et al. (2018) provide a second example of an all-encompassing, immersive learning environment.

The integration of remote labs, virtualized workplace environments and labs, AR/VR/AR, other mobile devices, additive manufacturing technologies, and teaching/learning factories is becoming more common in MOOCs and teaching/learning factories. These efforts create lifelike scenarios and experiences that aim to develop the knowledge, skills, and attitudes required to thrive in the mixed-reality environment of the 4IR era (Ally & Wark, 2019a, 2019b; Block et al., 2018; Grodotzki et al., 2018; Mavrikios et al., 2019; Mourtzis et al., 2018).

According to Ally & Wark (2019a, 2019b; Qi, 2020; Salmon, 2019), education 4.0 aims to align educational systems through the use of 4IR technologies in order to personalize learning and offer flexible learning possibilities for all citizens, regardless of geography or status. Instead of needing students to attend a physical site for instruction, learner-centered education may be provided anywhere, at any time, through the use of online learning and eLearning. The Hole in the Wall Project has shown that independent learning and self-direction are possible for students (Mitra, 2014).

The personalization of learning and learning materials is where artificial intelligence (AI) has the most potential for education, according to Vincent-Lancrin & van der Vlies (2020). An educational strategy known as "personalized learning" tries to tailor instruction to each student's unique needs and abilities. Based on data from individual students, AI programs may recognize instructional materials and procedures that are tailored to each student's level and can forecast, suggest, and decide what should be learned next (p. 7).

With the advent of the 4IR era, there is a growing demand for personalized, interactive, on-demand, and eternal learning, which is driving the growth of online learning thanks to the development of 4IR technologies (Ally & Wark, 2019b; Buasuwan, 2018; Wan Chik & Arokiasamy, 2019). Online and MR learning environments, such as holistic, immersive learning environments and MOOCs, are replacing traditional formal

classroom-based learning. These learning environments can offer timely, relevant apprenticeships and on-the-job training (Block et al., 2018; Grodotzki et al., 2018; Mavrikios et al., 2019; Mourtzis et al., 2018).

Increased accessibility to online and mobile learning platforms (Aziz Hussin, 2018; Bhattacharjee et al., 2018; Block et al., 2018; J. Chen et al., 2018; Jia et al., 2019; Lou, 2018; Stock et al., 2018) as well as a recent initiative to build an open-source, global, AI-enabled online learning platform (Duraiappah, 2018) show that in the near future, demand for traditional face-to-face instruction will be surpassed by online and MR learning (Ally & Wark, 2019b).

In order to ascertain the value of "machine learning" the process of using algorithms derived from sample data and experiences to program software for problem-solving in the field of education, Kučak and colleagues (2018) carried out a comprehensive review of the literature. They came to the conclusion that machine learning (ML) had a big impact on education in a lot of areas, like learner performance prediction, fair and equitable learning evaluation, better learner retention, and giving teachers administrative responsibilities. Additionally, machine learning (ML) has the potential to deliver individualized instruction, do away with standardized testing, and give parents, instructors, and students "continuous feedback about how the student learns, the support they need, and the progress they are making towards their learning goals" (p. 409).

CONCLUSION

This systematic literature review reconnoitered the implications of the Fourth Industrial Revolution (4IR) on HEIs. What this means is that the 4IR has had ripple effects on higher education. This encompasses its sustainability, consequences, difficulties, and impacts on teaching and learning. For example, synthesis of a variety of studies offers in-depth insight into the transformational capacities of 4IR in higher learning and its contribution towards sustainable educational practice.

In addition, various aspects were identified that are vital for the continuation of 4IR in universities. Such as the integration of advanced technology such as artificial intelligence, blockchain and internet of things into educational frameworks; strong institutional backing for ongoing digital innovation; and development of adaptive learning environments that cater to changing needs among students and educators. Additionally, connecting fourth industrial revolution technologies with some SDGs like quality education for all as well as resource efficiency was found to be important for long-term sustainability. There is no doubt that the Fourth Industrial Revolution has had a profound impact on higher education. Thus the fourth industrial revolution has enormously reshaped how institutions function and deliver education. Fourths Industrial Revolution Technology Implementation Has Improved Higher Education.

Though it may bring advantages, incorporation of 4IR technologies in higher learning faces several barriers. The major challenges include the high costs that arise from this technology adoption as well as maintenance, substantial investments required for digital infrastructure and resistance to change by teachers and administrators. Furthermore, there are issues such as data privacy, cyber security and digital divide that stand on the

way of achieving equity in technology use across various learning contexts. To solve these problems would demand collective efforts from policy makers, teachers and developers so that the integration of 4IR is effective and sustainable. Higher education teaching has changed significantly due to the Fourth Industrial Revolution. Traditional teaching methods have been revolutionized through the application of technologies like virtual reality (VR), augmented reality (AR) and machine learning (ML). These tools allow customization of study materials with regards to different individual styles and preferences hence improving student participation and achievements.

Study Implications

In the higher education field, this systematic literature review identified by the Fourth Industrial Revolution (4IR) has important implications for educational policymakers, institutional leaders, educators and researchers:

1. **Strategic Integration of 4IR Technologies:** There is a need for institutions of higher learning to integrate strategically into their educational frameworks the 4IR technologies such as Artificial Intelligence, block chain and big data analytics. This will help improve administrative efficiency, personalize learning experiences, and prepare students to enter future job markets characterized by rapid advancements in technology.

2. **Investment in Digital Infrastructure:** Policymakers and institutional leaders are urged to invest in strong and scalable technological infrastructures acknowledging that digital infrastructure plays an important role in supporting 4IR initiatives. They must therefore ensure adequate connectivity, cyber security measures as well as availability of digital resources to enable smooth adoption and use of 4IR technologies across different educational contexts.

3. **Support for Continuous Professional Development:** The transformative impact of 4IR technologies on teaching and learning necessitates ongoing professional development programs for teachers. Such programs should enhance teacher's digital skills

FUNDING

This research was funded by the Scientific Research Deanship at University of Ha'il, and Kingdom of Saudi Arabia, grant project number (RG-20 206).

ACKNOWLEDGMENTS

The researchers acknowledge the support of the Scientific Research Deanship at University of Ha'il, and Kingdom of Saudi Arabia, grant project number (RG-20 206).

CONFLICTS OF INTEREST

The authors declare no conflicts of interest of the study.

REFERENCES

Abduvakhidov, A. M., Mannapova, E. T. & Akhmetshin, E. M. (2021). Digital Development of Education and Universities: Global Challenges of the Digital

Economy. *International Journal of Instruction, 14*(1), 743-760. https://doi.org/10.29333/iji.2021.14145a

Advani, A. (2023). *Education 4.0: here are 3 skills that students will need for the jobs of the future World Economic Forum*. Available at: https://www.weforum.org/ agenda/2023/01/skillsets-cultivated-by-education-4-0-davos23/

Ahmed, T. T. (2013). Toward successful e-learning implementation in developing countries: A proposed model for predicting and enhancing higher education instructors' participation. *International Journal of Academic Research in Business and Social Sciences, 3*(1), 422. https://doi.org/10.6007/IJARBSS/v3-i1/479

Aker, M., & Herrera, L. J. P. (2020). *Smart literacy learning in the 21st century: Facilitating PBSL pedagogic collaborative clouds.* In S. Yu, M. Ally, & A. Tsinakos (Eds.), Emerging technologies and pedagogies in the curriculum (pp. 429–446). Springer

Alakrash, H. M., & Razak, N. A. (2020a). Redesigning the English Classroom Towards Fourth Industrial Revolution, Are the Students Motivated? *The Asian ESP Journal*, 16, 6-21.

Al-Fraihat, D., Joy, M., & Sinclair, J. (2020). Evaluating e-learning systems success: An empirical study. *Computers in Human Behavior, 102*, 67-86. https://doi.org/10.1016/j.chb.2019.08.004

Ally, M. (2019). Competency profile of the digital and online teacher in future education. *International Review of Research in Open and Distributed Learning*, 20(2), 302–318. https://doi. org/10.19173/irrodl.v20i2.4206

Ally, M., & Wark, N. (2019a, September). Learning for sustainable development in the Fourth Industrial Revolution. In Proceedings of the Pan-Commonwealth Forum 9 (PCF9). Commonwealth of Learning. http://oasis.col.org/handle/11599/3393

Ally, M., & Wark, N. (2019b, November). Online education in the Fourth Industrial Revolution era. Paper presented at the International Council on Distance Education (ICDE) World Conference on Online Learning (WCOL) 2019, Dublin, Ireland. https://wcol2019.ie/wp-content/ uploads/presentations/CP_052,%20ALLY.pdf

Andersson, A. and Gronlund, A. (2009) A Conceptual Framework for E-Learning in Developing Countries: A Critical Review of Research Challenges. The Electronic Journal on Information Systems in Developing Countries, 38, 1-16.

Anderson, A. (2008). Seven major challenges for e-learning in developing countries: Case study eBIT, Sri Lanka. *International Journal of Education and Development using ICT*, *4*(3). https://doi.org/10.2139/ssrn.1306135

Andreassen, C. S., Pallesen, S., & Griffiths, M. D. (2017). The relationship between addictive use of social media, narcissism, and selfesteem: Findings from a large national survey. Addictive Behaviors, 64, 287-293

Antonio, A., & Tuffley, D. (2014). The gender digital divide in developing countries. *Future Internet, 6*(4), 673-687. https://doi.org/10.3390/fi6040673

Armstrong K., Parmelee, M., Santifort, S., Burley, J., Fleet, J.V., Koziol, M., Greenberg, R., Schwartz, J., & Tetrick, R. (2018). Preparing tomorrow's workforce for the Fourth Industrial Revolution for business: A framework for action, Deloitte Global Business Coalition for Education

Association of American Medical Colleges (AAMC). (2009). *Scientific foundations for future physicians*. Washington, D.C.: Association of American Medical Colleges.

Aziz Hussin, A. (2018). Education 4.0 made simple: Ideas for teaching. *International Journal of Education and Literacy Studies*, *6*(3), 92. http:// dx.doi.org/10.7575/aiac.ijels.v.6n.3p.92

Barnes, K., Marateo, R., & Ferris, S. P. (2009). Teaching and learning with the Net Generation. *Innovate Journal of Online Education, 3*(4).

Bhattacharjee, D., Paul, A., Kim, J. H., & Karthigaikumar, P. (2018). An immersive learning model using evolutionary learning. *Computers & Electrical Engineering, 65*, 236–249. https://doi.org/10.1016/j. compeleceng.2017.08.023

Block, C., Kreimeier, D., & Kuhlenkötter, B. (2018). Holistic approach for teaching IT skills in a production environment. *Procedia Manufacturing, 23*, 57–62. https://doi. org/10.1016/j.promfg.2018.03.161

Bosch, N., Härkki, T., & Seitamaa-Hakkarainen, P. (2022). Design empathy in students' participatory design processes. *Design and Technology Education: An International Journal, 27*(1), 29-48.

Brown-Martin, G. (2017). *Education and the Fourth Industrial Revolution.* Available at: https://www.groupemediatfo.org/wp-content/uploads/2017/12/FINAL-Education-and-the-Fourth-IndustrialRevolution-1-1-1.pdf.

Buasuwan, P. (2018). Rethinking Thai higher education for Thai 4.0. *Asian Education and Development, 7*(2), 157–173. https://doi. org/10.1108/AEDS-07-2017-0072

Bucciarelli, L., & Drew, D. (2015). Liberal studies in engineering – A design plan. *Engineering Studies, 7*(2–3), 103–122.

Butler-Adam, J. (2018). The Fourth Industrial Revolution and education. *South African Journal of Science, 114*(5/6):1–2.

Cezzar, J. (2020). Teaching the designer of now: A new basis for graphic and communication design education, She Ji: *The Journal of Design, Economics, and Innovation, 6*(2), 213– 227. https://doi.org/10.1016/j.sheji.2020.05.002

Chai, C. S., & Kong, S. C. (2017). Professional learning for 21st century education. *Journal of Computers in Education*, *4*(1), 1–4. https://doi.org/10.1007/s40692-016-0069-y

Chang, V. (2016). Review and discussion: E-learning for academia and industry. *International Journal of Information Management, 36(*3), 476–485. https://doi.org/10.1016/j.ijinfomgt.2015.12.007

Chatti, M. A., Dyckhoff, A. L., Schroeder, U., & Thüs, H. (2012). A reference model for learning analytics. *International Journal of Technology Enhanced Learning, 4*(5/6), 318-331. https://doi.org/10.1504/IJTEL.2012.051815

Chen, G., Xu, B., Lu, M., & Chen, N.-S. (2018). Exploring blockchain technology and its potential applications for education. *Smart Learning Environments, 5*(1), 1. https://doi. org/10.1186/s40561-017-0050-x

Cohen, R.M. & Mule, L. (2019). Collaborative pedagogy in a design thinking education course, *InSight: A Journal of Scholarly Teaching, 14*, 29-42.

Daniel, B. K. (2015). Big data and analytics in higher education: Opportunities and challenges. *British Journal of Educational Technology, 46*(5), 904-920. https://doi.org/10.1111/bjet.12230

Davis, N. (2016).What is the Fourth Industrial Revolution? Retrieved from

Duraiappah, A. K. (2018). Director's message: Artificial intelligence for education. *The Blue DOT, 9*, 1. https://mgiep.unesco.org/the-blue-dot-issue-9

Eckert, C.M., Maier, A.M., & McMahon, C. (2005). *Communication in design.* In J. Clarkson & C. Eckert (eds.) Design process improvement: A review of current practice, SpringerVerlag London, pp. 232-261. DOI: 10.1007/978-1-846

Elrod, S., & Kezar, A. J. (2016). *Increasing student success in STEM: A guide to systemic institutional change*. Washington, D.C.: AAC&U.

Grodotzki, J., Ortelt, T. R., & Tekkaya, A. E. (2018). Remote and virtual labs for Engineering Education 4.0. Procedia Manufacturing, 26, 1349–1360. https://doi.org/10.1016/j. promfg.2018.07.126

Hilborn, R. C., Howes, R. H., & Krane, K. S. (Eds.). (2003). *Strategic programs for innovations in undergraduate physics*. College Park: The American Association of Physics Teachers.

Hooker, J. and Kim, T.W. (2019). Ethical implications of the 4th Industrial Revolution for business and society. In Wasieleski, D.M. and Weber, J. (Eds.). *Business Ethics (Business and Society 360(*3). Bingley: Emerald Publishing Limited.

Jia, M., Komeily, A., Wang, Y., & Srinivasan, R. S. (2019). Adopting Internet of Things for the development of smart buildings: A review of enabling technologies and applications. *Automation in Construction, 101*, 111–126. https://doi.org/10.1016/j.autcon.2019.01.023

Kaygan, P. & Demir, Ö. (2017). *Learning about others: Developing an interdisciplinary approach in design education,* Proceeding, Design Management Academy Conference: Research Perspectives on Creative Intersections, Hong Kong, pp. 1596-1611

Kunisch, S., Menz, M., Bartunek, J.M., Cardinal, L.B., & Denyer, D. (2018). Feature topic at organizational research methods: How to conduct rigorous and impactful literature reviews? *Organizational Research Methods, 21*(3), 519–523. https://doi.org/10.1177/1094428118770750

Lambert, L. (2017). The four challenges of the Fourth Industrial Revolution. *Market Mogul*. Retrieved from https://themarketmogul.com/industry-4-0-challenges/?hvid=2Gt2CE

Lame, G. (2019). Systematic literature reviews: An introduction. Proceedings of the Design Society: *International Conference on Engineering Design, 1*(1), 1633–1642. https://doi.org/10.1017/dsi.2019.169

Lor, R.R. (2017). D*esign thinking in education: A critical review of literature, Proceedings.* International Academic Conference on Social Sciences and Management (ACSSM) & Asian Conference on Education and Psychology (ACEP), Bangkok, Thailand, May 24- 26, 2017, pp. 36-68.

Lou, Y. (2018). Designing interactions to counter threats to human survival. *She Ji: The Journal of Design, Economics, and Innovation, 4*(4), 342–354. https://doi.org/10.1016/j. sheji.2018.10.001

Lubinga, N. S., Ramnarain, J., & Tonkin, L. (in press). *Quandaries of Contract Cheating in South African Higher Education Institutions: The Way Forward*

Mudau, A. & Sikhosana, L. (2024). Integration of Fourth Industrial Revolution in teaching and learning during COVID-19 pandemic. *International Journal of Informationand Communication Technology*. *24*(6), 35-56. https://doi.org/10.1504/IJICT.2024.138560

Maj-Waśniowska K., Stanienda J., Wyrobek J. (2023). "Challenges for the education system in the era of the fourth industrial revolution" in *Public goods and the fourth industrial revolution*. ed. Plonka M. (Oxfordshire, England, UK: Taylor & Francis;)

Maringe, F., & Chiramba, O. (2022). The emerging discourse of the 4IR: Theoretical and conceptual overview in the context of teacher education in South Africa. In F. Maringe & O. Chiramba (Eds.), *The 4IR and teacher education in South Africa: Contemporary discourses and empirical evidence (Disruptions in higher education: Impact and implication, Volume 2)* (pp. 1–16). AOSIS. https://doi.org/10.4102/aosis.2022

Mavrikios, D., Alexopoulos, K., Georgoulias, K., Makris, S., Michalos, G., & Chryssolouris, G. (2019). Using holograms for visualizing and interacting with educational content in a Teaching Factory. *Procedia Manufacturing, 31*, 404–410. https://doi.org/10.1016/j. promfg.2019.03.063

Mazur, E. (2009). Farewell, lecture? *Science, 323*(5910), 50–51.

McDermott, L., Boradkar, P., & Zunjarwad, R. (2014). Interdisciplinarity in design education: Benefits and challenges. IDSA Education Symposium, Austin, 13 August, 2014. Mhlanga, D., & Moloi, T. (2020). The stakeholder theory in the fourth industrial

revolution. *International Journal of Economics and Finance Studies, 12*(2), 352-368. Doi: 10.34109/ijefs.202012207

Mhlanga, D., & Moloi, T. (2020). COVID-19 and the digital transformation of education: What are we learning on 4IR in South Africa? *Education Sciences*, 10 (7), 180

Mitra, S. (2014). The future of schooling: Children and learning at the edge of chaos. *Prospects*, *44*, 547–558. https://doi.org/10.1007/s11125-014-9327-9

Mitra, S. (2019, September). *The future of learning*. Keynote speech presented at PanCommonwealth Forum 9 (PCF9), Edinburgh, Scotland

Mourtzis, D., Boli, N., Dimitrakopoulos, G., Zygomalas, S., & Koutoupes, A. (2018). Enabling small and medium enterprises (SMEs) to improve their potential through the Teaching Factory paradigm. *Procedia Manufacturing, 23*, 183–188. https://doi.org/10.1016/j. promfg.2018.04.014

Naidoo, J. & Reddy, S. (2023). Embedding Sustainable Mathematics Higher Education in the Fourth Industrial Revolution Era Post-COVID-19: Exploring Technology-Based Teaching Methods. *Sustainability, 15*. 9692. 10.3390/su15129692.

Naidu, S. (2003). Designing instruction for e-learning environments. In M. G. Moore & W. G. Anderson (Eds.), *Handbook of distance education* (pp. 349-365). Mahwah, NJ: Lawrence Erlbaum Associates.

Naresh, B., & Reddy, B. S. (2015). Challenges and opportunity of e-learning in developed and developing countries: A review. *International Journal of Emerging Research in Management & Technology, 4*(6), 259-262. https://doi.org/10.23956/ijermt.v4i6.23

Ng'Ambi, D., Brown, C., Bozalek, V., Gachago, D., & Woos, D. (2016). Technology enhanced teaching and learning in South African higher education –A rearview of a 20-year journey. *British Journal of Educational Technology*, *47*(5), 843–858. https://doi.org/10.1111/bjet.12485

Nordin, N. and Norman, H. (2018). Mapping the Fourth Industrial Revolution global transformations on 21st century education in the context of sustainable development. *Journal of Sustainable Development Education and Research*, *2*(1), 1–7.

Oke, A., & Fernandes, F. A. P. (2020). Innovations in teaching and learning: Exploringthe perceptions of the education sector on the 4thIndustrial Revolution (4IR). *Journal of Open Innovation: Technology, Market, and Complexity*, *6*(2), Article 31. https://doi.org/10.3390/joitmc6020031O

Oroma, J. O., Wanga, H. P., & Ngumbuke, F. (2012, July). Challenges of e-learning in developing countries: The Ugandan experience. *In Proceedings of the EDULEARN-2012 Conference, Barcelona*. https://doi.org/10.13140/2.1.4754.1448

Oyediran W. O., Omoare A. M., Owoyemi M. A., Adejobi A. O., Fasasi R. B. (2020). Prospects and limitations of e-learning application in private tertiary institutions amidst COVID-19 lockdown in Nigeria. *Heliyon,* 6:e05457.

Penprase, B.E. (2018). *The Fourth Industrial Revolution and Higher Education*. Available at: https://link.springer.com/chapter/10.1007/978-981-13-0194-0_9

Petrova, M.N., de Steffen, M.D.C.C., Piumatti, R.G. & Lingán, C.R.L. (2022). *Collaborative learning in international interdisciplinary teams*, International Conference on Engineering and Product Design Education, 8–9 September 2022, London South Bank University, London, UK.

Pitchforth, E., Nolte, E., Corbett, J., Miani, C., Winpenny, E., van Teijlingen, E., Elmore, N., King, S., Ball, S., Miler, J., & Ling, T. (2017). *Community hospitals and their services in the NHS: identifying transferable learning from international developments – scoping review, systematic review, country reports and case studies.* NIHR Journals Library, 5, 1–220.

Popenici, S. D., & Kerr, S. (2017). Exploring the impact of artificial intelligence on teaching and learning in higher education. *Research and Practice in Technology Enhanced Learning*, *12*(22), 1–13. https://doi.org/10.1186/s41039-017-0062-8

Puriwat, W. & Tripopsakul, S. (2020). Preparing for Industry 4.0 – Will youths have enough essential skills? An Evidence from Thailand. *International Journal of Instruction. 13*(3), 89-104. https://doi.org/10.29333/iji.2020.1337a

Qi, W. (2020). Learning Cell: Intelligent technologies and resources in curriculum development. In S. Yu, M. Ally, & A. Tsinakos (Eds.), *Emerging technologies and pedagogies in the curriculum* (pp. 199–214). Springer

Qureshi, I. A., Ilyas, K., Yasmin, R., & Whitty, M. (2012). Challenges of implementing e-learning in a Pakistani university. *Knowledge Management & E-Learning: An International Journal, 4*(3), 310-324.

Rana, H., & Lal, M. (2014). E-learning: Issues and challenges. *International Journal of Computer Applications, 97*(5). https://doi.org/10.5120/17052-7144

Ray Schroeder (2026). Higher Education and the Four Industrial Revolutions. UPCEA. The Online and Professional Education Association.

Rosa, W. (Ed.). (2017). Transforming our world: The 2030 agenda for sustainable development. In A new era in global health. https://doi.org/10.1891/9780826190123.ap02

Salmon, G. (2019). May the fourth be with you: Creating Education 4.0. *Journal of Learning for Development*, *6*(1), 95–115.

Sandeep, K., Carlye, L. Christopher, M. Catherine, B., & Jessica, M. (2021). Novice designers' use of prototypes as communication tools, International Conference on Engineering Design (ICED21), 16-20 August 2021, Gothenburg, Sweden

Schwab, K. (2016). *The fourth industrial revolution*. Crown Publishing.

Sife, A., Lwoga, E., & Sanga, C. (2007). New technologies for teaching and learning: Challenges for higher learning institutions in developing countries. *International Journal of Education and Development using ICT, 3*(2). http://ijedict.dec.uwi.edu/viewarticle.php?id=246

Sivathanu, B., & Pillai, R. (2018). Smart HR 4.0: How industry 4.0 is disrupting HR. *Human Resource Management International Digest, 26*(4), 7-11. https://doi.org/10.1108/HRMID-04-2018-0059

Stock, T., Obenaus, M., Kunz, S., & Kohl, H. (2018). Industry 4.0 as enabler for a sustainable development: A qualitative assessment of its ecological and social potential. *Process Safety and Environmental Protection, 118,* 254–267. https://doi.org/10.1016/j.psep.2018.06.026

Tarus, J.K., Gichoya, D. & Muumbo, A. (2015). Challenges of implementing e-learning in Kenya: A case of Kenyan public universities. *International review of research in open and distributed learning, 16*(1). https://doi.org/10.19173/irrodl.v16i1.1816

Vincent-Lancrin, S., & van der Vlies, R. (2020). *Trustworthy artificial intelligence (AI) in education: Promises and challenges.* OECD Education Working Paper, No. 218. https://doi. org/10.1787/a6c90fa9-en

Wan Chik, W. N. A., & Arokiasamy, L. (2019). Perceived higher education climate of academics in Malaysian private institutions in Industry 4.0. *Global Business & Management Research, 11*(1), 488–504. http://www.gbmrjournal.com/pdf/vol.%2011%20no.%201/V11N1_2019.pdf

World Economic Forum. (2017). *Realizing Human Potential in the Fourth Industrial Revolution -An Agenda for Leaders to Shape the Future of Education, Gender and Work.* White Paper, Geneva: World Economic Forum.

World Economic Forum. (2018). The future of jobs report 2018. *World Economic Forum*.

Xing, B. and Marwala, T. (2017). Implications of the Fourth Industrial Age for higher education. *The Thinker, 73,* 10–15

Yende, S. J. (2021). A transition towards the Fourth Industrial Revolution in the South African education sector: A perspective from rural-based higher education. *African Journal of Development Studies, 11*(2). https://doi.org/10.31920/2634-3649/2021/v11n2a3

Zande, R.V. (2011). Design education supports social responsibility and the economy. *Arts Education Policy Review, 112,* 26–34. DOI: 10.1080/10632913.2011.518123

Zhongbin, Z. (2023). Integrating arts education system enhancing students' level of creativity: A case study in Beijing, China. *International Journal of Academic Research in Progressive Education and Development, 12*(2), 2462–2472. DOI:10.6007/IJARPED/v12-i2/17639